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Responses of grapevine cvs Chenin blanc and Chardonnay to phosphorus fertilizer applications under phosphorus-limited soil conditions

by

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Reaktion der Rebsorten Chenin blanc and Chardonnay auf Phosphordüngung bei begrenztem Phosphorangebot des Bodens

Zusammenfassung: Reben der Sorten Chenin blanc und Chardonnay, die auf zwei phosphatarmen Böden wuchsen, wiesen in ihren Blattstielen Gesamtphosphorgehalte (TP) auf, die unter den gegenwärtig geltenden Minimalwerten der Sorte Thompson Seedless lagen. Behandlung der Böden mit verschiedenen P-Düngern steigerte den Gehalt an extrahierbarem Phosphor (EP) in den Blattspreiten sowie das Schnittholzgewicht im unmittelbar auf die Düngung folgenden Jahr. Im 2. Jahr nach der P-Anwendung waren die Anzahl der Trauben/Rebe und der Traubenertrag/Rebe gegenüber den unbehandelten Kontrollen erhöht. P-Mangel ließ sich durch verschiedene P-Dünger in unterschiedlicher Konzentration, während der Vegetationsperiode oder der Winterruhe gestreut, wirksam beheben. Die nachhaltigste Verbesserung der P-Versorgung erfolgte mit den höchsten P-Gaben. Auf bestimmten Böden mit schwachem P-Angebot können deshalb wiederholte kleinere Düngergaben im Abstand von 2-3 Jahren notwendig sein, um eine angemessene P-Versorgung aufrechtzuerhalten. Aufgrund der Ertragsreaktionen wurden vorläufige P-Mindestwerte von 0,8 g EP/kg Blattspreiten (T.G.) für Chardonnay (wurzelecht) und 1,5 g EP/kg Blattspreiten (T.G.) für Chenin blanc (Unterlage St. George) ermittelt.

Key words: soil, acidity, phosphorus, nitrogen, leaf, bunch, yield, shoot, variety of vine, USA.

Introduction

The phosphorus mineral nutrition of winegrapes is poorly understood and inadequately investigated. Early field studies showed no responses of yield or fruit composition to phosphorus (P) fertilizer applications (Partridge 1931; Gladwin 1936; Shaulis and Kimball 1956; Larsen *et al.* 1959; Williams 1943, 1946), and there are no greenhouse studies in the literature which describe the effects of P on grapevine vegetative and reproductive growth. In addition to cultivation on soils with adequate P levels, the relative absence of vegetative or reproductive responses to P applications can be attributed partially to deep root systems, low P requirements, and recycling of P stored in bark, wood, and roots. Nevertheless, P deficiencies have been described in vineyards in Australia (Tulloch and Harris 1970), France (Champagnol 1978), and Germany (Gärtel 1965), and positive yield responses to P applications have been reported (Randolph 1944, Fleming 1961, Kobayashi 1961 a, b; Tulloch and Harris 1970). However, present criteria for sufficiency in soil and vine P levels are not based on experimental results which established relationships between those parameters and yield (Cook and Wheeler 1976; Christensen *et al.* 1978).

Indeed, until recently (Cook *et al.* 1983) there have been no positive vegetative or reproductive yield responses to P fertilizer applications reported in California (Williams 1943, 1946; Cook 1966). The need for field experiments to establish the P requirements of winegrapes was magnified by the recent reports of P deficiencies on soils acidified to control *Phymatortrichum omnivorum* root rot in Arizona vineyards (DUTT *et al.* 1986) and on low P California hillside soils (COOK *et al.* 1983).

Substantial new plantings of premium winegrapes have been made on hillsides in the Coast Range and Sierra Nevada in northern California over the past 20 years due to a decreasing availability of planting acreage on the valley floors and to a search for improved environmental conditions. Soils in these areas are often of low pH and low fertility (LILLELAND *et al.* 1942; U.S.D.A. SOIL CONSERVATION SERVICE 1965, 1978). Appropriate management practices for low pH soils for premium winegrape production in California have not been established. Therefore, this investigation was initiated to determine the P requirements of premium winegrape varieties by analyzing growth and yield responses to P fertilizer applications under P-limiting soil conditions.

Materials and methods

Site characteristics

Commercial vineyards of *Vitis vinifera* cultivars were selected for experimentation on the basis of preliminary assays which indicated low soil or plant P. The vineyards were 3-year old Chenin blanc (St. George rootstock) at Chappelet (Napa County, CA) and 3-year old Chardonnay (own roots) at Spanish Creek (El Dorado County, CA). Soil types were Sobrante loam (Fine-loamy, mixed, thermic Mollic Haploxeralf) and Musick rocky sandy loam (Clayey, kaolinitic, mesic Ultic Haploxeralf) at Chappelet and Spanish Creek, respectively. The parent material of the Sobrante loam consists of fine grained sandstone while the Musick rocky sandy loam is underlain by acid igneous rock. The vines were drip-irrigated, spur-pruned, and cordon-trained to a 2-wire overhead trellising system and had a planting density of approximately 1120 vines/ha. Standard cultural practices for disease and pest management were utilized as required.

Experimental design

A randomized complete block design consisting of 3 replicates and 10 vines/replicate was used in both trials. P fertilizer treatments (Table 1) were applied initially during August 1982 (Chenin blanc) and February 1984 (Chardonnay). Fertilizers were applied either on the soil surface (Chenin blanc 1982) or at a depth of 15 cm (Chardonnay and Chenin blanc 1986) directly below the drip irrigation emitter. Higher rates were used on the Musick soil (Chardonnay) because of lower initial P levels (Table 2) and a greater P adsorbtion capacity (data not shown) compared to the Sobrante soil (Chenin blanc). Fertilizers were reapplied at both locations prior to the 1986 growing season (Table 1).

