Italian Journal of Agrometeorology
Rivista Italiana di Agrometeorologia

Firenze University Press
www.fupress.com/ijam

OPEN ACCESS

Citation: C. Chieco, L. Morrone, M. Magli, A. Gelmetti, S. Pedò, T. Roman, M. Stefanini, F. Rossi, G.A. Battistel, E. Eccel (2023) Italian winegrowers' and wine makers' attitudes toward climate hazards and their strategy of adaptation to the change. *Italian Journal of Agrometeorology* (1): 47-65. doi: 10.36253/ijam-1874

Received: October 28, 2022

Accepted: May 29, 2023

Published: August 03, 2023

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

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Italian winegrowers' and wine makers' attitudes toward climate hazards and their strategy of adaptation to the change

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Abstract. This study reports the results of a survey disseminated to Italian winegrowers and wine makers to understand their attitude toward the main climate risk factors on grape and wine productions and their willingness to proactively act in facing the related consequences. A general noticeable concern about the future effects of climate change and variability emerged, even with some differences between stakeholders operating in different geographic and climatic areas. Current signals of adaptation mostly emerged at technological level, but they also included the varietal choice, with evidence to a switch from traditional varieties to others showing better pest and drought tolerance. In addition, some climate-smart cultural practices are considered ranging from water-saving irrigation methods to sustainable energy management.

Keywords: climate change, grapevine, wine, adaptation, survey.

HIGHLIGHTS

- Climate change concerns currently appear to be as relevant as the economic ones in the wine sector.
- Concern for climatic hazards strongly increases for the future scenarios, compared to the present situation.
- In the choice of varieties, the preference of market-driven ones prevails over the "climate-resilient" ones.
- Impact of climate change on wine quality is clearly less perceived in the southern Mediterranean.
- To date, weather event insurance as a tool for farm income stability seems still poorly appreciated.

1. INTRODUCTION

Climate is a determinant forcing factor on grapevine vegetative and productive growth (Van Leeuwen et al., 2004; Neethling et al., 2019), with a greater effect on vine development and fruit composition (Van Leeuwen and Darriet, 2016). CC effects on wine production, and their quantitative and qualitative socioeconomic impacts at stake, have been investigated for few decades (Jones et al., 2005; Ashenfelter and Storchmann, 2010; Webb et al., 2012; Droulia and Charalampopoulos, 2022). In the Mediterranean area, the change entails an overall temperature increase, local changes in precipitation patterns, but also the increase in the frequency of extreme event e.g. heat waves, hailstorms, late frost spells, and excessive rainfall events negatively affecting all crops, and particularly highly specialized ones as grapevine (Bindi et al., 1996; White et al., 2006; Fraga et al., 2013a; Mosedale et al., 2015). In addition, the vegetative cycle of plants is already taking place in warmer and drier conditions, showing a general anticipation of some phenological stages over time. The earlier budding timing thwarts the potential reduction of frost risk, enhanced by a possible higher temperature variability (Mosedale et al., 2015), and the dynamics of diseases and pests may be influenced (Castex et al., 2018; Van Leeuwen et al., 2019). On the other hand, earlier ripening induces a change in the composition of the grapes and their qualitative potential, with direct influence on higher sugar and lower acidity levels, but also on secondary metabolites, affecting wine quality (Tate, 2001; Mira de Orduña, 2010).

A major consequence of CC is the negative trend in water availability (Fraga et al., 2018; Weiler et al., 2019). Grapevine itself can tolerate moderate drought events as vineyards have been traditionally grown on relatively dry and scarce soils, allowing to favor the production of high-quality wines (Koundouras et al., 1999, Chacón-Vozmediano et al., 2021).

The concept of *terroir*, conceived for typical wine production bound to their geographic, environmental, and cultural contexts, represents the linkage uniqueness between wines and territories in the agricultural sector (Jones, 2006). It is implicit that CC may become a strong challenge to the permanence of the optimal conditions of grapevine production in their original areas (Van Leeuwen et al. 2004; White, 2020). In general, the idea that specific grapevine varieties will be permanently linked to their original areas might be subject to a revision in the future, and model simulations involving the future development of grapevine growing witness the interest in such prognostic exercises (Jones, 2006; Malheiro et al., 2010; Moriondo et al., 2011; Hannah et al., 2013; Eccel et al., 2016; Alikadić et al., 2019). In the wine sector, the existence of a climate-driven risk is particularly evident (Seccia et al., 2016), with an expectation of a further change in the configuration of the Italian grapevine cultivation areas. The Mediterranean region is in fact a climate "hot spot", with temperature increase higher than in other geographic regions (Fraga et al., 2013b; Cos et al., 2022). Heterogeneous impacts of climate changes are envisaged across vine varieties and regions, leading to conditions that might turn out too warm to produce specific Protected Designation of Origin wines (Bernetti et al., 2012; Jones et al., 2006; Alikadić et al., 2019), pointing out the relevance of the adoption of adaptation and mitigation strategies and policies. Such measures should strategically regard the entire value chain, including those enabling to deal with the future impact on grape processing (Droulia and Charalampopoulos, 2021).

Current technical information campaigns aimed at adaptation, that also take into account specifically tailored local climate scenarios, have proven to be successful in increasing the resilience of winegrowers and wine makers, as shown from the California (Babin et al., 2022). Thanks to the economic importance and to its historical tradition, the wine sector, more than other agricultural ones, has always been characterised by a strong capacity of autonomous adaptation, due to the high attention of winegrowers to the environment and, specifically, to climate (Battaglini et al., 2009). However, the strong linkages with cultural and market capital calls for a major effort aiming at an adaptation to the increasing difficulties for farmers and producers imposed by an unprecedented changing environment (Fraga et al., 2013b; Santillán et al., 2019). De Salvo et al. (2019) highlights how, in the specific case of "climate risks", the adoption of protective measures makes winegrowers more aware of hazard probability, increasing their perception of "residual risk".

Surveys may be reliable and powerful sources of data and information to provide bases for analysis of the actual and perceived risks, fostering their engagement in supporting adaptation and mitigation strategies. For instance, in Bois et al. (2017), the information retrieved worldwide on the presence of grapevine pests and cryptogamic diseases were used to map their incidence according to present and future climate conditions. Aigrain et al. (2019) utilized an expert-consultation method associated with a bottom-up participatory approach as a foresight exercise to design adaptation policies to CC. Battaglini et al. (2009) depicted the state of awareness and the concerns about CC in the viticul-

tural regions of France, Germany, and Italy, while Teil (2020) focused on the adaptation of the wine supply chain in two viticultural regions of France, and Carroquino et al. (2020) in Spain. Wheeler and Marning (2019) designed a survey on specific water-related and irrigation management issue in arid vine-growing Australian regions – pointing out differences in the behavioural adaptation strategies between conventional, organic, and biodynamic growers. Consultation with farmers may also lead to unexpected results; as in the case of Italian Emilia – Romagna (Merloni et al., 2018), where a countertrend perception of the water issues emerged, as farmers highlighted their concern for water-excess seasons.

A particular aspect of resilience enhancement in agricultural farms is the adoption of insurance policies. In Sicily, Sgroi and Sciancalepore (2022) pointed out that, despite of the positive benefits deriving from the adoption of insurance policies (see, e.g. Russo et al., 2022), the viti-vinicultural enterprise adherence to this opportunity remains below the expectations. It is then urgent to adopt appropriate adaptation policy schemes, to obtain the sector actors' feedback to understand their concern and risk perception, as well as their proactive attitude.

With this aim, under the MEDCLIV project, an European project co-funded from EIT Climate-KIC, a survey was disseminated to the actors of the vine and wine value chain in six EU countries (France, Spain, Italy, Portugal, Cyprus and Slovenia) in their respective national languages. The present work focuses on the results for the Italian community.

2. MATERIALS AND METHODS

2.1 The survey design

The link to the survey was nationally disseminated from May to November 2020 and was extended to winegrowers and wine makers operating in all regions. The questionnaire was accessible online and designed using PHP scripting language.

