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Interactive effects of high temperatures and drought on grapevine physiology during a simulated heat wave

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Climate change is expected to increase the frequency and intensity of extreme weather events like heat waves (HW), with potential negative impacts on grapevine productivity and wine quality in several regions. High temperatures during heat waves are usually accompanied by decreases in soil moisture, but few studies have explored the single and combined effects of temperature and drought on grapevine physiology. Using fully controlled environmental chambers we simulated a 6-day heat wave. Each chamber was assigned to one temperature treatment (control or heat). Inside each chamber, four grapevine plants (cv. Sauvignon b. on SO4 rootstock) were placed on weighing lysimeters. Half of the plants in each chamber were well-watered (watered plants) and the other half were subjected to drought (dry plants). Radiation intensity and air temperature mimicked average summer conditions near Bolzano (Italy). In the control chambers, the maximum daily temperature (Tmax) was 30°C for the entire period. In the heat chambers, Tmax reached 40° C on day 6, then it decreased on day 12 to 30° C. Instantaneous leaf photosynthesis (Pn) as well as chlorophyll fluorescence parameters (Fv/Fm, Y(NPQ), qN, qP and qL) were measured manually in the late morning (10:00-12:00) and in the afternoon (15:00-17:00), together with stem water potential (SWP; 15:00-17:00). Plant transpiration (T), soil water potential and leaf temperature were continuously monitored throughout the experiment. During the HW, well-watered plants showed a marked reduction of Pn from the morning to the afternoon, which was not visible in the vines under control temperature. Drought significantly reduced Pn and, when combined with the heat stress, further decreased Pn with respect to the control temperature, both in the morning and in the afternoon. Daily T of watered plants during the HW was about 50% higher than T under the control temperature, while the HW had no effect on T of dry plants. Regardless of the chamber temperature, progressive drought caused stomatal closure, which in turn prevented stem water potential from reaching low levels (all SWP values were >-1.45 MPa). This, in turn, caused an increase of canopy temperature, which in the heated chambers reached a peak of around 45°C (up to 5°C warmer than in the watered plants). The heat stress decreased Fv/Fm both in watered and in dry plants, an effect that was stronger in the afternoon, but also occurred in the morning if the exposure to heat stress was prolonged. Other fluorescence parameters, like Y(NPQ) and qN,

were affected by heat stress, while qP and qL were affected mainly by drought. At the end of the HW, chlorophyll fluorescence parameters recovered in watered plants, but not in the dry ones. Grapevines of the cv. Sauvignon b. were able to cope with a 6-day heat wave provided enough soil water was available to support the significantly enhanced transpiration rate. Drought had adverse effects on Pn regardless of the air temperature, but the drought-stressed plants that were also exposed to the heat wave experienced excess canopy temperatures. Leaf chlorophyll fluorescence proved to be a reliable indicator of heat stress.