Plant tissue analysis

Leaf samples consisting of 10 leaves/replicate were taken opposite a basal cluster during anthesis. Lamina and petiole samples were separated, oven-dried at 70 °C for 48 h, ground to pass a 1 mm mesh screen, and stored at room temperature until analyzed. Extractable phosphorus (EP) was determined spectrophotometrically using a 2 % acetic acid extraction procedure with color development from the antimony catalyzed ascorbic acid reduction of the phosphomolybdate complex (SKINNER *et al.* 1987). Total phosphorus (TP) in dry-ashed petiole samples was determined spectrophotometrically using a common procedure (THOMAS and PEASLEE 1973). Nitrogen (NH_4-N and NO_3-N) and K were determined from an acetic acid extract using the Ammonia

Table 1

The locations of experimental vineyards, cultivars studied, and fertilizer rates, materials, and dates of application · Treatments are described in terms of units of P, where 1P ≈ 0.045 kg P/vine

Standorte der Versuchsanlagen, untersuchte Sorten und Düngergaben sowie Termine der Düngung · Bezeichnung der Düngungsstufen in P-Einheiten (1P ≈ 0,045 kg P/Rebe)

		Napa County (Chenin blanc)	
Treatment	kg P/vine	Aug 82	Mar 86
C	0	Control	Control
1P	0.045	NaH_2PO_4	H_3PO_4
2P	0.090	NaH_2PO_4	H_3PO_4
3P	0.135	NaH_2PO_4	H_3PO_4

		El Dorado County (Chardonnay)	
Treatment	kg P/vine	Feb 84	Mar 86
C	0	Control	Control
N 1)	0	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$
N + 4P	0.18	MAP 2) + TSP 3)	MAP + H_3PO_4
N + 6P	0.27	MAP + TSP	MAP + H_3PO_4
6P	0.27	TSP	H_3PO_4

1) N = Application of fertilizer included 0.05 kg N/vine.
2) MAP = $NH_4H_2PO_4$.
3) TSP = $Ca(H_2PO_4)_2$.

Analyzer (Carlson 1978) and flame photometry respectively. Other elements (Ca, Mg, Na, Cu, Mn and Zn) were determined from wet-ashed samples using atomic absorption spectroscopy and B was determined from dry-ashed samples using a curcumin-oxalic acid colorimetric assay (Johnson and Ulrich 1959).

Soil analysis

5 samples were collected from the surface (0—30 cm) soil of each 10-vine replicate. Samples were composited by replicate, air-dried, and passed through a 2 mm mesh sieve. Determinations were made of available P using a modified Bray-1 procedure (Olsen *et al.* 1982) and P soluble in 0.01 M $CaCl_2$ (Fox and Kamprath 1970), pH using a saturated paste (McLean 1982), EC using a saturation extract (Rhoades 1982 b), CEC using Ba saturation and Ca replacement (Rhoades 1982 a), exchangeable K, Ca, and Mg using NH_4OAc equilibration and flame photometry or atomic absorption spectrophotometry (Doll and Lucas 1973), and Cu and Zn using a DTPA extraction and atomic absorption spectrophotometry (Baker and Amacher 1982).

Yield and growth measurements

Cluster counts and cluster weights were determined each season at harvest. In the Chenin blanc vineyard in the 1986 season, 5 clusters from 3 randomly chosen vines in the 3P and C treatments were bagged at bloomtime using breathable polyethylene bags. The bags were removed at harvest and the number of abscised ovaries counted for each cluster. The percent set of each cluster was calculated by dividing the number of berries which developed by the total number of berries plus ovaries. Berry weights and seeds per berry were determined from 20-berry samples from individual clusters. Pruning weights and shoot numbers were measured during dormancy. Vegetative and reproductive growth are reported on a per vine basis.

Results and discussion

Soil parent material influences important soil characteristics including texture, depth, water holding capacity, pH, and P fertility level (THOMAS and PEASLEE 1973; BUOL *et al.* 1980). Soils of the Coast Range in California developed from sedimentary, metamorphic or volcanic parent materials (U.S.D.A. SOIL CONSERVATION SERVICE 1978). In contrast, soils in the Sierra Nevada foothills developed from decomposed igneous and metamorphic rock (U.S.D.A. SOIL CONSERVATION SERVICE 1974). A brief survey of hillside soils in these two winegrape growing regions of northern California showed several to have low pH and low soil P levels. Levels of P below 7 mg/kg in Bray-1 assays (OLSEN and SOMMERS 1982) and less than 0.1 mg/kg P in the aqueous extract of a 0.01 M $CaCl_2$ soil extraction (BINGHAM 1949) are considered inadequate for normal plant growth. The example soils selected from the Coast Range (Sobrante in Napa County) and Sierra foothills (Musick in El Dorado County) both had a pH below 6 and P levels below adequate (Table 2). Thus, low P soils developed from different parent materials in two premium winegrape growing regions of northern California. The Musick soil also had Zn levels below those which are considered optimum (0.5 ppm) for normal plant growth (BROWN and DE BOER 1976), but all other mineral elements appear to have been adequate for grapevines (Table 2).

