High Soil Moisture and Low Soil Temperature Are Associated with Chlorosis Occurrence in Concord Grape

Joan R. Davenport1 and Robert G. Stevens
Department of Crop and Soil Sciences, Washington State University, 24106 North Bunn Road, Prosser, WA 99350

Additional index words. Vitis labruscana, nutrients, cations, site specific, temporal variability

Abstract. Leaf yellowing (chlorosis) is not unique to Concord grape, but occurs with great intensity in the arid, irrigated central Washington state growing region. Past research on nutrients has not shown a clear cause and effect relationship between soil and/or plant nutrient status and chlorosis. We investigated both nutritional and climatic conditions for their association with chlorosis occurrence. Six vineyard sites were selected, 2 each with no history of chlorosis (achlorotic), occasional chlorosis, and annually reoccurring chlorosis (chronically chlorotic) and monitoring sites in chlorotic and achlorotic areas were established. Nutrient elements K, Ca, Mg, Mn, and Cu plus the nonnutrient elements Na and Al were monitored in soil (surface, 0 to 30 cm, and subsurface, 30 to 75 cm, depths) and leaf tissue (both petioles and blades) prebud burst (soil only), at bloom, and preveraison at 650 degree days at all vineyard sites for the 2001, 2002, 2003, and 2004 growing seasons. In addition, both soil temperature and moisture were monitored. To evaluate the intensity of chlorosis at each site, chlorotic vines were GPS marked and mapped post-bloom each year. Overall, chlorosis incidence was more widespread in 2001 and 2003 than in 2002 or 2004. There were few relationships with soil or tissue nutrient concentrations. However, soil moisture was consistently higher and soil temperature lower in the period between bud burst and bloom in the chlorotic sites. This suggests that a cold, wet soil environment prior to bloom impedes grape root growth and/or function and triggers plant chlorosis. Yearly differences strongly support this finding.

Leaf yellowing, or chlorosis, appears in a number of perennial fruit crops grown in the irrigated areas of Central Washington State. In this growing region Concord grape (Vitis labruscana Bailey) shows symptoms every year, with variation in how widespread the occurrence is from year to year. Concord grape yield significantly declines in chlorotic vines as they lose leaves and, with time, vigor (Ahmedullah and Kawakami, 1983). BavareSCO et al. (2005) found a similar decline in Vitis vinifera L. ‘Cabernet Sauvignon’ when grafted to a lime-susceptible rootstock.

Research into the causes of this type of chlorosis has had limited success in identifying causes and developing management strategies. Korcak (1987) found widespread chlorosis in fruit trees when soil pH and calcium carbonate levels were high. Studies on grapevine have associated grape chlorosis occurrence with high levels of soil bicarbonates (Dow and Tukey, 1985; Mengel et al., 1984). However, Li et al. (2005) found that in addition to high soil carbonate/bicarbonate content, fruit tree chlorosis was also found when soil bulk density increased and DTPA-extractable iron decreased in the 20 to 40 or 40 to 60 cm soil depth. Since soils throughout the central Washington growing region are typified as having high soil pH (>7.7) and presence of free calcium carbonates at relatively shallow depths (NRCS, 2005), the findings of Li et al. (2005) support the concept that some factor beyond pH and calcium carbonates are involved in grape chlorosis in areas similar to our growing region.

Research on cranberry (Vaccinium macrocarpon Ait.) chlorosis found that the symptoms occur in response to water stress (Lampinen, unpublished data). The suggestion that some aspect of climate, including soil climatic conditions, may contribute to chlorosis is supported by the recent findings that the physiological disorder blackleaf in grape is triggered by climatic (including soil) conditions (Olmstead et al., 2005; Smithyman et al., 2001). The year to year variability in the extent of grape chlorosis further supports the concept of climate as a potential contributor to the extent of the disorder.

Although the symptoms are classical of a number of different nutrient deficiencies (Ahmedullah et al., 1983; Marschner, 1986), research trials of different foliar nutrient sprays have been shown to have limited success in either alleviating the symptoms or reducing vine vigor decline (Ahmedullah and Kawakami, 1983; Stevens, 1998). These findings are consistent with other research that found limited, and only short-term, success in alleviating chlorosis with supplemental iron fertilizers (Natt, 1992; VeliksaR et al, 1995).