Survey dissemination strategies were implemented with the objective to reach the largest number of participants and operated with a range of supports. To be mentioned, the collaboration of some larger firms in wine industry which provided their networks to connect with a large community of winemakers and winegrowers, the publication of the survey through articles in specialised journals and magazines and social networks, such as the Facebook page of the project, individual emails to winegrowers and wine producers using addresses published online.

2.2 Questionnaire

Survey firstly informed about preliminary general questions on gender, age and region of production of responders, then addressed questions differently tailored for winegrowers and wine makers.

The questionnaire consisted of a total of 32 questions, 13 for winegrowers (Tab 1.) and 16 for wine makers (Tab. 2), plus three final questions, posed to both categories (Tab 3).

Some questions were single-choice (yes/no), while almost all the others were multiple-choice; this explains, for some answers, percentages higher than 100%. For two questions a five-point Likert scale was used.

The questionnaire was designed by authors and shared with a panel of project experts, with the aim to make it easy to understand, quick to answer and suitable for all countries. In order to minimize early dropouts of the questionnaire, excessive details and long lists of options were intentionally avoided. For example, the question on the "choice of new varieties" included in the options only some of those indicated in literature as relevant for improving vineyard adaptation to CC (Mozell and Thach, 2014; Fraga et al., 2016; Van Leeuwen and Destrac-Irvine, 2017) and no distinction was made between scion or rootstock.

A five-point Likert scale was used to assess the degree of danger of the listed grape pests (1= no threat; 5 = greatest threat), chosen as the most relevant for MEDCLIV partner countries among those indicated in the EIP-AGRI "Focus Group Diseases and pests in viticulture" (March 2019), by Mira de Orduña (2010) and by Bois et al. (2017). Similarly, only a limited selection of practices recognized in literature as capable to improve CC vineyard resilience were included in the list addressed to winegrowers (Celette et al., 2009; Palliotti, et al., 2013; Van Leeuwen and Destrac-Irvine, 2017).

When questioning about insurance, multi-peril insurance was also included in the list as it is already available in several parts of Europe (Santeramo and Ford Ramsey, 2017), but participants were not asked to further detail the kind of risks included in the insurance cover. To avoid excluding entrepreneurs with more recent business activity, the question about the reference time frame was not posed, leaving respondent free to refer to shorter or longer temporal distance when comparing the past insurance status with present conditions.

The changes in wine characteristics listed in the wine makers questionnaire (i.e., pH and alcoholic content increase and changes in aromatic profile) were those most likely impacting wine quality and its typicality in the future (Van Leeuwen and Destrac-Irvine, 2017).

Table 1. List of questions and their respective variables for winegrowers; SCq = Single choice question; MCq = multiple choice 157 question; LSq = Likert scale question.

N.	Questions for winegrowers	Answer options	Type of response
1	*Total agricultural surface of your vineyard (in hectares)*	< 1 ha; 1 – 5 ha; 6 – 10 ha; 11 – 25 ha; > 25 ha	SCq
2	*What kind of formal viticulture do you practice?*	Conventional; Integrated; Organic; Biodynamic	MCq
3	*Have you introduced in the last years additional varieties in your vineyard?*	Yes; No; No, but I plan to do soon	SCq
4	*Which type of new varieties did you introduce in your vineyard in the last years?*	Pest resistant; drought resistant; cold tolerant; late ripening varieties; early ripening varieties; market demand	MCq
5	*Do you have potential access to water resources in the perimeter of or near your vineyard?*	Yes; No; Partially	SCq
6	*Are your vines irrigated?*	Yes; No; Partially	SCq
7	*If so, which irrigation system do you have?*	Drip; sub-surface (underground); surface; sprinkler; flood	MCq
8	*Would you consider having, implementing or modifying the irrigation system in the future?*	Yes; No; Partially	SCq
9	*Indicate the danger intensity of the following items. Please rate each item on a 1-5 scale, with 1 being no threat and 5 being the greatest threat in a "normal" year.*	Downy mildew (*Plasmopara viticola*) Powdery mildew (*Erysiphe necator*) Grey mould (*Botrytis cinerea*) Grapevine trunk diseases Black–rot (*Guignardia bidwellii*) European grapevine moth (*Lobesia botrana*) Smaller green leafhopper (*Empoasca vitis*) Med. Mealy bugs *(Planococcus ficus*) Brown marmorated stink *bug (Halyomorpha halys*) Citrus flatid planthopper (*Metcalfa pruinosa*) Mites (different sp) Thrips (*Thrips tabaci/Frankliniella* sp.) Flavescence dorée (*Candidatus Phytoplasma vitis*) Pierce's disease (*Xylella fastidiosa*)	LSq
10	*Indicate the cultivation techniques that you employ now and that you did in the past.*	Thinning; use of anti-transpirants; green pruning; leaf removal practices; row cover cropping; late shoot topping (July, August).	MCq
11	*Do you have any insurance?*	Yes; No	SCq
12	*Did you have any insurance in the past?*	Yes; No	SCq
13	*Indicate the insurance policies that you have now compared to those that you had in the past*	Hail; late frost; wind; flooding; drought; wild animal; multi risk	MCq

Questions concerning the adoption of measures in favour of energy saving – and consequently facilitating CO_2 emission reduction – spanned over the main topics included in the survey described by Carroquino et al. (2020).

The three final questions, posed to both categories, addressed the main long-term concerns about one's own firm business and the perceptions of the impact of CC. The list proposed economic and regulation issues, as well CC-related problems; a five-point Likert scale was used to assess the degree of concern (1= no concern; 5= greatest concern).

2.3 Data analysis

Only fully-completed questionnaires were included in the analysis. All the responses were aggregated according to three main Wine Growing Zones (WGZs) identified in European Union (2013) – Appendix I: CI (Trentino-Alto Adige, Val d'Aosta), CII (Abruzzo, Campania, Emilia – Romagna, Friuli – Venezia Giulia, Lazio, Liguria, Lombardy, Marche, Molise, Piedmont, Tuscany, Umbria, Veneto), CIII (Basilicata, Calabria, Apulia, Sardinia, Sicily). This classification, considering the thermal-climate regimes of the regions, appropriately relates to the local influence on the required grape maturity at harvest and the levels of sugar reached.

Table 2. List of questions and their respective variables for winery owners; SCq = Single choice question; MCq = multiple choice question.

N.	Questions for wine makers	Answer options	Type of response
14	*Which category does your winery fall in?*	Single-member property; Cooperative winery; Noncooperative winery	SCq
15	*Average annual production*	< 100 hl/year; 100-1000 hl/year; 1 000-10000 hl/year; >10000 hl/year	SCq
16	*Have you noticed an increment in pH levels in the past 5 years?*	Yes; No; Do not know	SCq
17	*Have you noticed an increased alcoholic content in your wines compared to the past?*	Yes; No; Do not know	SCq
18	*Have you noticed any change in the aroma profile?*	Yes; No; Do not know	SCq
19	*Have you recently had an analysis of the cost/energy consumption/water consumption of your winery?*	Yes; No	SCq
20	*Will you consider having one in the future?*	Yes; No; Do not know	SCq
21	*Have you recently invested in equipment/infrastructures to optimize energy use for your winery?*	Yes; No	SCq
22	*If yes, have you invested in renewable energy?*	Yes; No	SCq
23	*In which type of renewable energy did you invest in your winery?*	Thermal solar panel; photovoltaic solar panel; wind power; bio digester; provider of renewable energy	MCq
24	*Do you plan to adopt renewable energy in the future?*	Yes; No; Do not know	SCq
25	*Have you recently invested in equipment/infrastructures to optimize water consumption of your winery?*	Yes; No	SCq
26	*Are you planning to invest in equipment/infrastructures to optimize water consumption of your winery in the future?*	Yes; No; Do not know	SCq
27	*Do you have any temperature and humidity control in your winery?*	Yes; No	SCq
28	*If yes, please mention which temperature and humidity control system you have in your winery*	Ventilation; insulation; air-conditioning; humidifier; dehumidifier	MCq
29	*Are you considering installing or implementing it in the future?*	Yes; No; Do not know	SCq

Table 3. Final questions and their respective variables; SCq = Single choice question; MCq = multiple choice question; LSq = 163 Likert scale question.