Table 2

Initial chemical conditions of the two California soils to which PO_4 fertilizer applications were made

Chemische Ausgangsbedingungen der beiden kalifornischen Böden, die mit PO_4-Dünger behandelt wurden

Soil characteristic	Musick (El Dorado)	Sobrante (Napa)
pH	5.5	5.9
Bray-1 P (mg/kg)	1.9	3.0
0.01 M $CaCl_2$ P (mg/kg)	0.001	0.051
EC (S/m)	0.028	0.032
CEC (meq/100 g)	15.5	24.0
K [1] (meq/100 g)	0.15	0.46
Ca [1] (meq/100 g)	3.5	11.1
Mg [1] (meq/100 g)	0.4	1.8
Zn [2] (mg/kg)	0.4	1.6
Cu [2] (mg/kg)	0.54	1.67

[1] Exchangeable.

[2] DTPA extractable.

Table 3

Bloomtime nutrient status of untreated control vines in two vineyards to which PO_4 fertilizer applications were made · Total phosphorus (TP) was determined from petiole samples of Chenin blanc vines in 1983 and from Chardonnay vines in 1984 · All other analyses, including extractable phosphorus (EP), were determined from samples collected in 1985

Ernährungszustand unbehandelter Kontrollreben des PO_4-Düngungsversuches zur Zeit der Blüte · Der Gesamtphosphorgehalt (TP) wurde aus Blattstielproben von Chenin blanc (1983) und Chardonnay (1984) ermittelt · Alle übrigen Analysen einschließlich extrahierbarem Phosphor (EP) wurden aus Proben des Jahres 1985 bestimmt

Nutrient	Chardonnay (Musick soil)	Chenin blanc (Sobrante soil)
	Petioles	
TP (%)	0.09	0.09
K (%)	4.59	2.63
Mg (%)	—	0.34
EP (g/kg)	0.51	0.91
NH_4-N (mg/kg)	140	250
NO_3-N (g/kg)	1.2	0.6
	Laminae	
EP (g/kg)	0.63	0.75
Ca (%)	1.42	1.63
Mg (%)	0.28	0.17
Na (%)	0.01	0.02
Cu (mg/kg)	14.0	11.0
Mn (mg/kg)	210	340
Zn (mg/kg)	17	15
B (mg/kg)	27	84

Plant tissue analyses from both vineyards indicated petiole TP levels were lower (Table 3) than the critical level (1.5 g P/kg dw) recommended for Thompson Seedless (COOK and WHEELER 1976). All other nutrients were in adequate supply with regard to currently accepted critical nutrient levels for Thompson Seedless (COOK and WHEELER 1976; CHRISTENSEN *et al.* 1978), although B and Zn levels in Chardonnay laminae and Mg and Zn in Chenin blanc laminae were somewhat low (Table 3).

For the Chenin blanc vineyard (Sobrante soil), lamina EP levels of control vines varied between 0.5 and 1.0 g P/kg dw during the 5 years of this study (Fig. 1 A). When 1, 2, or 3 units of P (1 P = 0.045 kg P/vine) were applied to the Sobrante soil, lamina EP levels increased the following season (1983). Lamina EP levels of treated vines were greater in 1984 than in 1983 and declined in 1985 (3rd year after application). Nevertheless, lamina EP levels of treated vines remained greater than controls in the 1984 and 1985 growing seasons (Fig. 1 A). In 1985, lamina EP in the 3P treatment was significantly greater than the 1P ($P < 0.05$) and C ($P < 0.01$) treatments, while lamina EP in the 2P treatment was significantly greater than the C treatment ($P < 0.05$).

The residual effects of large P applications, such as the 3P treatment in the present study, on maintaining adequate soil P levels to support maximum yields for several seasons has been established with annual crops on low P soils in Australia (PIPER and

DE VRIES 1964). However, the decline of EP levels in all treatments in 1985 indicates that P should be reapplied at least every 3 years on certain low P soils.

Lamina EP levels were increased to above 2.0 g kg^{-1} in all P treatments when P was reapplied before the 1986 growing season (Fig. 1 A). The magnitude of the increase in lamina EP may be attributed to a large rainfall event (≈ 45 cm) the week after the P was applied. The large and timely rainfall may have moved P deeper into the soil pro-