Thus, fruit tree and grape vine research suggest several different possible mechanisms to the development of grape chlorosis. The objective of this research was to study the following potential causes of grape chlorosis: 1) single element nutrient deficiency; 2) a multiple element nutrient deficiency or insufficiency (e.g., a transient deficiency [Marschner, 1986]); 3) high concentration of one nutrient element causing the exclusion of uptake of other nutrient elements; 4) physiological stress due to climatic (including soil) conditions; and 5) a combination of these factors. To this end, six vineyard sites in the Yakima Valley were intensively studied over

Fig. 1. Relative location of six vineyards for chlorosis study. Sites 2 and 3 are achlorotic, sites 1 and 6 occasionally, and sites 4 and 5 chronically chlorotic.
In each of the monitoring areas, soil moisture and temperature were recorded. Soil moisture measurements were collected weekly to a depth of at least 1 m using a neutron probe, with readings in 20 cm increments. Soil temperature data was collected with two-channel, ruggedized temperature data loggers (Onset Computers, Bourne, Mass.) which were buried in the soil adjacent to the neutron probe access tubes. Data was collected both at 5 and 30 cm below the soil surface on an hourly basis beginning at bud burst and continued until just prior to harvest.

In addition, weather data from 1999 and 2000 (the two years preceding the study) through October 2004 was compiled (PAWS, http://index.prosser.wsu.edu). Data compiled were average, maximum and minimum air temperatures (°C), precipitation (mm) and evapotranspiration (ET, mm). The data were used to evaluate weather trends in an 18 to 24 month period before the occurrence of chlorosis to establish if there is a characteristic set of climatic conditions associated with years when grape chlorosis is widespread.

Plant tissue, soil, and weather data were analyzed using ANOVA and regression analysis (PROCGLM, PROC REG) with PC SAS (SAS Institute, Cary, NC).

The studied portion or entire vineyard block was mapped to track the increase or decrease in site specific chlorosis with time and to verify that monitoring zones were in chlorotic or achlorotic sites. This was conducted just after bloom, when chlorosis was clearly visible, using a Trimble Ag-122 Global Positioning System (GPS, Trimble Corp., Sunnyvale, Calif.). The entire row length was traveled and plants with any visible chlorosis symptoms were marked. Maps of the chlorosis extent were made using ArcView 3.2 software (ESRI, Redlands, Calif.).

The two vineyards chosen as achlorotic sites did not develop chlorosis symptoms during this experiment despite several years where chlorosis was extensive in the region.

Results and Discussion

Chlorosis was associated with higher levels of soil Ca and Mg as well as lower levels of Fe and Mn (Table 1). Soil Al was statistically lower in the chlorotic sites but the actual value difference is small and unlikely to be biologically significant. Only Mn and Al were significantly different in leaf tissue, with Mn higher and Mn lower in leaves from chlorotic plants (Table 2). Lower leaf tissue Mn in chlorotic plants has been identified in past work on chlorosis, yet foliar Mn supplements were not found to be effective at reversing chlorosis (Ahmedullah and Kawakami, 1983; Stevens, 1998). The lower level of Fe in soils but not in tissue in chlorotic plants may be explained by the method of measurement. Recently, Smith...
and Shano at about 80 cm (NRCS, 2005).

There were differences between sites in soil pressure years. Bars are ± 1 standard error.

and Cheng (2005) reported that leaves of plants grown with different rates of soil applied Fe did not show differences in leaf tissue total Fe but did show differences when active Fe was extracted and measured. Regardless, the limited relationship between soil and plant nutrient differences associated with chlorosis occurrence suggests that neither nutrient abundance nor limitations alone trigger chlorosis.