N.	Questions for both categories	Answer options	Type of response
30	*Which are your main concerns for your professional activity in the long term? Please rate each item on a 1-5 scale, , with 1 being no concern and 5 being greatest concern*	Reduction of profitability of grape and wine production Increased pests and diseases Difficulty finding skilled labour Reduction of public aid and increased regulation Water stress Economic crisis and decreased in wine demand Climate change Reduction of quality and loss of typicity Unpredictable weather Increased barriers to export	LSq
31	*How do you rate the effect of climate change on your activity?*	No effect; Positive effect; Negative effect	SCq
32	*How do you rate the effect of climate change on your activity in the future?*	No effect; Positive effect; Negative effect	SCq

For data analysis, 'stats' package of R software was used (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/).

Categorical responses (both single and multiple-choice) were processed by applying Pearson's chi-square test to point out significant differences in the frequencies of responses among all WGZs ($p < 0.05$). When signifi-

cant, a pairs Pearson's chi-square test (CI vs CII; CI vs CIII; CII vs CIII) was performed to remark the association among the WGZs.

Since Bartlett's test proved there was not homogeneity of variance across populations, Kruskal-Wallis H test was applied when dealing with Likert-scale answers to examine the diversity among the three WGZs ($p < 0.05$). The Kruskal-Wallis H test is a non-parametric method for checking three or more sets of scores that come from different groups and it is equivalent to the one-way ANOVA but does not apply the ANOVA normality assumption (Kruskal and Wallis, 1952). Pairwise comparisons using Wilcoxon rank sum test with continuity correction was also performed.

3. RESULTS

364 fully completed responses had been received by the survey deadline. Most of respondents (75.3%) were both winegrowers and wine producers, while 18.7% of interviewed were exclusively winegrowers (for a total of 342 winegrowers) and 6% winery owners (for a total of 296 wineries). The gender of most responders was male (71.7%), and only 21.4% female. Ages were most represented in the two ranges of 30-45 years old (32.7%) and 46-60 years old (46.2%).

The highest percentage of answers (76.6%) came from the CII zone, which includes the largest number of Italian regions (12), while 16.5% were from CIII zone (5 regions) and 6.9 % from CI, including only 2 regions (Tab. 4 and Fig. 1).

3.1 Winegrowers

Table 5 shows the profile of grapevine farmers responding to the survey (questions 1 and 2). The vineyard extensions were evenly divided among 4 size classes (1-5 ha; 6-10 ha; 11-25 ha and > 25 ha); only 1,8% of participants declared a farm size less than 1 ha.

The farmers in the sample primarily declared a management of their vineyard by integrated or organic protocols, while representatives of conventional agriculture followed in the rating, and a small extent declared biodynamic protocols. 42 out of 342 farmers (12.3% of interviewed) declared to use more than one agricultural system ("Mix" in the table), depending on the vineyard, mainly organic and biodynamic farming (33.3% of this category) and integrated and organic farming (26.2%).

Table 4. Profile of survey participants.

	%
Gender	
Man	71.7
Female	21.4
No reply	6.9
Age	
< 30	4.7
30 – 45	32.7
46 – 60	46.2
> 60	16.5
Wine growing Zone (WGZ)	
ZONE CI	6.9
ZONE CII	76.6
ZONE CIII	16.5
Typology	%
winegrowers	18.7
winery producers	6.0
both	75.3

Figure 1. Map of Italian Wine Growing Zones (WGZ) as for European Union Reg. No 1308/2013, Appendix I; the number within each region corresponds to the number of responses received from that region.

Table 5 Profile of grapevine farms that participated in the survey.

	%
Vineyard extension	
< 1 ha	1.8
1 – 5 ha	25.7
6 – 10 ha	21.9
11 – 25 ha	26.9
> 25ha	23.1
Type of viticulture	
Conventional	17.5
Integrated	36.8
Organic	32.7
Biodynamic	0.6
Mix	12.3

3.1.1 Varietal change (questions 3 and 4)

Winegrowers were questioned about if they had introduced new varieties in the last years, and, if positive, which criteria was followed to drive the choice. In all zones, more than half of the farmers introduced new varieties, or plan to do it soon, without significant differences between the three WGZs (p-value = 0.6826) (Fig. 2).

Chi square test did not show significant differences (p-value = 0.9089) also in the type of new varieties introduced in the different WGZs (Fig. 3). The main criteria guiding the choice of new varieties for all zones was the market demand (61.5%, 46.8% and 50.0% for CI, CII and CIII, respectively). Data collected clearly indicated a prevalence in the choice of drought-resistant varieties in the southern areas, with 32.4% of winegrowers in CIII zone opting for this choice. A considerable percentage of farmers in zone CII (28.8%), gave preference to pest-resistant varieties, fewer in zones CIII (23.5%) and CI (23.1 %). As expected, late ripening varieties were preferred in the southern areas (11.8% in CIII), while early ripening varieties were the main choice in the northern areas (15.4% in CI).

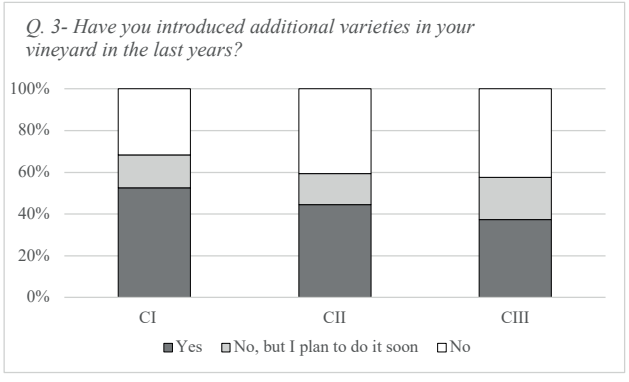

Figure 2. Percentage of winegrowers who introduced additional varieties; the frequency of answers among WGZs was 228 analysed using Chi-squared test; no significant differences were found.

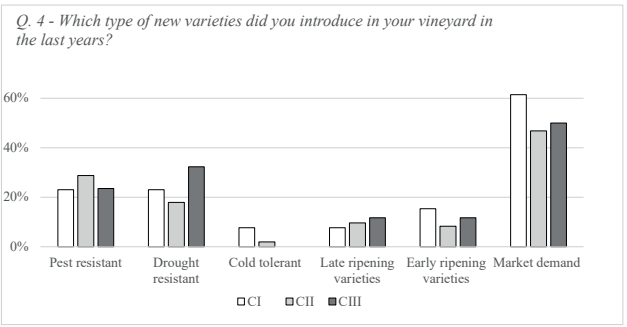

Figure 3. Percentage of new type of varieties introduced by winegrowers in the last years; frequency of answers among WGZs was analysed using Chi-squared test; significant differences were found.

3.1.2 Access to water and irrigation (questions 5 to 8)

This part of the survey was dedicated to collect information on water use in the field; growers were asked if they had access to any water resources near or in the perimeter of their vineyards and, in case of positive answer, whether irrigation was in place or not. They were also asked if they had considered having, implementing, or modifying the irrigation system in the future.

Almost 65% of participants declared a full or partial access to water resources. Chi-square test showed significant differences ($p < 0.0001$) between CI and the other

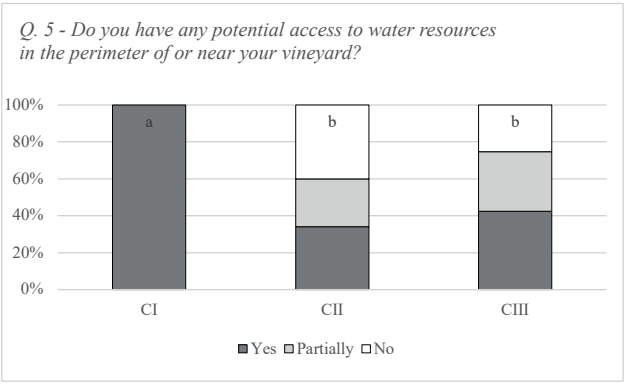

Figure 4. Percentages of farmers with access to water resources; frequency of answers among WGZs was analysed using Chi-squared test followed by pair Chi-squared (CI vs CII; CI vs CIII; CII vs CIII); significant differences are indicated by different letters.