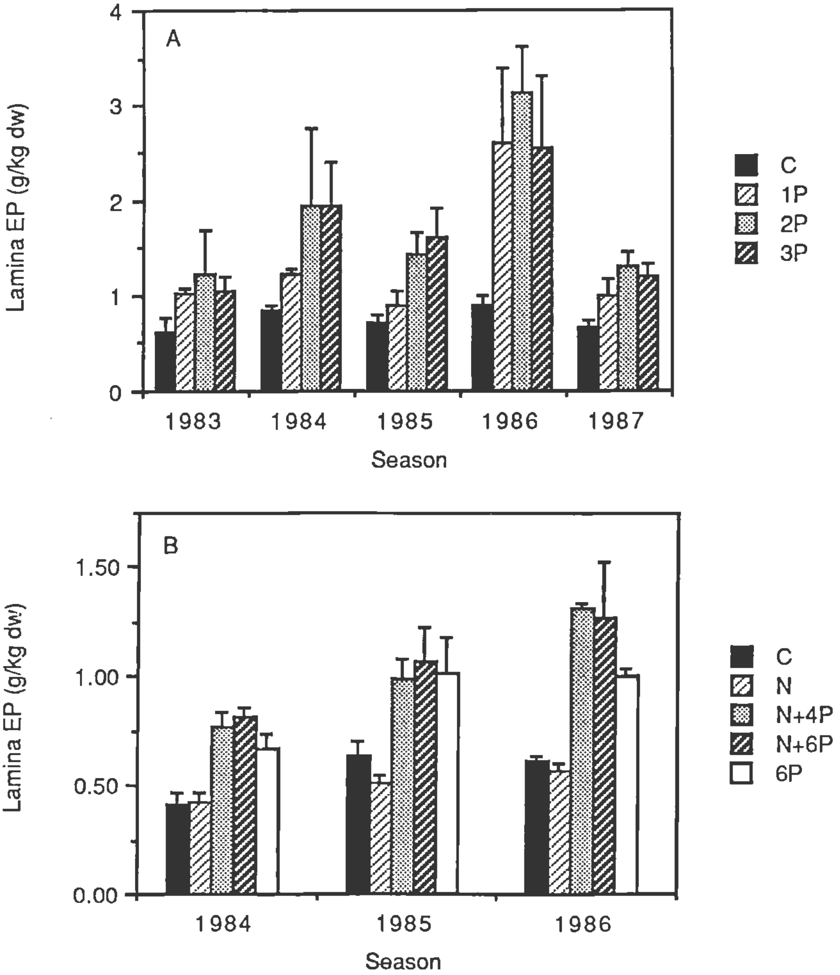

Fig. 1: Extractable phosphorus (EP) of leaf laminae sampled at bloomtime for Chenin blanc (A) vines (Sobrante soil) which received 1, 2, or 3 units of P (1P ≈ 0.045 kg P/vine) and Chardonnay (B) vines (Musick soil) which received 4 or 6 units of P with and without N from different fertilizer materials (see Table 1) over several seasons. Vertical bars represent the SE of the mean.

Extrahierbarer Phosphor (EP) der Blattspreiten zur Blütezeit. — A) Chenin blanc (Sobrante-Boden) bei Gaben von 1, 2 oder 3 P-Einheiten (1P ≈ 0,045 kg P/Rebe), B) Chardonnay (Musick-Boden) bei Gaben von 4 oder 6 P-Einheiten, mit und ohne N, aus verschiedenen Düngern (s. Table 1); mehrjährige Ergebnisse. Senkrechte Balken = Standardabweichung der Mittelwerte.

file, increased the root surface area in contact with fertilizer P, and thereby enhanced P uptake over previous P applications. In 1987, lamina EP levels decreased to levels similar to those found in 1983 (Fig. 1 A). This suggests that the high levels of P found in laminae in 1986 were reduced by either storage of P in permanent vine parts such as roots, trunk and wood, or by a loss of P as a result of the removal of fruit at harvest. Juice EP has been shown to increase with the P status of Carignane vines grown in a greenhouse under conditions of varying P supply (SKINNER and MATTHEWS 1988).

For the Chardonnay vineyard (Musick soil), lamina EP levels of control vines varied between 0.4 and 0.7 g P/kg dw over a 3-year period (Fig. 1 B). When 4 or 6 units of P were applied to the Musick soil, lamina EP levels increased above the controls the following season (1984, Fig. 1 B). Lamina EP of treated vines was greater in 1985 than in the initial season after application (Fig. 1 B), similar to the Sobrante vineyard (Fig. 1 A). Reapplication of P prior to the 1986 season increased lamina EP only in those vines which also received N (Fig. 1 B). Lamina EP was not increased by N application alone, but was greatest when P and N were applied together (Fig. 1 B). This is in agreement with results obtained from P uptake experiments with a variety of other species (MILLER 1974).

Recently, P deficiencies in grapevines were associated with reduced growth of roots and shoots, poor flower and berry development (SKINNER and MATTHEWS 1988) and premature leaf senescence (CURRLE *et al.* 1983). Shoot growth (pruning weight) increased in Chenin blanc following soil application of 1-3 units of P and remained greater than controls in subsequent years (Fig. 2). The large increase in lamina EP following reapplication of P in 1986 was not associated with a similar increase in pruning weight (Fig. 2). Pruning weight of Chardonnay vines was extremely variable and showed only a slight increase in the N + 4P treatment after the 1985 season (data not shown).

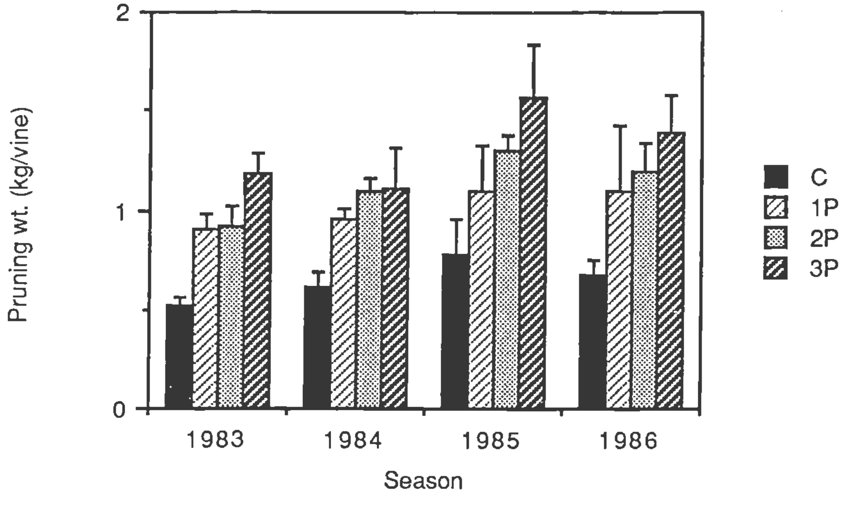

Fig. 2: Pruning weight of Chenin blanc vines (Sobrante soil) which received 1, 2, or 3 units of P (1P ≈ 0.045 kg P/vine) from different fertilizer materials (see Table 1) over 4 seasons. Vertical bars represent the SE of the mean.