Spring soil pH was significantly different by sample depth but not between chlorotic and achlorotic sites (P = 0.0001 and 0.1569, respectively). The soil pH at these sites was typical of the region, ranging between 7.7 to 8.5 in the surface and 7.7 to 8.6 in the subsurface soils. Free calcium carbonate was not tested at these sites, but soil series descriptions indicate that the Warden soil becomes effervescent at about 40 cm depth regardless of each vineyard clearly show that, with time, the region, ranging between 7.7 to 8.5 in the surface and 7.7 to 8.6 in the subsurface soils. Free calcium carbonate was not tested at these sites, but soil series descriptions indicate that the Warden soil becomes effervescent at about 40 cm depth. Furthermore, site 5 was chosen as a chronically chlorotic site. In 2001 the irrigation system at this site was changed from furrow to overhead sprinkler irrigation and there was a concurrent increase in soil moisture at this site (Davenport et al., 2003; Mills, unpublished data). Chlorosis symptoms had not been seen on that vineyard prior to the change in irrigation system, however, it became widespread following the change in irrigation management (Fig. 5).

The extent of chlorosis, measured as plants with chlorosis symptoms post-bloom, varied by site and year (Figs. 5, 6, 7, and 8). Chlorosis was most extensive across sites 1 and 3. Site 1 was initially being chosen as an occasionally chlorotic site. In 2001 the irrigation system at this site was changed from furrow to overhead sprinkler irrigation and there was a concurrent increase in soil moisture at this site (Davenport et al., 2003; Mills, unpublished data). Chlorosis symptoms had not been seen on that vineyard prior to the change in irrigation system, however, it became widespread following the change in irrigation management (Fig. 5). Likewise, site 5 was chosen as a chronically chlorotic site yet had decreasing levels of chlorosis during the study period. The yearly maps of each vineyard clearly show that, with time,
chlorosis occurs in a consistent area within a given vineyard.

Looking at the annual extent of chlorosis in the chlorotic vineyards, it is apparent that there was greater chlorosis presence in 2001 and 2003 when compared with 2002 and 2004 (Figs. 5, 6, 7, and 8). Total cumulative precipitation between dormancy and harvest suggests that 2003 was a wetter year and 2001 was a very dry year (Fig. 4a). In fact, 2001 was a drought year (Scott et al., 2002). However, due to drought conditions there were irrigation water restrictions in 2001 which influenced irrigation management. As a response to forecasts of drought conditions, fruit growers in the Yakima Valley typically irrigate at high rates in the spring, using the available cold snow melt water. In addition, cumulative precipitation between bud burst and fruit set was also higher in 2001 and 2003 than 2002 and 2004 (Fig. 4b).

Both soil moisture and soil temperature data collected from bud burst through bloom was classified into high (2001, 2003) or low (2002, 2004) chlorosis years. When compared for chlorosis incidence in the high pressure years, maximum surface soil temperature was highest at achlorotic sites whereas at chlorotic sites maximum soil temperature differed between high and low pressure years (Fig. 3). Soil moisture in the period leading up to bloom was also higher in both chlorotic and achlorotic sites in the high pressure years when compared to the low pressure years (Fig. 2b). The same analysis was conducted on soil and tissue nutrient levels and no differences were found. Thus, since soil moisture directly impacts soil temperature, this suggests that high early season soil moisture, particularly during bloom, triggers chlorosis. This may be related to an impedance in root growth, a reduction of root function, or a requirement for higher nutrient concentrations in soil solution in the cool, wet environment (Huang et al., 2005; Marschner, 1986).

Conclusions

The findings from this study suggest that high soil moisture conditions are critical to chlorosis occurrence. Figures 5 through 8 clearly demonstrate that there are areas of chlorosis every year and, in high chlorosis pressure years, these areas dramatically expand. Both Perret and Koblet’s (1984) work finding chlorosis in compacted soil zones resulting in wet, reducing conditions and the work of Li et al. (2005) showing chlorosis associated with high soil bulk density supports this finding. Our
results are also consistent with the published literature associating chlorosis to high levels of soil Ca (Bavaresco et al., 2005; Korcak, 1987). However, our results suggest that in alkaline soils, early season moist soil conditions result in an environment that adversely affects grape root function, triggering chlorosis, which is further exacerbated by presence of high levels of soil Ca. This is supported by differences in soil moisture and temperature conditions, but not of soil Ca levels, between high and low chlorosis pressure years. Chlorosis expansion in high pressure years may be related to factors such as depth of soil to an impermeable layer (e.g., hardpan) or free calcium carbonates, neither of which were measured in this study.

