A Role of Irrigation in Managing Vine Potassium Status on a Clay Soil

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Abstract: The relationships among soil potassium (K), soil water content (SWC), vine K status, and vine yield parameters were evaluated in a commercial vineyard of *Vitis vinifera* L. cv. Pinot noir on rootstock *Vitis rupestris* cv. St. George in the Carneros appellation in California. Treatments included two K-sulfate fertilizer application rates (0 and 3.6 kg per vine) and two irrigation regimes (standard practice and supplemental). The soil to a depth of 90 cm was a clay loam containing K-fixing species, smectite, and vermiculite. Two years after application, the applied K had moved to a depth of 90 cm, which corresponded to the zone where the majority of the root intercepts were found. Neither the irrigation nor the fertilization treatments had a significant effect on root density or distribution. The SWC was maintained nearer to field capacity and the midday leaf water potential (Ψ_{leaf}) was maintained 0.2 to 0.6 MPa higher by supplemental irrigation. Grapevine K status (petiole K concentration) was increased by both K fertilization and supplemental irrigation and the increase was attributed to increased diffusion of K to the roots. Supplemental irrigation ameliorated late-season decline in vine K status. Although vine K status was increased by K fertilization and supplemental irrigation, yield was not increased. The previously established critical level of 1.0% K as percent dry weight for grapevines in general does not appear to be suitable to Pinot noir on St. George rootstock in this area.

Key words: potassium, fertilization, irrigation, Pinot noir, X-ray diffraction, root distribution

Grapevine potassium (K) status is determined by both plant and soil factors, yet soil factors have received the most attention from researchers. Soil factors influencing K availability and uptake include soil texture, clay mineralogy, cation exchange capacity (CEC), soil pH, soil moisture, soil aeration, soil temperature, the amount of exchangeable K in the soil and subsoil, and rooting depth. The amount of clay particles in a soil and the clay mineralogy of the soil indirectly influence K availability by impacting the CEC and soil water-holding capacity. Potassium deficiencies occur more often on sandy soils than on soils with moderate to high clay content. Accordingly, much of the research used to establish criteria for K requirements of grapevines has been conducted on light soils (those with low clay content) prone to K deficiency. These soils have a low CEC and low soil water-holding capacity, which reduce K availability.

However, K deficiencies also occur on heavier soils, which are common in the North Coast region of California, where there is significant premium winegrape production and where there has been little or no research on K nutrition for over 50 years (Ulrich 1942). For example, during the drought cycle of the late 1980s there were increased grower observations of vine K deficiencies in the North Coast region.

Irrigation has for some time been known to influence the K status of grapevines. The concentration of petiole and leaf K during several sampling times (bloom, veraison, and harvest) increased when normally nonirrigated vineyards were irrigated (Vaadia and Kasimatis 1961, Freeman and Kliewer 1983). The concentration of leaf K has similarly been increased by both irrigation and K fertilization in tree fruit species (Hibbard and Nour 1958), indicating that the mechanisms by which soil moisture influences K availability are not unique to grape. The roles of mass-flow and diffusion first proposed by Barber (1962) have been particularly useful in explaining the mechanism by which soil water (irrigation) may affect the availability of K in the soil. Soil and fertilizer K moves to the root surface mainly by the process of diffusion, and this diffusion has been shown to be directly proportional to the soil water content. (Barber et al. 1963, Kuchenbuch et al. 1986). In short, the availability of both soil and fertilizer K can be improved by maintaining higher soil water content. Increased diffusion of K due to higher soil water content could possibly explain the quicker response to K fertilization often observed in irrigated vineyards in comparison to nonirrigated vineyards (Dundon et al. 1984, Sipiora 1994).

In addition, when irrigation regimes do not resupply the water extracted by the vines and soil water content decreases, certain clay minerals, such as montmorillinite,

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contract, thus trapping the K ions in the interlayers of the clay lattice. This can contribute to late-season K deficiency. On soils with significant amounts of contracting clays, K deficiencies may not occur early in the season when soil water contents are high from winter rains. However, as the soil becomes increasingly dry, K availability diminishes. Deficiency symptoms may develop later in the season when full canopies extract soil water more rapidly than early in the season. Thus, symptoms may appear after veraison in vineyards that might produce adequate (or nearly so) tissue K concentrations from samples taken at bloom. When drought has decreased the soil water content at the beginning of the season, a failure to compensate with more irrigation water can lead to greater soil water deficits, and subsequently reduced K availability, than vines had experienced in wetter years.

This trial was established in response to grower observations of annual declines in petiole K concentrations during a drought cycle in the late 1980s in northern California and to the fact that little or no research had been done on K fertilization of vineyards in this region since 1942 (Ulrich 1942). The objectives of this study were to determine whether the declining K status of grapevines in this area was due to soil water deficits, to low soil K levels, or to a combination of both.