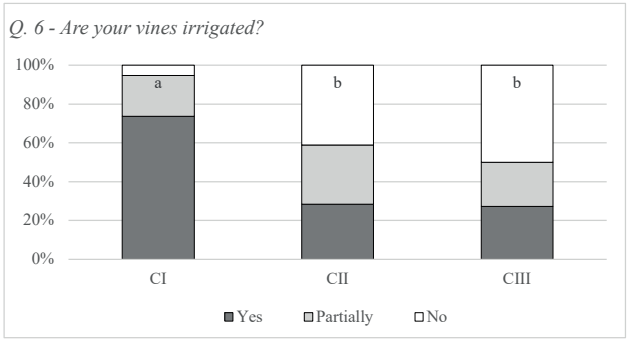

Figure 5. Percentages of farmers who irrigate among those who have water access; frequency of answers among WGZs was analysed using Chi-squared test followed by pair Chi-squared (CI vs CII; CI vs CIII; CII vs CIII); significant differences are indicated by different letters.

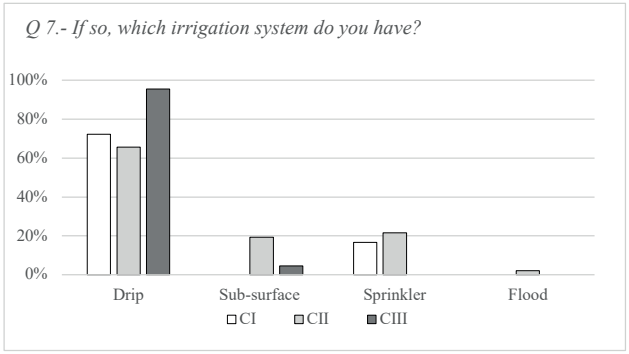

Figure 6. Irrigation systems used by winegrowers; frequency of answers among WGZs was analysed using Chi-squared test; no significant differences were found.

two WGZs, both for water access and use of irrigation (Fig. 4 and 5). In CI, all interviewed farmers confirmed having total access to water and 94.8% of them had an irrigation facility in place. In CII and CIII zones 60% and 74.6% of interviewees, respectively, had water access and about half of them, 59% and 50%, respectively, used water to irrigate.

However, no significant difference (p-value = 0.09038) concerning the irrigation systems emerged between WGZs (Fig. 6). Drip irrigation was recorded as the most widespread method in all WGZs, with a very reduced occurrence of sub-surface irrigation. Drip irrigation was the only method adopted in CIII and present in 84% of vineyards in CII zone. In CI and CII zones, a percentage of sprinkler irrigation is persisting (16.7% and 21.5%, respectively), while flood irrigation facilities are negligible (2.2%).

Even in the case of availability of water, only 39% of the winegrowers considered the option to have, implement or modify (even partially) the irrigation system in the future (question 8), without significant difference between WGZs (p = 0.4249).

3.1.3 Pests and diseases (question 9)

Winegrowers were asked to rate each of the most common pests and diseases for grapevine in the Mediterranean on a scale 1-5. The results evidence that damages caused by vine pests and diseases are currently low, never reaching level 3. However, the Kruskal-Wallis H test showed significant differences (p <0.0001) for some pathogens (Fig. 7).

Powdery mildew (*Erysiphe necator*) was the most recurring pest, followed by Downy mildew (*Plasmopara viticola*) without significant difference between zones. Conversely, grapevine trunk diseases were considered more harmful in CI and CII zones with respect to CIII. Flavescence dorée (*Candidatus Phytoplasma vitis*) was found to be a harmful pest in CII zone, while almost no damage was ascribed in CIII. Significant differences in the damage rate between the zones emerged also for grey mould (*Botrytis cinerea)*, brown marmorated stink bug (*Halyomorpha halys*) and *Metcalfa pruinosa*, even if with a very low damage level.

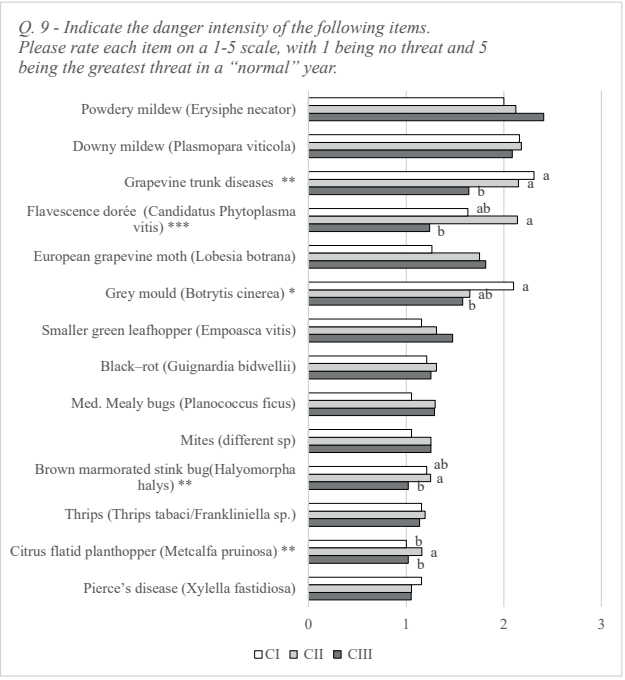

Figure 7. Levels of damage caused by vine pests and diseases (1-5 scale, 5 greatest threat). Statistical differences among WGZ were determined according to Kruskal-Wallis H test followed by Wilcoxon rank sum test; values followed by different letters are significantly different. Signif. codes: p < 0.0001 '***'; p < 0.001 '**'; p < 0.01 '*'; p < 0.05 '.'.

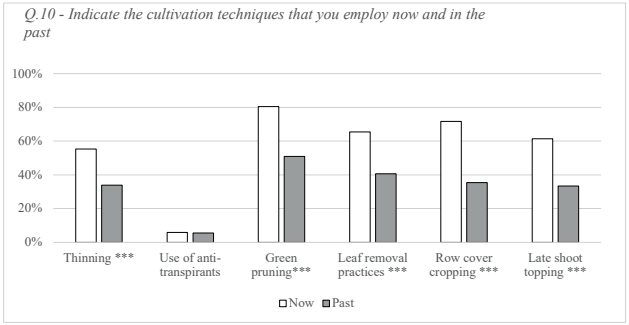

Figure 8. Cultural practices adopted by Italian farmers now and in the past; frequency of answers was analysed using Chi-squared test; significant differences between now and the past are indicated by significance codes: $p < 0.0001$ '***'; $p < 0.001$ '**'; $p < 0.05$ '*'.

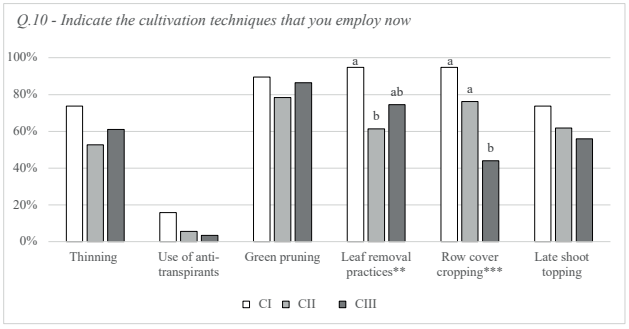

Figure 9. Percentages of cultural practices currently adopted by winegrowers by WGZs. Frequency of all answers was analysed using Chi-squared test; significant differences among WGZs are indicated by different letters. Signif. codes: $p < 0.0001$ '***'; $p < 0.001$ 309 '**'; $p < 0.05$ '*'.