Schnittholzgewicht von Chenin blanc (Sobrante-Boden) bei Gaben von 1, 2 oder 3 P-Einheiten (1P ≈ 0,045 kg P/Rebe) aus verschiedenen Düngern (s. Table 1); 4jährige Ergebnisse. Senkrechte Balken = Standardabweichung der Mittelwerte.

Cluster development begins in grape buds during the season preceding anthesis and maturation. Thus, any effect of altered P status on fruitfulness is unlikely to be observed until the 2nd season after P is applied. In the 2nd season (1984) following P applications to the Chenin blanc vineyard, clusters per vine were 60—75 % greater in all P treatments than in the controls (Fig. 3 A). Cluster counts declined in all treat-

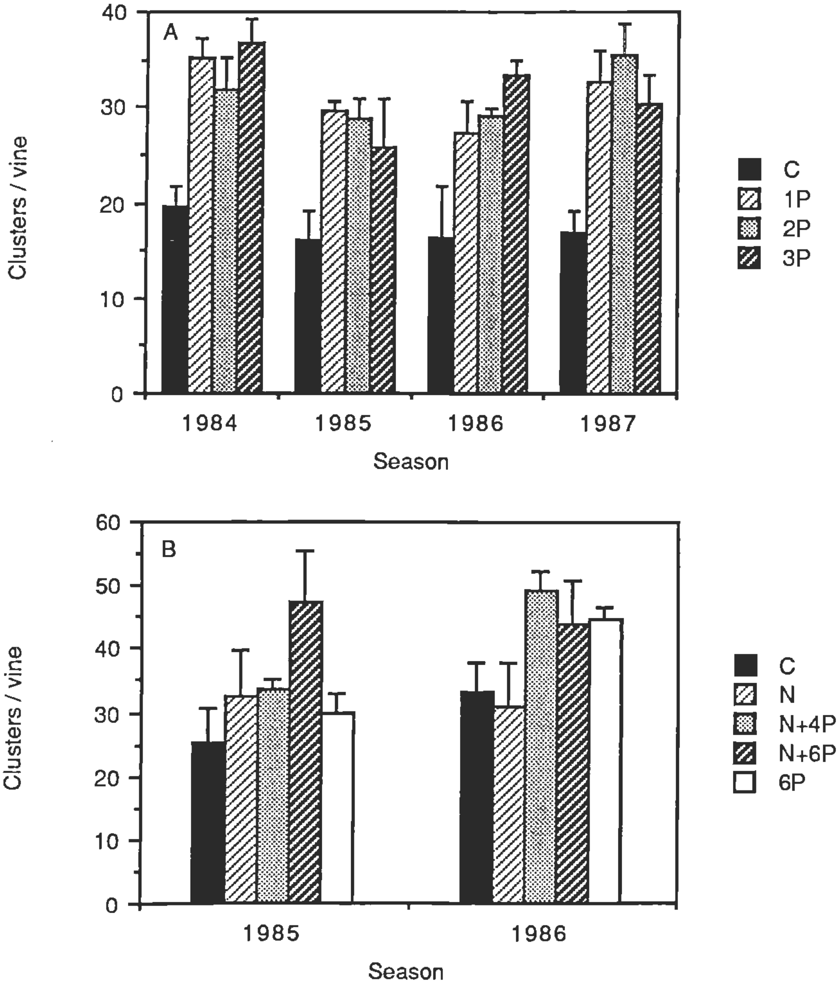

Fig. 3: Cluster number of Chenin blanc (A) vines (Sobrante soil) which received 1, 2, or 3 units of P (1P ≈ 0.045 kg P/vine) and Chardonnay (B) vines (Musick soil) which received 4 or 6 units of P with and without N from different fertilizer materials (see Table 1) over several seasons. Vertical bars represent the SE of the mean.

Anzahl der Trauben von A) Chenin blanc (Sobrante-Boden) bei Gaben von 1, 2 oder 3 P-Einheiten (1P ≈ 0,045 kg P/Rebe) und B) Chardonnay (Musick-Boden) bei Gaben von 4 oder 6 P-Einheiten, mit und ohne N, aus verschiedenen Düngern (s. Table 1); mehrjährige Ergebnisse. Senkrechte Balken = Standardabweichung der Mittelwerte.

ments in 1985 and were generally stable from 1985 to 1986 (Fig. 3 A). However, cluster counts remained significantly greater in all P treatments than the controls in 1985 and 1986 (Fig. 3 A). A second P application in 1986 increased cluster counts only in the 3P treatment over the previous (1985) season (Fig. 3 A). However, in 1987, cluster counts were also higher in the 1P and 2P treatments compared to 1985 and 1986 (Fig. 3 A).