Materials and Methods

Experimental design. Experiments were conducted in a commercial vineyard in the Carneros appellation in California that was planted in 1977 to *Vitis vinifera* cv. Pinot noir (Gamay Beaujolais clone) grafted onto *Vitis rupestris* cv. St. George rootstock on a gravelly clay loam (Haire series) (Lambert and Kashigawi 1978). Vines were spaced at 2 m x 3 m (1667 vines/ha) and trained on a bilateral cordon system. All vines were pruned to the same number of two-bud spurs each year and managed with standard commercial practices.

Treatments were imposed as a 2 by 2 factorial with rates of irrigation and K_2SO_4 fertilizer as factors and five replications. Each treatment combination plot had 25 vines, and plots were separated by buffer row. The two rates of K_2SO_4 fertilization were: 0 kg per vine (control) and 3.6 kg (8 lb) per vine. Fertilizer was applied in the spring of 1988 by shoveling it into the drip-irrigation basin next to the vine (Uriu et al. 1980). The irrigation treatments were begun in 1989 and continued in 1990. The rates of drip irrigation were 40 L per vine per week (~10 gal/vine) (standard) and 160 L per vine (supplemental) applied on one day each week. Vines under standard irrigation had one 1 gal/hr emitter and vines in supplemental irrigation had two 2 gal/hr emitters on one side of the vine, inserted into drip hose 30 to 45 cm from vine trunk. Irrigation was begun two weeks after bloom and discontinued two weeks prior to harvest for supplemental vines and four weeks prior to harvest for standard vines. Specific treatment combinations will be referred to as follows:

K fertilization level	Irrigation level	Code
0 kg/vine	Standard	0-Std (control)
3.6 kg/vine	Standard	K-Std
0 kg/vine	Supplemental	0-Supp
3.6 kg/vine	Supplemental	K-Supp

Soil K and mineralogy. Soil samples were taken from depths of 0 to 30, 30 to 60, and 60 to 90 cm with a Viehmeyer soil sampling tube in the spring of 1988, prior to treatment application, and again after harvest in 1989. The samples were taken from below the vine row midway between drip emitters and vine trunk (15 cm from vine). The samples from all replicates of each treatment at each depth were combined and aliquots analyzed for exchangeable K (K_{exch}) by extracting with 1N NH_4OAc (Knudsen et al. 1982) and for texture and cation exchange capacity (CEC) by standard methods (Blake and Hartge 1982). The clay mineralogy of the same samples was determined by X-ray diffraction (Whittig and Allardice 1986).

Soil and vine water status. The soil volumetric water content (SWC) was monitored during 1989 and 1990 using a neutron probe (model 3332, Troxler, Research Triangle Park, NC). Access tubes were installed at distances of 25, 75, and 150 cm from a representative vine perpendicular to the vine row in each irrigation treatment plot. Neutron probe readings were taken at intervals of 30 cm to a depth of 120 cm. The neutron probe was calibrated according to Grismer et al. (1995). Briefly, soil cores of 60 cm^3 were taken with a Madera soil sampler at depths of 30, 60, 90, and 120 cm from 10 randomly selected access tube sites. The volumetric water content was then determined and a regression analysis performed against the count ratio to establish a calibration.

Midday leaf water potentials (Ψ_{leaf}) were measured with a humidified pressure chamber following the procedure of Turner (1988). Measurements were taken three or four days after irrigation on a total of two recently mature leaves that were fully exposed to sunlight from one vine per plot.

Root distribution. The distribution of roots in the soil profile was mapped at the onset of veraison in 1990 following the root wall profile method of Böhn (1979). A backhoe trench was dug parallel to the vine row at a distance of 30 cm from each vine with a backhoe. The surface was made vertical, and the positions of root intercepts with the vertical surface were recorded as described by Araujo et al. (1995). The root distribution from a total of eight vines was mapped, representing two vines per treatment.

Vine K status. Approximately 20 petioles per plot were collected from leaves opposite clusters at three phenological stages: bloom, veraison, and harvest (and an additional preharvest sample in 1990). Petioles were air-dried, ground, ashed, and extracted with 2N HCl. Potassium was analyzed by atomic emission spectroscopy.

Yield components. Three vines per plot were harvested at fruit maturity (21 to 22 Brix) in 1989 and 1990. Average cluster weight was calculated using measured values for yield per vine and clusters per vine. Berry weight was determined from 100-berry samples collected at harvest from each plot.

Table 1 Analysis of texture, cation exchange capacity, and clay mineralogy for samples of soil from different depths at Carneros. (Samples from field replicates were combined for analysis.)

Soil depth (cm)	Texture	Clay %	Silt %	Sand %	CEC (meq/100 g)	Mineralogy of <2 µm clay fraction[a]
0 to 30	clay loam	40	35	25	22.2	SM, VR, KA
30 to 60	clay loam	38	35	27	21.4	SM, VR, KA
60 to 90	clay loam	38	35	27	16.7	SM, VR, KA

[a] SM: smectite, VR: vermiculite, KA: kaolinite.

Results and Discussion

Soil analysis. Our texture analysis classified the soil as a clay loam (Table 1), which agrees with the Napa County Soil Survey (Lambert and Kashigawi 1978). The clay content was between 38 and 40% by weight to a depth of 90 cm. The CEC was above 20 meq/100 g soil to a depth of 60 cm, and 16.7 meq/100 g below that. By comparison, the extensive study of K nutrition by Kasimatis and Christensen (1976) was done on a sandy loam soil much more commonly associated with K deficiency. The CEC of that soil was about one-third of the CEC in the Carneros clay loam, and the clay content was less than 15% compared to approximately 40%.

