Methods

Dormant winegrape cuttings were taken from the UC Davis Robert Mondavi Institute vineyard in December 2015, where phenology was monitored in the 2015 growing season. Observations using the modified Eichorn-Lorenz (EL) scale (REFERENCE) began 6 March 2015 and continued generally every 3-4 days 2 April 2015, when almost all plants had reached EL stage 11 or higher.

Following collection, cuttings were chilled for 21 days (4° C, 21 days) at the Arnold Arboretum, then forced in greenhouses in 26 cm diameter pots in January 2016. After several months of growth, on 27 May they were placed in growth chambers with day/night temperatures of 6/4 °C and an 8-hour photoperiod to induce dormancy, though the plants did not appear visibly dormant until 20 June.

On 15 August 2016, the 351 potted cuttings were moved out of the chambers and into a greenhouse where the initial day temperature was 18.5 ± 1.5 °C and night temperature was 16.75 ± 1.25 °C. After the first week, the temperatures were slowly raised to 25.5 ± 2.5 °C during the day and lowered to 10 °C at night. The cuttings were pruned the day they were removed from dormancy so that each cutting had two spurs and each spur had two nodes. Then, the diameter of each spur and node and the distance between the two nodes on each spur were measured with calipers.

Twice a week, beginning 22 August, each plant’s development was recorded using the modified Eichorn-Lorenz scale (REFERENCE) and soil moisture was measured with a probe in three locations in each pot. Each spur was kept at two shoots, but only the dominant shoot on each spur had observations recorded. Each shoot was trained up a stake for support. When an inflorescence had developed (EL stage 12), the plant was randomly assigned to one of five growth chambers if it was a part of the heat tolerance experiment. Otherwise, observations on it continued in the greenhouse. Varieties were chosen for inclusion in the experiment to include a diversity of phenology from those varieties for which there were five or more replicates growing.

The five chambers all had a 12-hour photoperiod with 800 m-2s-1 of fluorescent light, but varied in their temperatures: Chamber 1 was set at 17/23 °C, Chamber 2 was set at 23/29 °C, Chamber 3 was set at 27/33 °C, Chamber 4 was set at 31/37 °C, and Chamber 5 was set at 34/40 °C. Initially, CO2 levels were set at 400 ppm during the day and 600 ppm at night, because plants respire at night, increasing CO2 levels (REFERENCE). Each inflorescence was contained in a paper bag to collect the flower caps as they fell.

Observations on the percent flowering, leaf number, stem length, and number of fallen flower caps along with soil moisture readings were made three times a week. On 19 September, it was noted that some inflorescence bags also contained aborted buds that had yet to flower, and thereafter observations of aborted buds were also recorded. Once a plant had reached 100% flowering, or, in the case of plants where the entire inflorescence had died and fallen off, the plant spent a minimum 14 days in the chamber, it was returned to the greenhouse.

All analyses were performed in R version 3.3.3 (R Core Team).

Results

The plants underwent budbreak (EL …) between 17 August and 6 September (mean = 29 August) and leafout (EL …) between 22 August and 22 September (mean = 4 September). All plants had least one bud that burst, but two plants never leafed out. The first inflorescence formed on 5 September, and 51 plants eventually reached this stage (EL 12), though only 26 were of the varieties pre-selected for the experiment.

Budbreak and leafout timing among varieties were similar in the lab and field (Figure XX, budburst: F(1,47)=14.55, p=0.0004; leafout: F(1,47)=18.51, p<0.0001). Few plants developed inflorescences (see Table XX). Plants with thicker spurs were more likely to develop inflorescence (Figure in supplement, Z()=XX, p=XX), and more likely to reach 50% flowering (Figure in supplement, Z()=XX, p=XX).

Plants in Chamber 3 (mean temperature = 30 degrees C) had the greatest change in stem length during their time in the chamber (FIGURE #). Similarly, plants in Chamber 2 (mean temperature = 26 degrees C) had the greatest change in leaf number during the experiment (FIGURE #). However, there was no directional relationship between chamber temperature and either change in stem length or change in leaf number.

(DO YOU REPORT F AND P VALUES ETC EVEN IF THINGS WERE NOT SIGNIFICANT? YES! It helps reader fully evaluate the results.)

Introduction

(TOPIC SENTENCES?)*Vitis vinifera* subsp. *vinifera*, commonly known as the winegrape, is cultivated in vineyards worldwide. At least 6000 genetically distinct varieties are known, but only 1100 are grown commercially, and an even smaller number dominate the global market {Wolkovich, 2017 #22}(LACOMBE 2012). (CONNECT TO NEXT PARAGRAPH)

As the climate changes, the viticulture industry is going to need to adapt as well. Climate change is most likely going to raise temperatures 1-3 degreesC in wine growing regions across the world, which could drive the viticulture industry to shift towards the poles and to higher elevations to maintain ideal growing temperatures for winegrapes {Schultz, 2010 #33}{Hannah, 2013 #10}. In the Southern Hemisphere, where there is less landmass closer to the poles, this could mean a loss in total viticultural land. There is also concern that vineyards could move to land that is currently conserved {Hannah, 2013 #10}. Alternatively, vineyards could take advantage of the great genetic variety that already exists by planting varieties better suited to the new climate {Wolkovich, 2017 #32}. However, for this adaptation to be effective, the differences in phenology among these varieties must be better understood, so that the varieties could be matched with climates they could thrive in.

Studying the phenology of different varieties of winegrapes would help viticulturists better adapt to climate change. Phenology is extremely sensitive to temperature. Timing for leafout and flowering of plant species have advanced six to 20 days in the last 30-40 years of warming (ROOT 2003, MANZEL 2006). This translates to an advance of four to six days per degree Celsius warming (WOLKOVICH 2012). A similar advance is seen for winegrape harvest dates, which can change about 6 days per degree Celsius warming {Benjamin, 2016 #31}. In winegrapes, phenological timing varies across varieties, and it is this variation that could be used to better adapt to future climates. Generally, timing of phenology can vary from three to six weeks across varieties {Wolkovich, 2017 #32}. However, most varieties have very little phenological data from which to infer where they could best be grown (add CITE). Harvest dates are the only data available for over 90% of varieties, so for phenological data to be used for adaptation, more varieties need to be studied (cite Parker studies).

(CONNECTION TO ABOVE PARAGRAPH) Because successful flowers become berries, understanding how climate change will affect winegrape flowering is an important aspect of the overall effect on phenology and directly relates to harvest yields. Petrie and Clingeleffer (GIVE YEAR) found that winegrape (SPECIFY VARIETY?) buds exposed to elevated temperatures just before or just after budburst produced 24.2-32.6 less flowers per degreesC warming.