3.1.4 Cultivation techniques (question 10)

Winegrowers were asked to indicate, among a list of cultural practices, those currently applied versus those applied in the past.

With the only exception of the use of anti-transpirants, unaltered in the years, an overall significant increase in the adoption of the listed cultivation techniques by Italian winegrowers emerged. Between the listed practices, green pruning and row cover cropping were the most popular, with an increase of 29% and 37%, respectively. More than half of the winegrowers who responded to the survey currently use leaf removal practices (+ 24% respect to the past), late shoot topping (+ 28%) and thinning (+ 21%) (Fig 8).

All practices, except anti-transpirants spraying, are widespread in all three WGZs (Fig 9), often exceeding 50% of users. CI is the zone where practices are more popular, differing from CII for a larger adoption of leaf removal and from CIII for the use of row cover cropping. No other significant differences were found in the current application of the techniques among the WGZs.

3.1.5 Insurance (questions 11 to 13)

The survey asked winegrowers to indicate if they have now (question 11) and if they had in the past (question 12) any insurance policies and, in such case, for which damage (to be chosen from a list).

Although a significant increase in insurance coverage was recorded with respect to the past ($p < 0.001$), more than half of the interviewees (52%) do not currently adopt any form of insurance.

Considering single hazard agents one by one, Italian farmers have significantly increased their takeout of policies against wind (+ 8%) and flood damages (+ 5%), while those against hail, late frost, drought and wild animals did not change significantly. However, a relevant

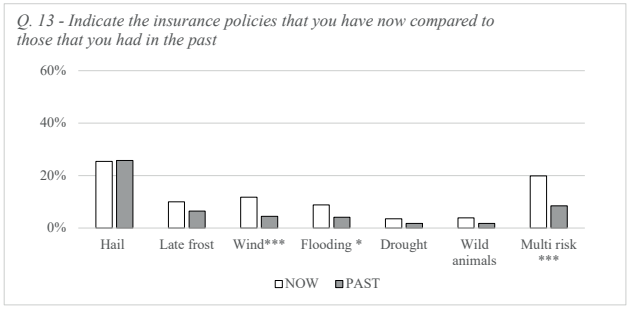

Figure 10. Type of insurance policies take out by Italian farmers now and in the past; frequency of all answers was analysed using Chi-squared test; significant differences between now and past are indicated by significance codes: $p < 0.0001$ '***'; $p < 0.001$ '**'; $p < 0.05$ '*'.

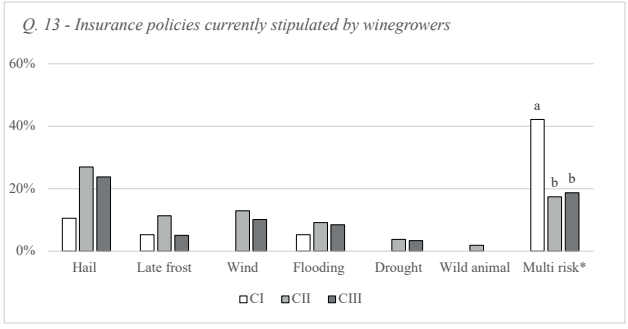

Figure 11. Type of insurance policies currently take out by winegrowers by WGZs. Frequency of all answers was analysed using Chi-squared test; significant differences among WGZs are indicated by different letters. Signif. codes: $p < 0.0001$ '***'; $p < 0.001$ '**'; $p < 0.05$ '*'.

increase was recorded in multi-risk 319 policies (+ 12%), encompassing, case by case, some of the aforementioned agents (Fig. 10).

When comparing the WGZs (Fig. 11), significant differences in the current insurance policies in use emerged only for the multi risk ones, more common in CI (42 %) than in CII (17 %) and CIII (19%).

Among the single-agent policies, that for hail damage alone is the most common among farmers in CII 327 (27%) and CIII (24%) zones, while only 11% of winegrowers adopts this policy in CI. Insurance against late frost is used by 11% of farmers in CII and by 5% in CI and CIII; while mono-risk wind damage insurance is exploited only by farmers in zones CII and CIII, similarly to drought damage insurance. Fewer than 10% of respondents to the survey reported flood damage policies.

3.2 Wine makers

Table 6 summarizes the profile of the wineries in the survey sample (questions 14 and 15). A large 337 majority of them were single-member owned; about one in eight represented the cooperative reality. Most wineries had an annual wine production in the two middle classes (100-1000 and 1000-10000 hl/year, respectively), and almost 29% of respondents were represented by smaller or bigger production classes.

3.2.1 Wine quality (questions 16 to 18)

Table 7 reports the results collected from wineries about the assessed changes so far in some wine 344 characteristics (increase of pH and alcoholic content and changes in the aromatic profile).

Chi-square test did not evidence significant differences in the increase of pH between the WGZs. On the contrary, significant differences emerged among the three WGZs both for alcoholic content and changes in wine aroma profiles. CI and CII resulted, in fact, characterised by a higher increase in the wine alcoholic content (64.7% and 67.5% respectively) with respect to CIII (31.3%), while zone CII is the most affected by changes in the wine aromatic profile (46.8%).

Table 6. Profiles of wineries that participated in the survey.

	%
Winery type	
single-member property	79.7
cooperative	12.0
non-cooperative	6.8
Wine production	
less than 100 hl/year	15.5
100 – 1000 hl/year	42.6
1000 – 10000 hl/year	28.7
over 10000 hl/year	13.2

Table 7. Assessment of changes in wine characteristics by WGZs. Data are in percentages. Frequency of answers among WGZs 351 was analysed using Chi-squared test followed by pair Chi-squared (CI vs CII; CI vs CIII; CII vs CIII); significant differences are 352 indicated by different letters.

Wine quality	WGZ	No	Yes	Not known
Q.16- Have you noticed an increment in pH levels in the past 5 years?	CI	41.2	52.9	5.9
	CII	40.3	44.2	15.6
	CIII	56.3	27.1	16.7
		p-value = 0.1007		
Q.17- Have you noticed an increased alcoholic content in your wines compared to the past?	CI a	23.5%	64.7%	11.8%
	CII b	30.7%	67.5%	1.7%
	CIII c	68.8%	31.3%	0.0%
		p-value = $6.995e^{-07}$		
Q.18- Have you noticed any change in the aroma profile?	CI a	76.5	23.5	0.0
	CII b	45.5	46.8	7.8
	CIII ab	62.5	31.3	6.3
		p-value = 0.03953		

3.2.2 Mitigation strategies in the winery (question 19 to 29)

An open interrogative is understanding how much wine makers are aware of the need to reduce the CC impact of their production activities and whether they are already doing so. About this, specific questions were posed to check if they had recently performed an analysis of cost, energy and water consumption 357 in the winery, and, if not, if they intended to have one in the near future.

Only less than 50% of participants stated that they had carried out such analysis (question 19), with no significant differences between WGZs (41% in CI, 44% in CII and CIII).

Between those who had not yet done this (Fig. 12), 40% in the CI and CII zones were planning to comply in the future, while this percentage significantly rises in CIII (67%).

Wine makers were also asked whether they had recently invested in equipment or infrastructure to optimise winery energy and water consumption and, eventually, whether they invested in renewable energy, and in which ones.

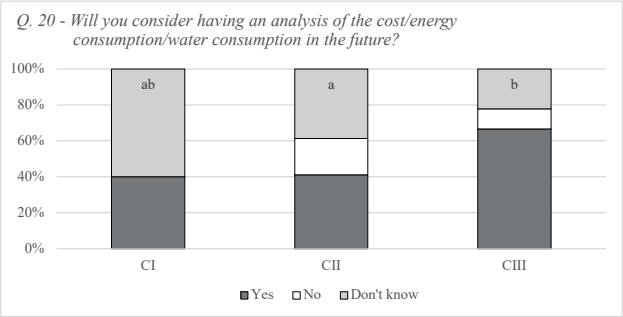

Figure 12. Percentages of winery owners who were considering having an energy and water consumption analysis in the future among those who did not have it yet; frequency of answers among WGZs was analysed using Chi-squared test followed by pair Chi-squared (CI vs CII; CI vs CIII; CII vs CIII); significant differences are indicated by different letters.