Literature Cited

Ahmedullah, M. and A. Kawakami. 1983. Experiments on foliar nutrition of Concord grape in Washington. Proc. Wash. Grape Soc. 15–21.

Ahmedullah, M., W.W. Cone, A.I. Dow, D.F. Mayer, R. Parker, and C.B. Skotland. 1983. Symptoms of grape disorders in Washington. Wash. State Univ. (Pullman) EB 0722.

Bavaresco, L., P. Presutto, and S. Civardi. 2005. VR 043-43: A lime susceptible rootstock. Amer. J. Enol. Viticult. 52:192–195.

Brady, N.C. and R.R. Weil. 1999. The nature and properties of soils. 12th ed. Prentice Hall, Upper Saddle River, N.J.

Davenport, J.R., J.M. Marden, L.J. Mills, and M.J. Hattendorf. 2003. Concord grape response to variable rate nutrient management. Amer. J. Viticult. Enol. 54(4):286–293.

Dow, A.I. and R.B. Tukey. 1985. Iron chlorosis in Washington orchards and vineyards. Wash. State Univ. (Pullman) EB 1335.

Huang, X., A.N. Lakso, and D.M. Eissenstat. 2005. Interactive effects of soil temperature and moisture on Concord grape root respiration. J. Expt. Bot. 56:2651–2660.

Keller, M., L.J. Mills, R.L. Wample, and S.E. Spayd. 2004. Crop load management in Concord grapes using different pruning techniques. Amer. J. Enol. Viticult. 55:35–50.

Korcak, R. 1987. Iron deficiency chlorosis. Hort. Rev. 9:13–186.

Li, L., J. Zhang, Y. Wang, W. Xing, and A. Zha. 2005. Effects of soil properties and depth on fruit tree chlorosis in the loess region in northern China. Comm. Soil Sci. Plant Anal. 36:1129–1140.

Marschner, H. 1986. Mineral nutrition of higher plants. Academic Press, San Diego.

Mengel, K., M., T. J. Breininger, and W. Bubl. 1984. Bicarbonate, the most important factor inducing iron chlorosis in vine grapes on calcareous soil. Plant Soil 81:333–344.

Natt, C. 1992. Effects of slow release iron fertilizers on chlorosis in grape. J. Plant Nutr. 15:1891–1912.

NRSC. 2005. Official soil series descriptions. 29 Dec. 2005. http://soils.usda.gov/technical/classification/osd/index.html.

Perret, P. and W. Koblet. 1984. Soil compaction induced iron chlorosis in grape vineyards: Presumed involvement of exogenous soil ethylene. J. Plant Nutr. 7:533–539.

Olmstead, M.A., J.R. Davenport, and R. Smithyman. 2005. Blackleaf of Grapes. Wash. State Univ. (Pullman) EB 0745.

Smith, B.R. and L. Cheng. 1998. Blackleaf of Concord grape. J. Amer. Soc. Hort Sci. 130:333–340.

Smithyman, R.P., R.L. Wample, and N.S. Lang. 2001. Water deficit and crop level influences on photosynthetic strain and blackleaf symptom development in Concord grapevines. Amer. J. Enol. Viticult. 52:364–375.

Stevens, R.G. 1998. The yellow vines of 1996. 1996 Proc. Wash. Grape Soc.

Veliskar, S.G., R.F. Syrcu, V.M. Bussiu, S.I. Toma, and A.I. Zemshman. Iron content in grape tissue when supplied with iron-containing compounds. J. Plant Nutr. 18:117–125.

Wample, R.L., L. Mills, and A. Kawakami. 2000. [CD-ROM] The effect of ten years of mechanical pruning on root development of Concord grapevines in Washington State. 5th Intl. Symp. Cool Climate Viticulture and Oenology. 16–20 Jan. Melbourne, Australia. Winetitles, Adelaide.

Wright, R.J. and T.L. Stuczynski. 1996. Atomic absorption and flame emission spectroscopy. p. 65–90. In D.L. Sparks (ed.). Methods of soil analysis. part 3. Chemical methods. Soil Sci. Soc. Amer. Press, Madison, Wis.