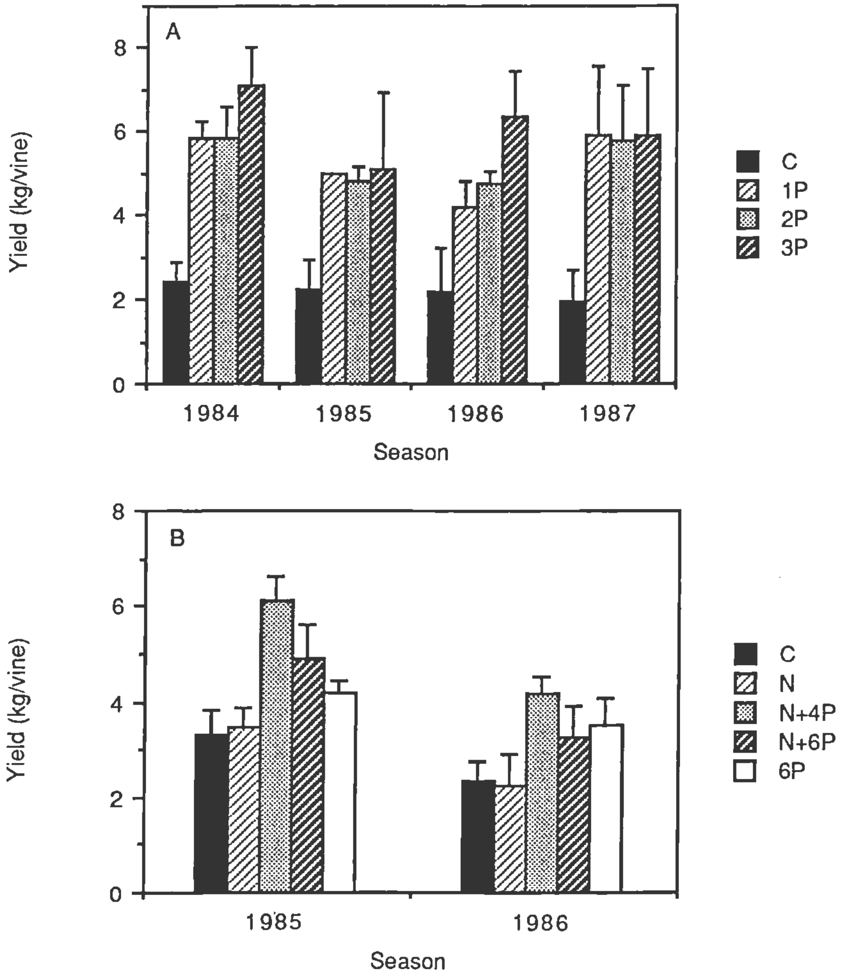

Fig. 4: Yield of Chenin blanc (A) vines (Sobrante soil) which received 1, 2, or 3 units of P (1P ≈ 0.045 kg P/vine) and Chardonnay (B) vines (Musick soil) which received 4 or 6 units of P with and without N from different fertilizer materials (see Table 1) over several seasons. Vertical bars represent the SE of the mean.

Traubenertrag von A) Chenin blanc (Sobrante-Boden) bei Gaben von 1, 2 oder 3 P-Einheiten (1P ≈ 0,045 kg P/Rebe) und B) Chardonnay (Musick-Boden) bei Gaben von 4 oder 6 P-Einheiten, mit und ohne N, aus verschiedenen Düngern (s. Table 1); mehrjährige Ergebnisse. Senkrechte Balken = Standardabweichung der Mittelwerte.

Thus, the increase in cluster initiation and/or maintenance in the 1P and 2P treatments was delayed 1 season compared to the increase in the 3P treatment in 1986.

In the 2nd season (1985) after initial P fertilizer applications, cluster counts in the Chardonnay vineyard were increased in the N, P, and N + P treatments (Fig. 3 B). The largest increase in clusters per vine was obtained in the N + 6P treatment (Fig. 3 B), perhaps suggesting increased P uptake when N and P were applied together. In 1986, cluster numbers in the P and N + P treatments were similar and were greater than the control and N treatments (Fig. 3 B). Thus, it appears that on low P soils with high P adsorption capacities (Musick) vine response to large P applications is more rapid when N is applied with P initially. With time, however, P applications alone have a similar effect on cluster number.

Table 4

The response of Chenin blanc yield components to the 2nd P fertilizer application in 1986 · Treatments are the same as in Table 1 · Data are means ± SE (n = 15 clusters)

Auswirkungen der 2. P-Düngung (1986) auf die Ertragskomponenten von Chenin blanc · Behandlungen wie in Table 1 · Bei den Zahlen handelt es sich um Mittelwerte ± Standardabweichungen (n = 15 Trauben)

Treatment	Cluster wt (g)	Berries/cluster	% Set	Berry wt[1] (g)	Seeds/berry[1]
C	69.8 ± 7.8	140 ± 13	34.6 ± 2.0	0.47 ± 0.02	1.18 ± 0.04
3P	103.1 ± 5.0	172 ± 8	41.7 ± 3.8	0.60 ± 0.02	1.44 ± 0.04

[1] n = 20 berries.

Soil applications of P increased yield significantly on both soils, although the P application rates (Table 1) were twice as high on the Musick soil (6P) as on the Sobrante soil (3P). In the Chenin blanc vineyard, yields in all P treatments were increased by 150 % or more over the controls in 1984 (Fig. 4 A). Yields declined in 1985, but were still more than 100 % greater in all P treatments than in the controls (Fig. 4 A). The second P application in 1986 did not result in further increases in yield in any P treatment (Fig. 4 A), although the yields of all P-treated vines remained greater than the control. The increased yield in the 3P treatment compared to the control in 1986 was due to increases in clusters per vine (Fig. 3 A) and cluster weight (Table 4). Cluster weight was greater in 3P-treated vines due to more berries and greater berry mass than in control vines (Table 4). Berries per cluster were increased by 3P treatments at set with little effect on flowers per cluster (Table 4). The increased berry weight of 3P vines compared to controls was associated with more seeds per berry (Table 4). Similarly, berry weight and the rate of ^{14}C-photosynthate translocation from leaves to berries was correlated with increased seed number in Concord (*Vitis labrusca* L.) grapevines (CAWTHON and MORRIS 1982). Like cluster number, yield increased in the 1P and 2P treatments in 1987 (Fig. 4 A). Thus, on certain low P soils (Sobrante) P applications may need to be repeated every 2—3 years in order to maintain optimum yields.