Table 2 Exchangeable soil K (µg/g) in the drip zone before and two years after fertilization with potassium sulfate. (Samples from field replicates were combined for analysis.)

Depth (cm)	Initial sample spring 1988	Fall 1989 sample[a]			
		0-Std	0-Supp	K-Std	K-Supp
0 to 30	199	129	131	4430	1270
30 to 60	148	83	71	1910	1130
60 to 90	101	50	46	730	630

[a] Std: standard grower irrigation practice (40 L/vine/week); Supp: supplemental irrigation practice (160 L/vine/week).

The X-ray diffraction analysis indicated that the clays in this soil are composed of three main mineralogical types: smectite, kaolinite, and vermiculite. Both smectite and vermiculite are K-fixing clays; kaolinite does not fix K. One consequence of the ability of certain California soils to fix K is a reduced infiltration of K fertilizers into the soil profile (Ganje and Page 1970). That can be especially important with deep-rooted crops, such as prunes or grapes, where high doses of K fertilizers have normally been recommended to overcome the high K fixation capacity of these soils (Uriu et al. 1980, Christensen et al. 1978). Ross and Cline (1984) estimated that 1200 kg K/ha could potentially be fixed by a soil with 1% vermiculite and a CEC of 15.4 meq/100 g. Assuming that the K-fixing capacity of the soil in this trial had 1% vermiculite, it would be able to fix up to 0.7 kg of K or 1.6 kg K_2SO_4 per vine, which is 40% of the applied K at the vine spacing in this trial.

The soil K_{exch} was initially between 100 and 200 µg/g soil and decreased with depth (Table 2). This is five times higher than for more comprehensively studied San Joaquin Valley soils (Kasimatis and Christensen 1976), but similar to values reported by Ulrich (1942) for two North Coast vineyard soils.

During this experiment the soil K_{exch} in the drip zone (nearest to the vine) of the nonfertilized plots (0-Std and 0-Supp) decreased at all depths by about 30% (Table 2), indicating that periodic K applications may be needed to maintain K availability in this soil type. The K_{exch} in the drip zone was greatly increased to a depth of 90 cm with application of K_2SO_4 under both standard and supplemental irrigation treatment levels. That is not always the case, however, as we have observed the movement of an application of 3.6 kg of K_2SO_4 was limited to the top 30 cm in heavy clay soils in the North Coast (Sipiora 1991). The application of K through the drip system or under the drip emitter has been shown to improve the penetration of K into the soil profile and quicken K uptake in prunes compared to surface application (Uriu et al. 1980). Supplemental irrigation did not increase the K_{exch} **at depth compared to standard irrigation**.

Soil water status. Supplemental irrigation maintained higher SWC near the vine. The influence of supplemental irrigation on SWC at three different distances (25, 75, and 150 cm) from vine row out into the row middle on 21 July 1989 is shown in Figure 1; this was a representative SWC profile for the entire growing season. The increase in SWC was greatest adjacent to the vine (25 cm) at all depths (Figure 1A). Supplemental irrigation also increased SWC at a distance of 75 cm away from the vine row (Figure 1B), especially in the top 90 cm of the soil profile. At a distance of 150 cm from the vine row (Figure 1C), SWC was depleted during the season similarly under both irrigation rates, demonstrating that the lateral movement of the water applied through the drip system did not reach the row middles.

The SWC next to the vine row (75 cm) was maintained higher with supplemental irrigation than with standard irrigation to a depth of 120 cm in 1989 (Figure 2). The depletion of SWC at various depths between the beginning and the end of the 1989 season indicates that under both standard and supplemental irrigation, the majority of water uptake occurred between 30 and 90 cm. A higher SWC was also maintained in 1990 with supplemental irrigation, but not to the same degree as occurred in 1989 (Figure 3). The SWC was lower at the beginning of the season in 1990 than at the beginning of 1989. These data once again indicate that the uptake of water occurred mainly at a depth of 30 to 90 cm, although there may have been greater loss of SWC at 120 cm under standard irrigation in 1990 than 1989. The

SWC in the top 30 cm of soil 25 cm from the vine was maintained close to early-season values even under standard irrigation.

Root distribution. The distribution of grapevine roots is influenced by soil characteristics and cultural practices as well as rootstock (Swanepoel and Southey 1989). The rootstock variety in our experimental rows (Rupestris St. George) is vigorous, deep rooted, and has a high root density (number of roots per m^2 in profile) in comparison with other rootstocks normally used in this region (Morano and Kliewer 1994). A representative example from the mapping of St. George root intercepts in this trial is provided in Figure 4. The effective rooting depth for all treatments was approximately 120 cm, although a few roots were found between 120 and 150 cm in each treatment.