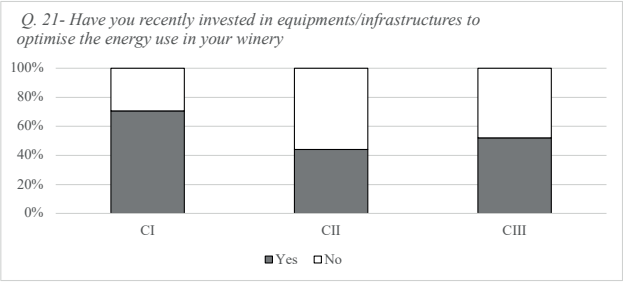

Figure 13. Percentages of winery owners who invested in equipment or infrastructures to optimise energy use in the winery; frequency of answers among WGZs was analysed using Chi-squared test; no significant differences were found.

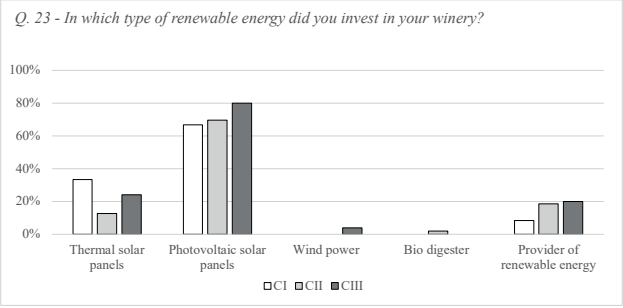

Figure 14. Type of renewable energy systems adopted by winery owners; frequency of answers among WGZs was analysed using Chi-squared test; no significant differences were found.

No significant difference (p-value =0.08023) emerged among the WGZs in such investments, even if CI zone resulted to be the one with the largest investments (71%), followed by CIII (52%) and CII (44%) (Fig. 13). Among the winery owners who answered positively

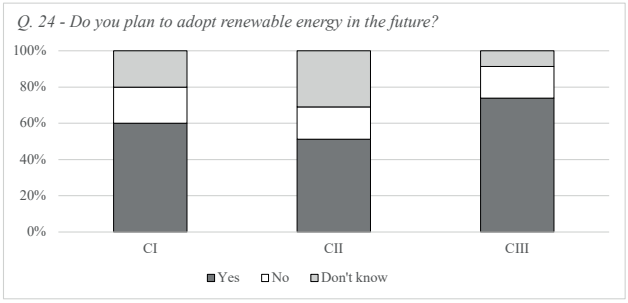

Figure 15. Percentages of winery owners who plan to adopt renewable energy in the future among those who have not done it yet; frequency of answers among WGZs was analysed using Chi-squared test; no significant differences were found.

to the question, almost all (92%, 82% and 96% for CI, CII and CIII, respectively) invested in renewable energy (question 22). No significant differences (p-value = 0.4026) were found among WGZs in the kind of renewable energy chosen (Fig. 14); photovoltaic panels were the most popular facility adopted by winery owners in all the WGZs; around 20% of wineries use energy provided by renewable energy suppliers and solar panels. Among the owners who have not yet invested to reduce energy consumption in the winery (Fig. 15), more than 50% are planning to do it, without significant differences between zones (p-value = 0.159).

When compared to the investments for the optimisation of energy consumption, those aimed at reducing water use (question 25) were in lower amount, especially in the CI and CII zones, where only 29% and 32% of the respondents respectively declared an active investment. Zone CIII turned out to be the one with the largest percentage of water-saving actions (48%). Interestingly, even though C1 is, to date, characterized by the lowest investment actions, it shows the highest percentage of win-

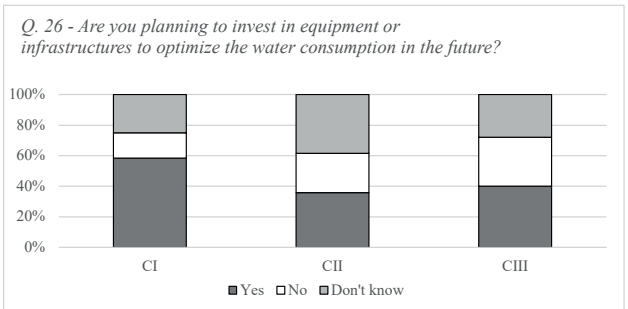

Figure 16. Percentages of winery owners who plan to invest in equipment or infrastructures to optimize water consumption in the winery in the future, among those who have not done it yet; frequency of answers among WGZs has been analysed using Chi-squared test and no significant differences were found.

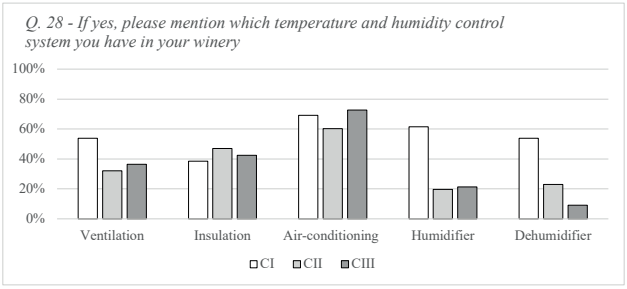

Figure 17. Type of environmental control systems adopted by winery owners; frequency of answers among WGZs 413 was analysed using Chi-squared test; no significant differences were found.

ery owners who declared the higher willingness to plan investment in the future (58%), followed by 40% in CIII zone and 36 % in CII (Fig. 16).

Finally, wine makers were asked about the presence in the winery of any environmental system to control temperature and humidity (question 27), and its specification.

Most of them (76%, 66% and 69%, respectively for CI, CII and CIII) stated to adopt temperature and humidity control systems, with no significant differences between the WGZs (p-value = 0.6659). Similarly, no significant differences (p-value = 0.1849) were detected among WGZs about the type of environmental control systems use in the winery: air-conditioning turned out the preferred way to monitor temperature in all the regions without significant difference, while almost 40% of winery buildings are already insulated (Fig. 17). From the survey, all the WGZs showed an overall limited interest (less than 30%) in investing in climate control systems in the future (question 29).

3.3 Main future concerns (question 30)

A list of potential problems related to the professional activity was posed both to winegrowers and wine 416 producers, who were asked to rate each of them on a Linker scale 1-5.

The average values obtained for the whole Italy are shown in Table 8. Climate change, unpredictable weather, economic crisis and reduction of profitability of productions were found to be the significantly greater concerns for the national wine sector. Conversely, the increasing barrier to export and the reduction of quality and loss of typicity were found, among those proposed, the least worrisome concerns for the future.

When separately analysing the values per WGZs, no significant differences emerged, except for the 423 concern linked to the difficulty in finding skilled labour, stronger in zone CIII than in CI and CII (Fig. 18).

Table 8. Average values for future concerns (1-5 scale, 5 greatest concern). Statistical differences among future concerns were determined according to Kruskal-Wallis H test (p<0.0001) followed by Wilcoxon rank sum test; values followed by different letters are significantly different.