Chardonnay yields (Musick soil) were not increased by P application as much as in Chenin blanc (Sobrante soil) but were greater in the P and N + P treatments than in the controls in 1985 and 1986 (Fig. 4 B). The application of N alone had no effect on the yield of Chardonnay in either season (Fig. 4 B). Yield was reduced in all treatments in the 3rd season (1986) due to severe powdery mildew infection (CAVANAUGH 1986). A large yield response might have been expected without the powdery mildew infection since there were large effects on clusters per vine (Fig. 3 B) and since similar differences in clusters per vine resulted in large yield differences of Chenin blanc vines (Figs. 3 A, 4 A).

Present recommendations for P requirements of winegrapes in California (COOK and WHEELER 1976; CHRISTENSEN *et al.* 1978) are tenuous since critical levels are not based upon studies in which vegetative or yield responses to P applications were obtained either in the field or in the greenhouse, and since critical levels were based on

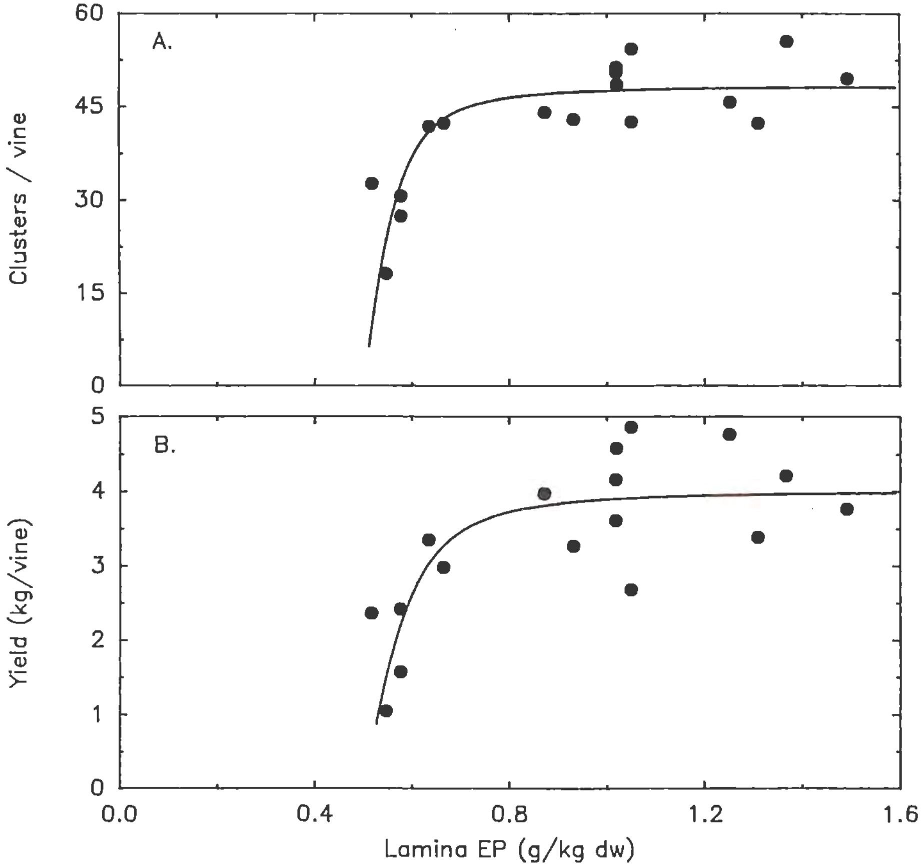

Fig. 5: The relationship between Chardonnay lamina EP and cluster number (A) and yield (B), respectively, in the 2nd season after P applications. The equations are of the form:

$$y = ab(x-c)/\sqrt{b^2 + a^2(x-c)^2}$$

where a, b and c are constants and x = lamina EP. Curves were generated by fitting the data to the above equation using a least squares iterative procedure after selecting an initial maximum cluster number or yield (b), a minimum lamina EP (c), and an approximative slope (a).

Beziehung zwischen EP der Blattspreite von Chardonnay und der Anzahl der Trauben (A) sowie dem Ertrag (B) in der 2. Vegetationsperiode nach der P-Behandlung. Gleichung der Korrelationskurven s.o.

the normal range of total phosphorus (TP) in bloomtime petioles of Thompson Seedless grapevines grown in the San Joaquin Valley. Phosphorus requirements may be indicated with greater sensitivity by lamina EP than petiole TP (SKINNER *et al.* 1987). More importantly, nutrient requirements are likely to vary among fruiting varieties and rootstocks. Genetic variability in root systems associated with P acquisition and use has been established in annual crops (GABELMAN *et al.* 1986) and in grapevine rootstocks (GRANT and MATTHEWS, unpublished). Genetic variability among grape varieties is likely to be greater than among many annual crops due to the broad distribution of the native species, the propensity for vegetative propagation which avoids genetic drift and allows maintenance of very old genotypes, and the potential to graft scions to stock of significantly different parentage (EINSET and PRATT 1975; OLMO 1976).

