Climate change and possible effects on the phenological development of grapevines (*Vitis vinifera* L.), simulated varietal suitability and sugar and acidity concentration in the fruits

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Project description

Based on data on future climate developments elaborated by Meteo-Research, several simulation models were used and developed, respectively to estimate the impact of predicted changes on some aspects of viticulture in the Hessian wine-growing areas. Three locations were used; Geisenheim as a representative of the "Rheingau" area, Frankfurt as a representative of the most easterly extension of viticulture in Hesse and Gernsheim as a representative for the "Hessische Bergstraße". Several future climate scenarios were used to model the effects on grapevine phenology, sugar and acidity concentration in the fruits and varietal suitability. Some rough estimates on the possible impact on vineyard site water balance were also conducted, yet without incorporating a suitable grapevine water relations model.

Results

Calculations with respect to temperature-driven factors showed that most of the predicted changes will be reached already by 2050-2060. The increase in temperature will affect varietal suitability and phenological development. Milder winter, spring and summer conditions will speed up plant development. Currently, bud break occurs already 7 days earlier, full bloom around 10 days earlier and veraison (beginning of ripening) 12 days earlier as compared to the average conditions over the last 40 years. This development will continue and depending on the climatic scenario used will cause an additional shift to earlier bud break of up to 1 week and flowering of up to 10 days. Despite earlier bud break, the risk of spring frost will decrease.

Our simulation results showed a general increase in sugar content of the fruits (juice) if the frequency of dry years does not increase disproportionally. Higher temperatures will cause faster and more intense respiration of malic acid which on the long-term could lead to a different wine style. The results demonstrate that the Hessian wine producing areas will become suitable for the cultivation of other varieties, which are currently requiring a higher heat sum as present in these areas. Concomitantly to the increase in temperature, a shift in the precipitation pattern is expected. At least for winter there is a clear trend towards increased amounts of precipitation. For the summer period the tendency is less clear, but generally a decrease in precipitation rates is expected. The frequency of heavy rainfall events will increase which, with unchanged total annual amounts, will cause a decrease in soil moisture content in the summer due to increased surface run-off and erosion. There will be a need to modify soil water management especially at dry sites and vineyards on slopes.

Impact of climate change

The predicted shift in veraison to earlier dates will cause ripening to occur under higher temperatures which will affect grape composition. For Californian vineyards, for example, changes in wine quality have already been correlated with increased night temperatures. Higher temperatures have a substantial effect on the decay rates of malic acid. Because acidification is currently not allowed according to the German wine law, the future will necessitate the development of a legal framework to mitigate expected problems. These

problems will be associated with increases in juice pH, which will cause an increase in the risk of microbiological spoilage.

Within Europe, the predicted warming will lead to a modification in the general varietal spectrum. For the “Rheingau” area simulations of the development of heat sums over the next 4-5 decades showed that varieties such as Merlot or Cabernet Sauvignon may be cultivated in the future but that the production of ice-wine as a traditional product will become more risky. The increase in temperature will shift possible viticultural areas by about 200-400 km to the North and by 100-150 m to higher altitudes. Consequences for the wine industry in general are inevitable.

Within the current project, we primarily investigated the possible effects of higher temperatures. However, there are many other factors with a potential impact on plant growth and functioning. The strong increase in atmospheric CO_2 concentration as the primary cause of global warming will impact directly on the physiology of plants. An increase in photosynthetic capacity is expected with an associated increase in the water use efficiency (amount of water lost per unit of carbon acquired). These effects are not yet sufficiently quantified to include them in model simulations on grapevines. The projected increase in summer drought periods will necessitate changes in soil water management. However, quantification of these changes and adaptation strategies are problematic, since the variability in model projections is substantial.

For some vineyard sites, in particular on steep slopes, the question will arise if cover crops will be an acceptable soil management strategy in the future, since competition for water will be substantial. On the other hand, cover crops act as a sink for CO_2, buffer for heavy rainfall events, source for organic material, constitute the basic requirement of mechanisation, and reduce the risk of erosion and thus are important in a larger context. One strategy may therefore be a combination of cover crops and irrigation, yet the necessary infrastructure for irrigation on these sites is largely absent.

Several other consequences for viticulture result from the projected climate developments. Higher temperatures will increase the decay of organic material in the soil and will affect the availability of nutrients, specifically nitrogen, possibly increasing the leaching rates into the ground water. During summer, nutrient requirements of the vines may have to be met by foliar applications to avoid the lack of soil moisture as transport medium. Additionally, the principal choice of rootstocks needs to be re-considered. Rootstocks currently used in the dry and warm areas around the Mediterranean basin may be alternatives for the German wine-growing regions.

It is also estimated that the warming will cause migration of pests and diseases to the North. Leaf hoppers, Esca, Eutypa and/or black rot, for example, were nearly unknown to German viticulture 20 years ago. The “crossed” form of the grape berry moth was rare and its occurrence confined to exceptionally warm years. Mild winters cause an increase in the survival rate of fungal populations in or near the soil and thus a larger re-infection potential is established. The population size and number of certain insects will also increase.

Possible adaptation strategies

1) Changes in canopy management strategies to delay ripening to cooler periods. This may be a possibility to retain wine style.
2) Changes in the soil management to bring in organic matter, improve water holding capacity and counteract faster decay rates.
3) Use of water-saving strategies such as soil coverage with organic material.

4) Use of drought-tolerant rootstocks and modifications in the nitrogen management.
5) Implementation of irrigation in risk sites.
6) Modification of the legal framework with respect to acidification to stabilise the pH.
7) Use of grapevine varieties currently not suitable for the present climate.
8) Use of different pesticides and management strategies to combat new pests and diseases.

Outlook

The results of this project show that specifically the limited water supply and water holding capacity of soils in steep slope vineyards may become problematic in the future. Since water deficit has been linked to off-flavour formation in white wines, additional studies need to be conducted to quantify the risk for the Hessian wine-growing areas. Grapes of the future will have a high sugar content and thus high potential alcohol in the resulting wines and reduced acidity and some research is needed to establish methods to shift the ripening period to cooler months.