Q. 30 – Which are your main concerns for your professional activity in the long term?	Average value
Climate change	3.70 a
Unpredictable weather	3.66 a
Economic crisis and decrease in the wine demand	3.57 a
Reduction of profitability of grape and wine production	3.24 a
Reduction of public aid and increased regulation	3.19 bc
Increased pests and diseases	3.15 bc
Water stress	3.12 bc
Difficulty finding skilled labour	3.05 bc
Increased barriers to export	2.94 c
Reduction of quality and loss of typicity	2.34 d

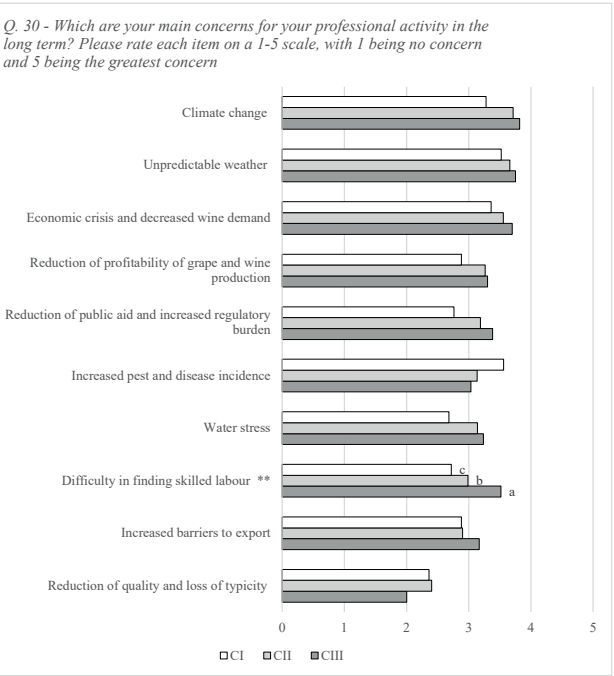

Figure 18. Levels of future concerns expressed by respondents for WGZ (1-5 scale, 1 no concerns 5 greatest concern). Statistical 430 differences among WGZ were determined according to Kruskal-Wallis H test followed by Wilcoxon rank sum test; values followed 431 by different letters are significantly different. Signif. codes: p < 0.0001 '***'; p < 0.001 '**'; p < 0.01 '*'; p < 0.05 '.'.

3.4 Climate change effects (question 31 and 32)

Respondents to the survey were finally asked to express their opinion about the current effects of CC on their activity, and on those expected in the future.

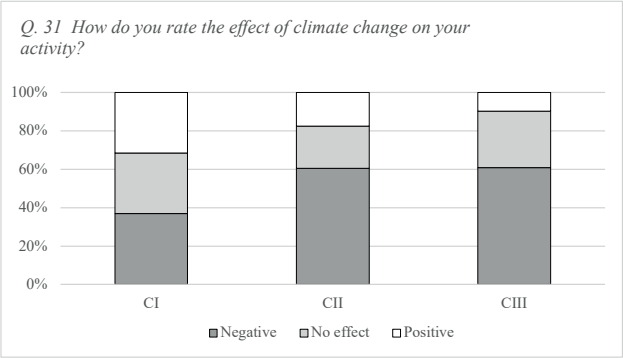

Figure 19. Respondents' evaluation of CC effects in the short-term; frequency of answers among WGZs was analysed 448 using Chi-squared test; no significant differences were found.

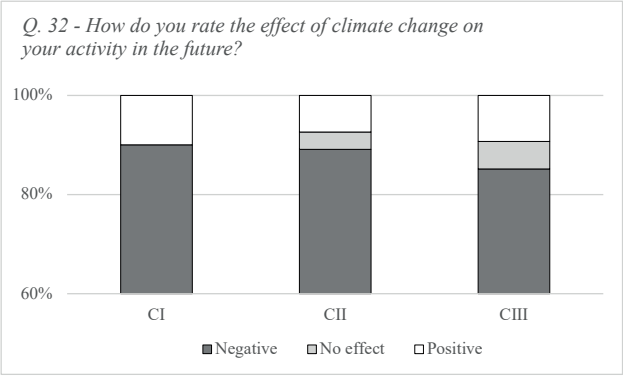

Figure 20. Respondents' evaluation of CC effect in the long-term; frequency of answers among WGZs was analysed using Chi-squared test; no significant differences were found.

The Chi-squared test showed no significant differences among the WGZs in the perceived effects of CC both at short (p-value = 0.1282) and long term (p-value = 0.7921).

At the short-term (Fig. 19), a negative evaluation of the effect of CCs between the actors of the wine value chain is prevalent, and more pronounced in CII and CIII (61%) than in CI zone (37%). However, a high percentage of respondents claims that CC is not currently affecting their production (about 30% in all zones). 32% of respondents located in CI positively rated the effect of current climate on production, while this percentage reduced to only 18% and 10% for CII and CIII, respectively.

In the longer term (Fig. 20), the percentage of respondents believing that climate change will have no impact or will have a positive impact on winery activities drastically drops, thus producing a substantial increase of those believing that climate change will have a negative effect (90%, 89% and 85% for CI, CII and CIII, respectively).

4. DISCUSSION

The sample of respondents to our survey can be considered reliable to roughly represent the wine production pool for the three Italian wine regions, especially for CI and CII. Zone CIII was mostly represented by islands, as few responses were received from the other three regions. In our survey, the percentage of farms which declared to follow organic growing protocol (32.7%) is higher compared to the national percentage of organic wine farming, standing at around 16% in 2019 (Varia et al., 2021).

The following discussion highlights some aspects of the results obtained, aggregated by topic.

Varietal change

The introduction of well-adapted genotypes is recognized as a strategic tool for both adaptation and mitigation, as it leads to minimizing chemical and agronomic inputs and water use (Van Leeuwen and Destrac-Irvine, 2017; Venios et al., 2020). The national rate of farms which introduced new varieties is already high, and likely increasing, according to the declared intentions (more than 50% as national average). Nevertheless, at the moment, the choice of new varieties is still driven by market preferences, as in line with the declared concerns and fears related to economic crisis and reduced profitability of production for the future. Introduction of drought-resistant varieties, however, highlights a potentially growing relevance of this approach, in agreement with Fraga et al., 2016.

Grapevine is highly sensitive to climatic conditions, and its growing and ripening are going to be negatively affected by increased temperatures. Traditionally, in the northern hemisphere, the ideal time for ripening is between early September and early October, when temperature start to decrease (Van Leeuwen and Destrac-Irvine, 2017). Introduction of late varieties to delay ripeness can greatly contribute to overcome any negative effect of CC (Van Leeuwen and Destrac-Irvine, 2017). Despite this, the survey did not reveal a significant inclination of farmers toward this adaptation strategy.

Water availability and use

Water scarcity is one of the greatest risks for crops due to CC, especially for the southern areas (Fraga, 2016). In viticulture, water deficit generally positively impacts berry sugar promoting wine quality, so, traditionally, vineyards are not irrigated; but, if the water

deficit is severe, berry sugar content can decrease due to reduced plant photosynthesis (Van Leeuwen and Destrac-Irvine, 2017). Easy access to water and its efficient use are, therefore, key factors in managing new variable climatic conditions. As expected, the highest rate of water availability characterizes the coolest mountainous areas; such highwater availability resulted in a larger diffusion of irrigation practice among winegrowers. On the contrary, in the Mediterranean part of the peninsula (CII and CIII zones), the limited access to the water resource leads to the reduction of irrigation in the vineyards. However, even among winegrowers with potential access to water, less of 60 % (and even less for CIII) claims their willingness of establishing an irrigation facility on site. Consequently, it may be deducted that the need for irrigation is not felt as an urgency yet, and this hypothesis is also supported by the results emerged from the question about major future concerns, where water stress occupies the fourth-to-last position in the ranking, also in the South.

At the same time, the high investment costs of irrigation systems (Van Leeuwen and Destrac-Irvine, 2017) may also be contributing factors in limiting their adoption, and this even more markedly in the Southern areas, where drought events are more probable and the stabilization of production will become ever more important.

Data on the adopted irrigation systems confirm that, regardless of wine growing zones, farmers prefer systems that optimise water use (drip and sub-surface irrigation), showing a responsible attitude, especially in the South, with a 100% of farmers.

Pests

This section of the survey displayed some minor differences between the three zones. Although CC is potentially involved in a modification of the distribution and severity of pests and diseases (Mira de Orduña R., 2010; Bois et al., 2017), current pest-related damages on grapevines are not rated high in Italy. Current pathogen containment strategies seem to be still adequate, and farmers expressed only a moderate concern about the increase of pathogens in the long term.