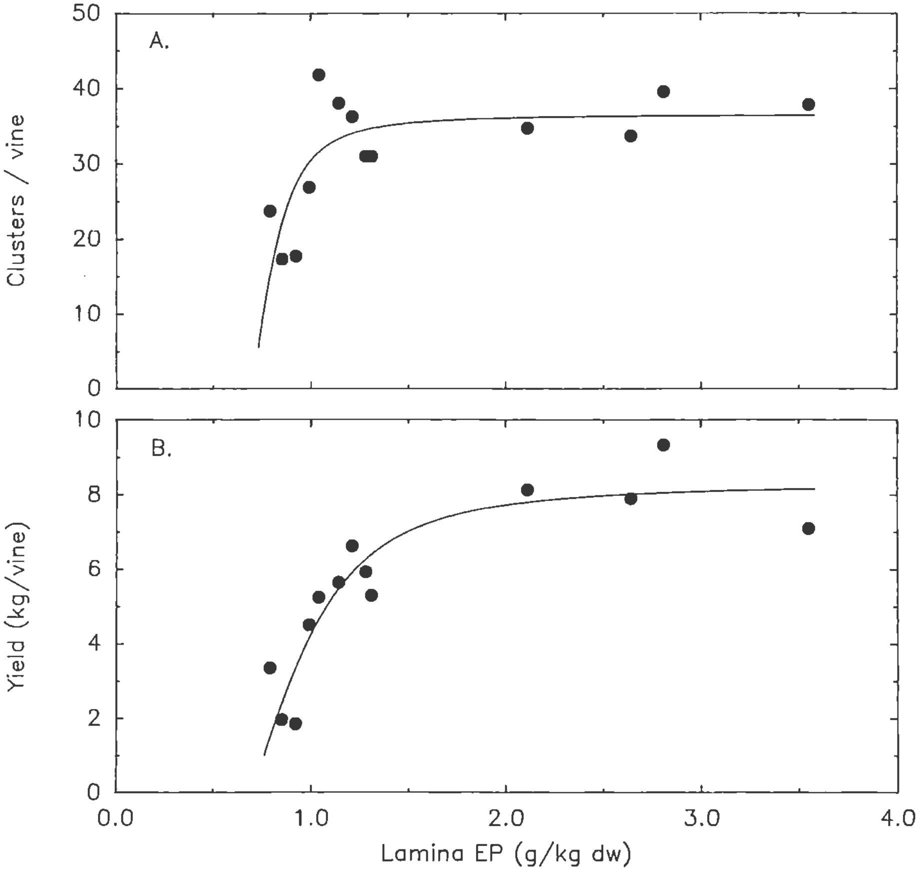

Fig. 6: The relationship between Chenin blanc lamina EP and cluster number (A) and yield (B), respectively, in the 2nd season after P applications. Curves were generated as in Fig. 5.

Beziehung zwischen EP der Blattspreite von Chenin blanc und Anzahl der Trauben (A) sowie dem Ertrag (B) in der 2. Vegetationsperiode nach der P-Behandlung. Gleichung der Korrelationskurven s. bei Fig. 5.

The results from this and other studies show that there are cultivar differences in the P required to obtain maximum yields. In a recent 3-year survey of 12 winegrape cultivars grown on several soils in the San Joaquin Valley, EP in laminae sampled at bloomtime ranged from a low of 2.4 g P/kg dw in Carignane and Ruby Cabernet to 3.8 g P/kg dw in Sauvignon blanc (CHRISTENSEN 1984). Levels for EP in Chenin blanc laminae during the same 3-year period averaged 3.2 g P/kg dw (CHRISTENSEN 1984). In contrast, the untreated control Chenin blanc (Sobrante) and Chardonnay (Musick) vines had lamina EP levels less than 1.0 g P/kg dw throughout this study. In the 2nd season after P was applied to the Musick soil, Chardonnay cluster number increased with bloomtime lamina EP to approximately 0.8 g P/kg dw, but did not increase with further increases in lamina EP (Fig. 5 A). A similar relationship was established between Chardonnay yield and lamina EP during the same season (Fig. 5 B). Results from Chardonnay vines grown with and without P in a greenhouse have also shown a similar relationship between total shoot dw and lamina EP (data not shown).

The relationship of lamina EP to cluster number (Fig. 6 A) and to yield (Fig. 6 B) was also quite similar in Chenin blanc in the 2nd season after P application to the Sobrante soil. In contrast to Chardonnay, Chenin blanc cluster number (Fig. 6 A) and yield (Fig. 6 B) increased with lamina EP to approximately 1.5 g P/kg dw. Berry weight of Chenin blanc (not determined for Chardonnay) was greater in P-treated vines in the 2nd season after P application (SKINNER *et al.* 1987), but did not differ between control and P-treated vines in subsequent seasons. Thus, it appears that berry number per vine was the yield component primarily responsible for increased yields in the P-treated vines compared to the control.

Summary

Grapevines growing on two low P soils were shown to have petiole TP levels below currently accepted critical levels established for the Thompson Seedless variety. Soil application of different P fertilizers increased lamina EP and pruning weights in the season immediately following application. In the 2nd season after application, cluster numbers and yields of P-treated Chardonnay and Chenin blanc grapevines were greater than for the untreated controls. Different sources of P, applied at various rates either during the growing or dormant seasons, were effective in alleviating P deficiency. However, the largest and most sustained increases in P status were associated with the largest P application rates. Therefore, under certain low P soil conditions repeated small applications of P every 2—3 years may be necessary to maintain adequate vine P status. Preliminary critical P levels of 0.8 g lamina EP/kg dw for Chardonnay (own roots) and 1.5 g lamina EP/kg dw for Chenin blanc (St. George rootstock) were established based on yield responses.

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