Root density did not simply decrease with depth. Root intercepts between 30 and 60 cm were generally greater than 0 to 30 cm. Large roots (>2 mm in diameter), and over 50% of root intercepts, were concentrated between 30 and 90 cm. This depth coincides with the zone of greatest soil water loss during both seasons. Van Zyl (1988) similarly found a reasonably good correlation between root distribution within the soil profile and soil water depletion for furrow- and border-irrigated grapevines.

Significant differences in the total number of root intercepts by depth were not found; however, the means may nevertheless indicate an important aspect of root distribution and K uptake. There was no evidence of a proliferation of roots under the drip emitters (Figure 4). The root intercepts for the 0-Std treatment (control) were concentrated in the subsoil (30 to 90 cm) where the K$_{exch}$ was lower than in the topsoil (0 to 30 cm) (Table 2, Figure 5). All other treatment combinations (0-Supp, K-Std, and K-Supp) had a larger percentage of roots in the top 30 cm of soil. The reduced ability of 0-Std vines to exploit K in the topsoil may have contributed to the low petiole K levels at this site. The abil-

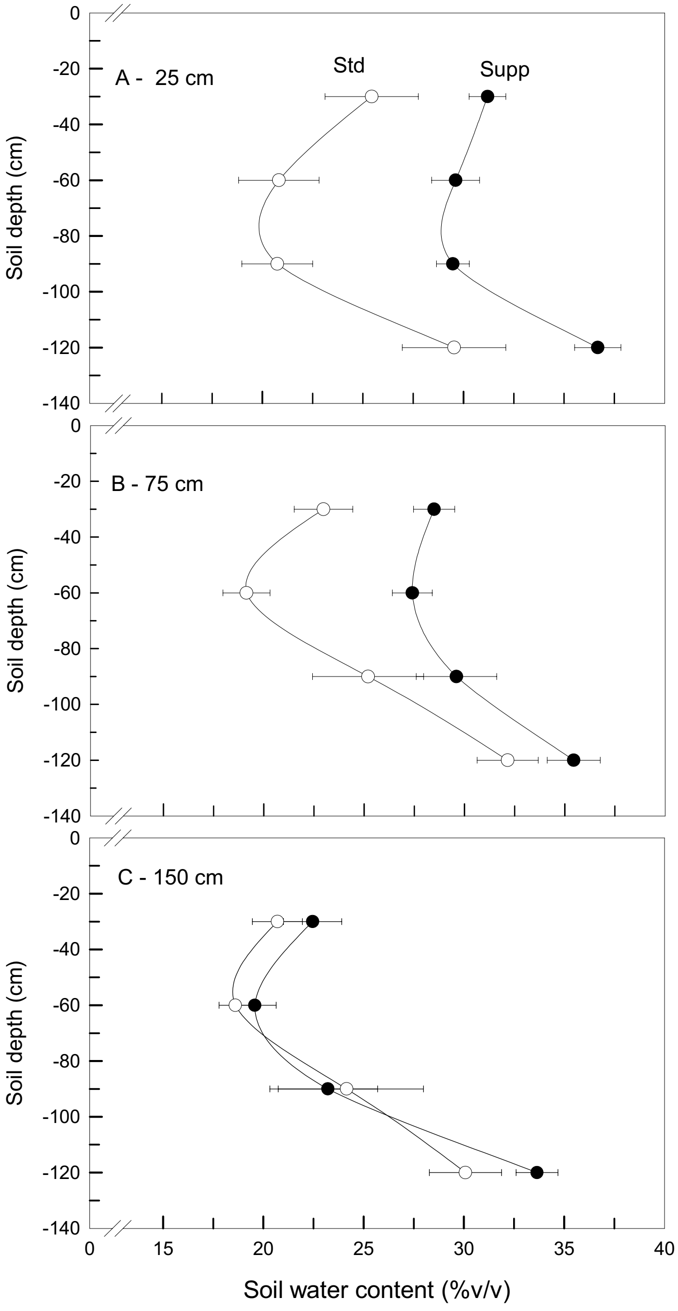

Figure 1 Soil water content of standard and supplemental irrigation treatments at distances of (**A**) 25 cm, (**B**) 75 cm, and (**C**) 150 cm from vine row on 21 July 1989.