Cultivation techniques

With respect to the past, an evident implementation of cultural practices recognized as environmentally friendly and climate-smart emerged as an important sign of adaptation. Row cover cropping is now the most widely implemented practice with respect to the past, although much more applied in northern than in southern areas, probably due to the commitment in avoiding water deficit caused by competition with the grass cover (Celette et al., 2009). It is however already demonstrated that grass cover generally has a smaller impact on vines' water status because of their deeper root systems, enabling them to access deeper water reserves (Van Leeuwen and Destrac-Irvine, 2017).

The many benefits deriving from green pruning on cluster ripening and shoots development make it the most commonly used practice both today and in the past. Late shoot topping and leaf removal practices resulted also highly exploited by farmers in this survey. The attention of vine growers towards the latter two last techniques is higher than in the past, since they are now more carefully modulated, allowing a slower ripening, with lower sugar levels and a more marked acidity (Petrie et al., 2003). Anti-transpirants are mainly adopted in coolest zones even if they could be particularly effective in the dry areas. In fact, they reduce transpiration by forming films that reduce moisture losses and are also effective in reducing sugar accumulation without significantly affecting phenolic compounds accumulation (Paliotti et al., 2013)

The general increase of application of adaptation techniques witnesses, on one hand, the necessity of facing more challenging conditions during the growing season, showing, on the other hand, a good preparedness of farmers who answered the poll to cope with more challenging climate conditions.

Insurances

The adoption of insurance policies is highly recommended by EU Common Agricultural Policies (CAP), as they are considered a valuable tool for fostering agricultural resilience and adaptation to CC (Iglesias and Garrote, 2015; Jørgensen et al., 2020). Targeted insurance policies have, in fact, the potential to stabilise farm income, and this is even more marked in the case of high-value crop as winegrapes (Čop et al., 2020). With respect to the past, a significant increase of specific weather risk policies and multi-peril crop insurance was recorded. Among mono-risk, the insurance that dominates both today and in the past is that against hail damage. This evidence confirms the high concern against this meteorological phenomenon, considered to be potentially more hazardous today than in the past, as according to supported some time series analysis (Eccel et al., 2012; Sanchez et al., 2017). The increased adherence to multi-risk insurance emerged from the survey is in line with the policies adopted since 2000, aimed at

encouraging the transition from mono-risk to pluri-risk contracts (Santeramo, 2018).

Nevertheless, an alarming observation emerged from the survey: more than half of the interviewed winegrowers are not currently adopting any form of insurance policies. This may be in part explained since the adoption of an insurance implies an increase of bureaucracy for farmers and additional costs (Santeramo, 2018). Although there is a long tradition of farm subsidies to cover part of the insurance costs in Europe (Martinez Salgueiro, 2019), individual farmers' participation in crop insurance is still difficult due to scarce knowledge, non-uniform information and lack of experience (Chiappori and Salanie, 2013; Santeramo, 2018) and public intervention alone is clearly not enough to ensure an adequate insurance coverage for the sector.

Impacts on wine quality

The increase of the adoption of management practices able to contribute to the reduction of sugar accumulation (such as late shoot topping and leaf removal practices) reflects the wine producers' assessment of a modification in wine characteristics. The survey evidenced impacts on wine quality as measured by three parameters (pH, alcohol content, aroma profile), with some differences among the zones. A lower impact resulted in the Southern Mediterranean (CIII), where producers reported, compared to the past, the least variations for all three quality parameters. This difference can be partly explained by the fact that warmer regions have been longer faced with the need to correct grape quality parameters, and consequently have consolidated technologies and solutions for adapting to such urgencies. Short-term climate change adaptation strategies such as irrigation, adaption of sunscreens or soil management (van Leeuwen et al, 2019; Santos et al., 2020) and oenological practices for pH and ethanol management (Dequin et al., 2017) are effective strategies to mitigate the undesirable effects of CC on wine quality.

Mitigation strategies in wineries

Analysis of costs and of energy and water consumption can greatly contribute to rationalise and optimise management, saving money, at the same time decreasing the environmental impact of the winery. The analysis revealed the most critical points in the production chain and the most expensive steps in terms of energy and water consumption; such consideration reinforces the need to introduce tailored strategies to mitigate consumptions and costs, making use of environmental control systems and less impactful energy sources. Although less than half of the owners have not carried out this type of analysis yet, they showed some interest, and especially in the southern area 67 % expressed interest in doing so in the future.

Even if there are still not many winery owners who have invested in infrastructures to optimise energy, a large percentage is intending to do so in the future, especially relying on renewable energy, and especially in the South (74%). The choice of the technology to adopt has to be seriously considered, as different control systems for temperature and humidity parameters have different emission impacts. Air conditioning, found to be the most common temperature control system in wineries, is also the most environmentally impactful; fortunately, cellar insulation, which is less impactful and highly encouraged by community policies, has also turned out to be well spread.

The contribution of wine to global anthropogenic greenhouse gas emissions has been estimated approximately 0.3% of annual global GHG emissions, increasing at 0,6% in countries with a high wine consumption per capita (e.g. Ponstein et al., 2019). Although wine making processes account for a small portion of the emissions attributable to the wine sector (Rugani et al., 2013), adopting measures to limit the energetic footprint in the winery such as the use of renewable energy and insulation systems is a viable mitigation strategy.

Another key issue in the strategy of reduction of resource consumption is water. In line with previous findings regarding the lower use of irrigation and the high propensity in saving water in the field, southern regions turned out the ones with the largest percentage of investments to optimise water consumption in winery (48%).

5. CONCLUSIONS

Many of the results of the survey point out the concern for climate change and the needs for adaptation and the importance of addressing climate-linked issues in the whole value chain. A proper awareness of climate urgencies might in fact enhance appropriate adaptation actions, given the higher openness, in this category of farmers, towards the implementation of long-run strategies (Merloni et al., 2018). However, climate change concerns were found to be currently at the same level as the economic ones for the wine sector and slightly higher than all of the proposed threat categories, rated around a medium level of concern. It is not to be overlooked the contingency of the period when the survey was proposed to firms: in 2020 the great uncertainty brought by the

pandemic crisis was potentially able to bias the general feeling about the most stringent urgencies for a sector tightly connected with HoReCa. With these premises, direct consequences of climate change, such as potential increases in pest and diseases and water stress were not perceived as major threats, resulting in medium concerns, with negligible differences among climate zones.

An interesting result is the clear strong increase of the concern about climate impacts in the future with respect to the present time; the majority of respondents claimed some effects, with a generalised pessimistic outlook, and the percentage of farmers and wine makers who considered climate change as potentially positive until now (reaching 32% in CI zone) decreases to negligible values for the future scenarios.

In agreement with Jørgensen et al. (2020), signals emerged in this study about the fact that farmers are already partially adapting to climate change and are aware of future challenges due to unpredictable weather: a significant percentage of farmers has already switched from traditional to more climateadaptable varieties, such as the pest- and drought-resistant ones, although the choice of marketable varieties prevailed. Likewise, the prevalence of water-saving irrigation methods, such as drip irrigation or sub-surface irrigation, is indicative of the farmers' commitment in water use efficiency. An evident implementation of cultural practices recognized as environmentally friendly and climate-smart, as row cover cropping, late shoot topping, and a better defoliation management, also emerged as an important sign of adaptation. Conversely, the risk associated with a scarce use of insurance as a tool for fostering adaptation to climate change, as revealed by the survey, should not be overlooked.

The strong link of European viticulture with traditional practices is likely to be complemented by more marked-oriented adaptation capacities, enabling farmers and wine producers to successfully cope with a wide range of climate change-induced threats. In addition, administrators and policy makers are called to seriously address the issues brought to their attention by the supply chain.

ACKNOWLEDGEMENTS

This study was carried out in the framework of project MEDCLIV, co-funded by EIT Climate-KIC. The authors wish to thank Luca Zulini (FEM) for his collaboration.

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