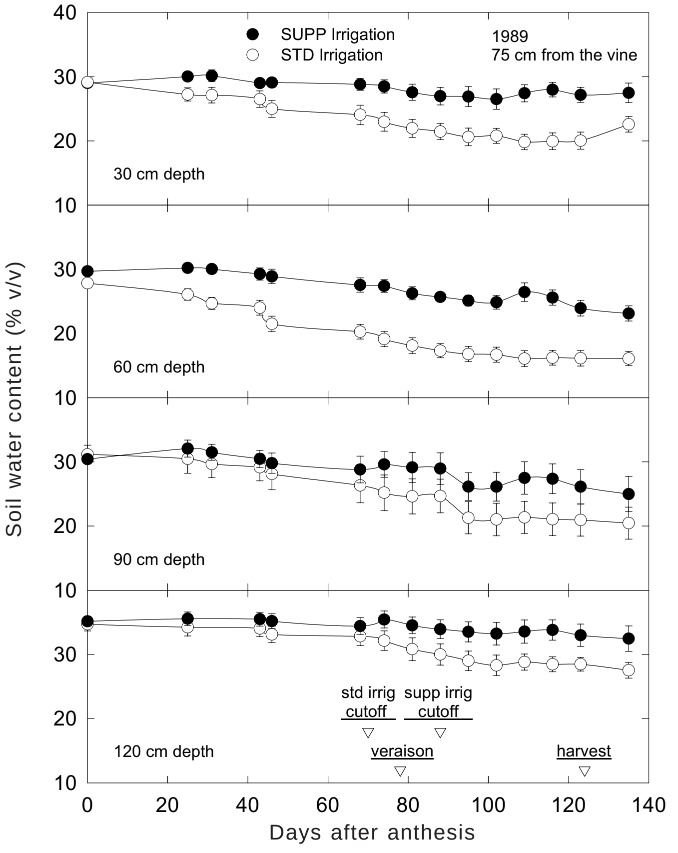

Figure 2 Soil water content of standard and supplemental irrigation treatments 75 cm from vine during 1989 growing season.

ity of shallow-rooted plants (barley) to exploit the topsoil and the inability of deep-rooted plants (cotton) to exploit the topsoil has been shown to lead to a greater chance of K deficiency in deep-rooted plants (Gulick et al. 1989).

Vine water status. In 1989, Ψ_{leaf} reflected the higher SWC maintained by supplemental irrigation compared to standard irrigation (Figure 6). The Ψ_{leaf} differences due to irrigation rate ranged between -0.2 and -0.6 MPa. Midday Ψ_{leaf} was maintained above -1.0 MPa until after harvest by supplemental irrigation but became more negative than -1.2 MPa late in the season for vines that were irrigated following standard practice. Vine Ψ_{leaf} was also significantly higher because of supplemental irrigation in 1990, although the differences in SWC between irrigation treatments were not as large as in 1989. Differences in Ψ_{leaf} because of irrigation level were noticeable shortly after bloom and continued to increase during the 1990 season. A decline in midday Ψ_{leaf} between bloom and veraison for grapevines grown in this area has been observed (Williams and Matthews 1990), even when irrigated at two times the standard grower practice of 40 L/vine/week (Matthews et al. 1987) or at four times the normal practice as in this study. Thus, the increased vine transpiration brought on by increased leaf area and evaporative demand exceeds the ability of the roots to uptake water, especially as the SWC decreases (Williams and Matthews 1990).

There was no clear effect of K fertilization on vine water status, although the data indicated a trend for higher midday water potential in fertilized than nonfertilized vines. This observation contrasts a previous report that K fertilization caused more negative midday Ψ_{leaf} in both irrigated and nonirrigated vineyards (Dundon and Smart 1984).

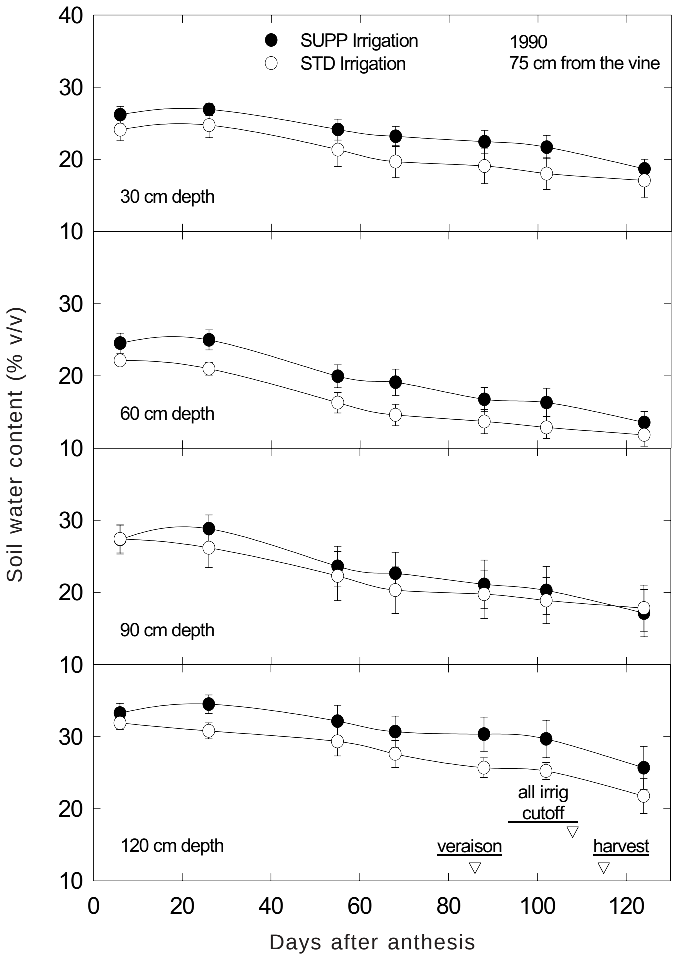

Figure 3 Soil water content of standard and supplemental irrigation treatments 75 cm from vine during 1990 growing season.

Vine K status. Correction of K deficiency (leaf symptoms, petiole K, yield) in grapevines usually does not occur until the second or third season after K application (Christensen et al. 1978). The high rate of fertilizer used in this study was no exception to this generalization. Vine K status (concentration of K in petioles as % dry wt) was not affected by applied K during the first year (1988) under standard irrigation practices (data not shown). Furthermore, there were no significant differences in K status at bloom in 1989 (Figure 7).

As is commonly observed, vine K status declined throughout the 1989 season in 0-Std vines (Figure 7). A similar decrease in petiole K between bloom and veraison was not observed in vines that had received K under both standard and supplemental irrigation. The concentration of petiole K increased between veraison and harvest

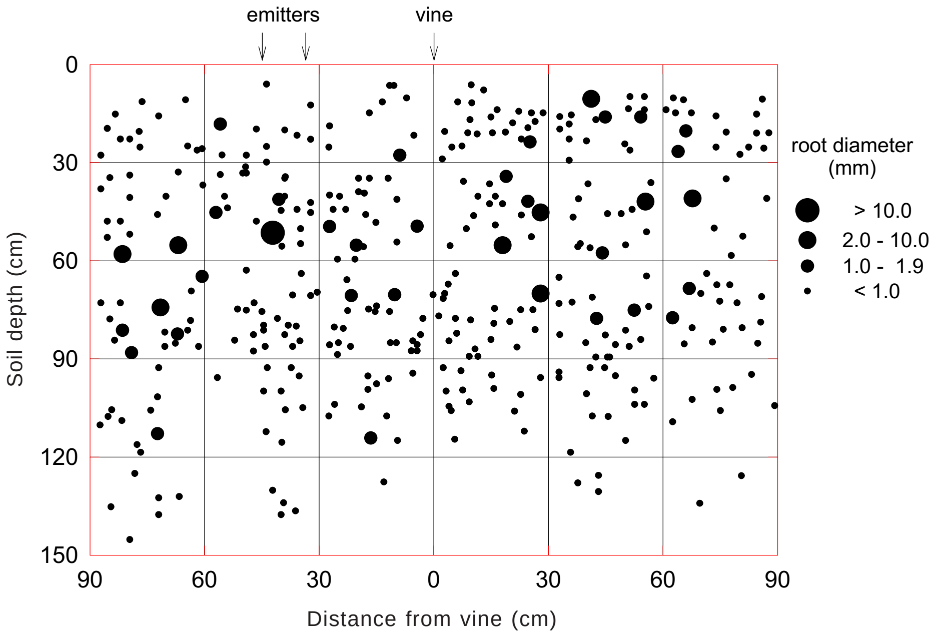

Figure 4 A representative distribution of root intercepts (K-Supp treatment) for Pinot noir grapevines on St. George at this site.

in 1989 in supplemental irrigated grapevines at both K fertilization levels.

The petiole K at bloom in 1990 was significantly higher in the K-Supp, K-Std, and 0-Supp treatments than in the 0-Std treatment. That was due to differences in vine K status established by harvest of 1989 because irrigation was not begun until two weeks after bloom in both years. This carry-over effect could be attributed to an increase in root growth due to K application, which was not obvious here, or to increased K uptake, storage, and retranslocation to new growth. Both Obbink et al. (1973) and Conradie (1980b) found that vines use K stored in the roots and trunk for new vegetative growth. The data indicate that the ability of vines to take up and store K at the end of a season may influence the K status of vegetative tissues early the following season. The maintenance of high SWC facilitates late-season K uptake.

The concentration (% dry wt) of K in the petioles is usually highest at bloom, followed by a decrease between bloom and veraison (Conradie 1980a, Klein et al. 2000). This decrease in petiole K occurs even though total vine uptake of K is greatest during this period (Conradie 1980b, Williams et al. 1987). Thus, the application of K diminished the usual decline in petiole K in 1989. Supplemental irrigation in 1989 led to an increase in vine K status of fertilized and unfertilized vines after veraison. Accordingly, petiole K concentration for all treatments declined between bloom and the onset of veraison in 1990. This decline was greater for vines under the standard irrigation regime. Shortly after veraison in 1990, however, a temporary increase in petiole K was observed in all the treatments; a higher increase in petiole K in supplemental treatments once again implied that

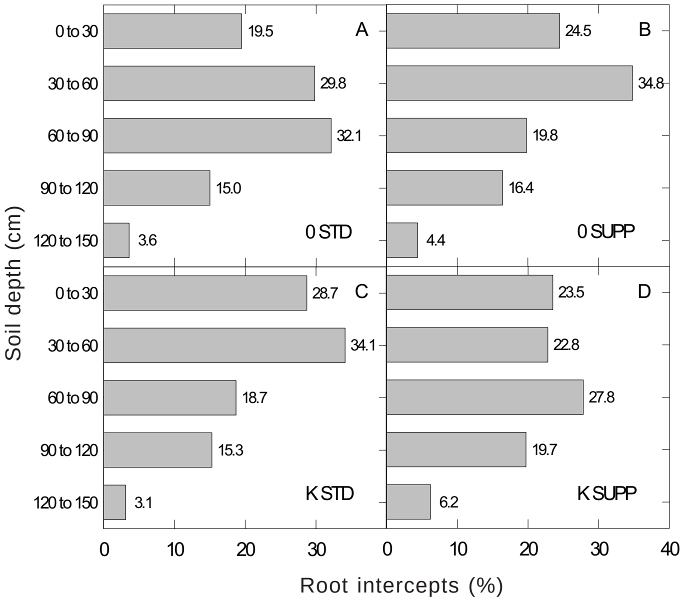

Figure 5 The percent distribution of roots in the soil profile for each treatment combination.

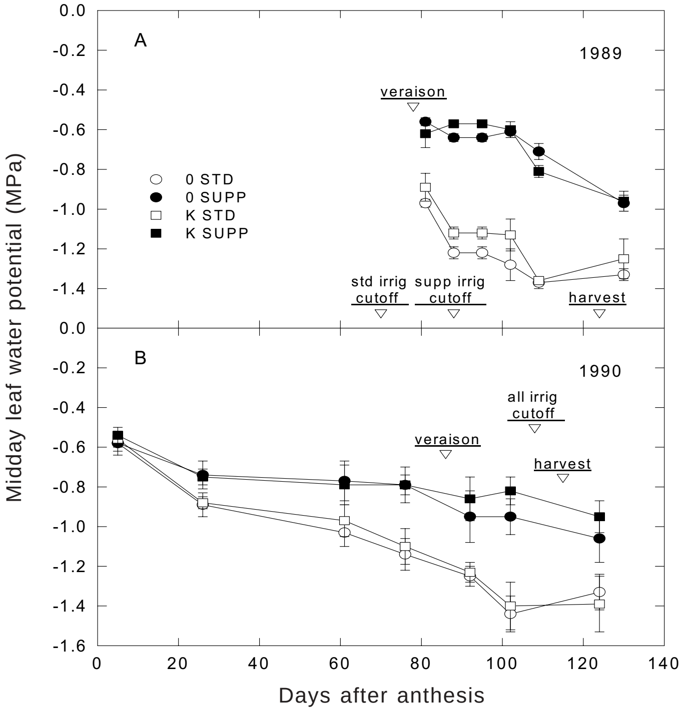

Figure 6 Influence of irrigation schedule on midday leaf water potentials during (**A**) 1989 and (**B**) 1990.

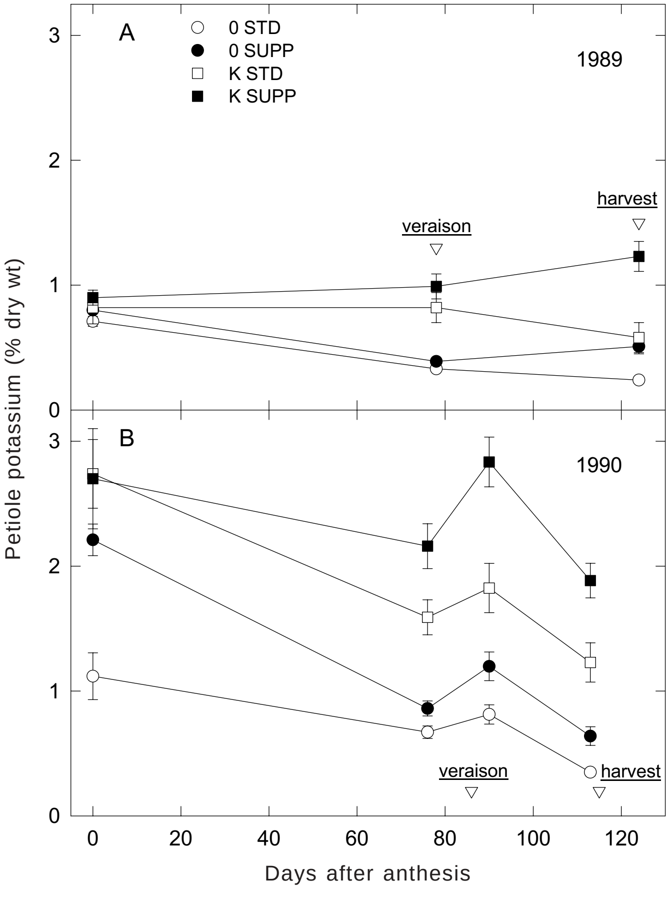

Figure 7 Effects of K fertilization and irrigation treatment combination on petiole K (% dry wt) in (**A**) 1989 and (**B**) 1990.

the uptake of K was increased or sustained with increased SWC. After veraison in 1990, petiole K declined in all the treatments. Vine K status at harvest in 1990 was improved by both K fertilization and supplemental irrigation. Klein et al. (2000) also observed higher petiole K levels in winegrapes that were irrigated using higher crop coefficients, indicating that the efficiency with which winegrapes take up K from fertilizers is dependent upon irrigation regime.

Yield. There were no significant yield increases due to K applications in any year (Table 3). In 1989, yield was similar for all treatments, with the exception that the yield for the K-Supp treatment was slightly increased over the other treatments. The number of clusters per vine was similar for all treatments. In 1990, yield and clusters per vine were significantly reduced by K fertilization. A significant yield response to K application has only been obtained when bloom petiole K was below 1.0% (Cook and Carlson 1961, Christensen 1975). Although there are other reports of yield decreases following similar treatments (Kliewer et al. 1983), we interpret these data to show no yield increase, as has also been observed previously (Dundon et al. 1984).

The lack of a positive yield response for vines with bloom petiole K below 1% has implications for the critical levels used to evaluate winegrape nutrient status. Bloom petiole K concentrations above 1.5% are considered adequate and between 1.0 and 1.5% are considered marginal by the widely applied criteria developed for grapevines in the San Joaquin Valley of California (Christensen et al. 1978, Cook 1972). Other criteria for adequacy include petiole K at veraison between 1.2 and 3.0% dry wt (Robinson 1990).

Table 3 Effects of K fertilization and irrigation treatment combination on yield of Pinot noir grapevines for 1989 and 1990 seasons.

Treatment	Yield (kg/vine)	Clusters/ vine	Cluster wt (g)	Berry wt (g/berry)
1989				
0-Std	9.38	69.7	136.8	1.24
0-Supp	9.57	65.4	145.9	1.50
K-Std	9.17	66.5	136.3	1.40
K-Supp	10.46	67.4	155.8	1.43
Significance[a]				
K fertilization	ns	ns	ns	ns
Irrigation	ns	ns	*	*
1990				
0-Std	8.43	79.1	112.1	1.19
0-Supp	9.14	81.6	112.9	1.42
K-Std	6.94	69.3	99.2	1.26
K-Supp	7.53	66.6	110.8	1.47
Significance[a]				
K fertilization	*	*	ns	ns
Irrigation	ns	ns	**	***

[a]ns, *, **, and *** indicate not significant or significant at $p \leq 0.05$, 0.01 or 0.001, respectively.

The failure to obtain increased yields on vines that were clearly K deficient by existing criteria and that greatly increased K status following treatments raises at least two questions that require further study. First, the extent of genetic differences in vine K requirements needs to be better established. For vine nitrogen status, there are many well-documented differences among varieties (Christensen 1984). Thus, the critical level for K may be lower for this variety. There is evidence of differences in petiole K concentration among rootstock (Brancadoro et al. 1994) or scion varieties (Christensen 1984), but less is known about genotypic variation in K nutrition among the most common premium winegrape varieties on different rootstocks. Cook and Lider (1964) observed higher bloomtime petiole K in all of 22 different winegrape varieties, not including Pinot noir, when grown on St. George instead of AxR #1 or 99-R; yet yields were usually lower on St. George.

Second, the standard of K status, bloomtime petiole K of basal leaves, may not give accurate estimates for some genotypes or growing conditions. If K deficiencies develop later than bloom due to soil drying and K fixation on certain clay soils, for example, the standard sampling approach may not detect the ensuing deficiency. Indeed, several authors have observed that K deficiency symptoms are more likely to be observed when midsummer petiole K levels are below 0.5% (Christensen 1984, Ulrich 1942). In this study, foliar symptoms of K deficiency were not observed, even though veraison petiole K in unfertilized vines was below 0.5% in 1989. Thus, it may be necessary to reevaluate critical K levels at different phenological stages for those varieties and rootstocks grown in the North Coast region of California.

Although supplemental irrigation did not significantly increase yield, mean yields were always greater when supplemental irrigation was supplied compared with standard irrigated vines (Table 3). Supplemental irrigation significantly increased cluster and berry weight. In previous irrigation studies in California, a decrease in cluster weight because of water deficits was consistently observed (Kliewer et al. 1983, Matthews and Anderson 1989, Vaadia and Kasimatis 1961). The reduced cluster weight has been attributed to a reduction in berry weight in the initial year of each irrigation trial and to a combination of reduced berry growth and lower number of berries per cluster in following seasons (Kliewer et al. 1983, Matthews and Anderson 1989).

Conclusions

There are three primary implications of these results. First, although the fixation of K fertilizer may be a concern on many North Coast clay soils, the application of 3.6 kg K_2SO_4 under the drip emitter resulted in movement of significant K to a depth of 90 cm under both irrigation regimes at this site with K-fixing clays. That is sufficient to place the material in contact with the majority of the roots.

Second, supplemental irrigation (at rates greater than standard practice) diminished the usual seasonal decline in soil water content and increased the uptake of both applied and indigenous soil K. Supplemental irrigation did not, however, appear to increase root growth, suggesting that diffusion of K to the root surface is the dominant mechanism for movement of K in these soils. This diffusion is reduced as soil water deficits are developed under normal irrigation practices. It also implies that deficit-irrigation practices reduce K availability in these soils, especially late in season when demand may be high.

Third, the application of K did not increase yields two years after application, even though bloom petiole K of 0-Std (control) grapevines was below the previous established critical level of 1.0% dry wt during one of the years of this trial and fertilizer and irrigation treatments increased petiole K concentrations to over 2.5% dry wt.

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