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Advancement of 'Riesling' Fruit Maturity by Paclobutrazol-induced Reduction of Lateral Shoot Growth

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Abstract. **Paclobutrazol (PB) was sprayed on hedged 'Riesling' (Vitis vinifera L.) vines at one of five concentrations (0, 1000, 2000, 3000, or 4000 mg·liter^{-1}) as single annual applications over 3 years (1987-89). Observations were made on growth, yield, and fruit composition during the years of application and 1 year thereafter (1990) to test carryover effects. PB had no effect on vine vigor, expressed as weight of cane prunings, during the three application years, but reduced vine vigor linearly with concentration in 1990. Yield was reduced by PB in the first 2 years of the trial, while in one season cluster weight and berries per cluster were also reduced. °Brix was increased by PB during all 3 years of application; titratable acidity was reduced and pH increased in the first year of application. PB sprays significantly reduced lateral shoot length, mean leaf size on both main and lateral shoots, and total leaf area on main and lateral shoots. Winter injury to buds, cordons, and trunks was also reduced with increasing PB level. Residues of PB in fruit in the first year of application ranged from 9 µg·kg^{-1} at the 0-m·gliter^{-1} level to 638 µg·kg^{-1} at the 4000-mg·liter^{-1} level. PB shows promise as a viticultural tool for advancement of fruit maturity, with possible additional benefits such as improved vine winter hardiness. Chemical name used β -[(4-chlorophenyl) methyl]- α -dimethylethyl)-1-H-1,2,4-triazole-l-ethanol (paclobutrazol, PB).**

Successful cultivation of wine grapes largely depends on effective management and control of vine vigor. In some vineyards, excessive vigor has an unfavorable impact on fruit composition and fruitfulness due to canopy shade (Shaulis et al., 1966). Excessive vigor can be accommodated through proper choice of rootstock, vine spacing, or canopy division (Shaulis et al., 1966; Smart et al., 1985), or it can be attenuated through hedging (Reynolds and Wardle, 1989a), basal leaf removal (Reynolds and Wardle, 1989b; Smith et al., 1988; Wolf et al., 1986), or the use of growth retardants such as paclobutrazol (Reynolds, 1988a; Reynolds and Wardle, 1989b; Williams et al., 1989).

PB is a growth retardant that inhibits gibberellin biosynthesis (Graebe, 1982). Its effect on fruit crops in general is well known and was recently reviewed (Reynolds, 1988b). In potted grapevines, reductions in vigor have been achieved through soil drenches (Reynolds and Wardle, 1990), stem application (Wample et al., 1987), and foliar sprays (Intrieri et al., 1986). In the field, soil drenches of PB have resulted in short-term reductions in vigor and yield, and delayed fruit maturity in 'Thompson Seedless' (Williams et al., 1989). Trunk applications of PB had no effect on 'Concord' vine performance (Ahmedullah et al., 1986), but enhanced certain yield components and advanced fruit maturity in 'Okanagan Riesling' (Reynolds, 1988b). Foliar sprays to mature vines have also advanced fruit maturity (Reynolds, 1988a; Reynolds and Wardle, 1989b), with little effect on yield or vine vigor.

Most *V. vinifera* vineyards in British Columbia are trained on a narrow, vertical trellis and are hedged in early summer to restrict vegetative growth. This combination of cultural practices often leads to excessively dense canopies due to a proliferation of lateral shoot growth. Initial research suggested that lateral regrowth could be controlled in low-vigor 'Riesling' vines by 500 to 750 mg PB/liter (Reynolds, 1988a) and in highly vigorous 'Gewurztraminer' by 1000 to 2000 mg·liter^{-1} (Reynolds and Wardle, 1989b). The purpose of the study reported here was threefold: 1) to investigate the effect of five concentrations of foliar-applied PB on vine performance; 2) to evaluate any carryover effects after three consecutive years of PB application, and 3) to determine the degree, if any, to which PB accumulates in fruit tissue during the initial application year.

Materials and Methods

The 9-year-old 'Riesling' (clone 21B Weis) vines on 5C rootstock we studied were located in Pioneer Vineyards, Kelowna, B.C. Vines were trained to a 0.7-m-high bilateral cordon and pruned to enough two-node, upward-oriented spurs to allow a shoot density of 20 nodes per meter of row. Shoots were trained vertically upward through catch wires. Vines were hedged once each summer (9 July 1987, 30 June 1988, 6 July 1989, and 18 July 1990) when berry diameter was about 3 to 5 mm. Vines were spaced 1.4 m apart in north–south-oriented rows that were 2.4 m wide. Irrigation was supplied by overhead sprinklers. Pest control and soil management practices were consistent with published recommendations (B.C. Ministry of Agriculture and Fisheries, 1987).

The design was a randomized complete block containing five treatments, four blocks, and five-vine treatment replicates. Each block consisted of a portion of a single vineyard row. Treatments were 0, 1000, 2000, 3000, and 4000 mg a.i. PB/liter and were applied to the canopy above the fruit zone using a backpack sprayer 7 days following summer hedging in 1987-89.

Weight of cane prunings (vine size) was recorded each seas as an estimate of vine vigor. Shoots per vine were counted i late May and adjusted to ≈ 30 per vine (21 shoots per meter of row). Clusters per vine and yield per vine were determined each

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Table 1. Growth of 'Riesling' vines as affected by five rates of paclobutrazol, 1987 to 1990.

Paclobutrazol ($mg \cdot liter^{-1}$)	Wt of cane prunings (kg/vine)				Shoots retained/vine (no.)				Winter injury[z]
	1987	1988	1989	1990	1987	1988	1989	1990	1989
0	0.21	0.21	0.22	0.25	36.2	31.6	25.0	27.4	2.5
1000	0.20	0.22	0.19	0.25	36.5	31.4	29.2	29.7	1.2
2000	0.17	0.18	0.17	0.19	33.6	32.2	30.0	30.3	0.2
3000	0.19	0.19	0.19	0.23	31.0	31.2	28.7	29.4	1.0
4000	0.18	0.19	0,13	0.12	34.1	31.6	30.0	29.8	0.3
Significance	NS	NS	NS	L**	NS	N S	N S	L*, Q*	L***, Q**

[z]Legend: 0 = no injury; 1 = injury to one cordon; 2 = injury to both cordons; 3 = both cordons killed, plus one trunk injured; 4 = vine killed to the ground.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, and 0.001, respectively. L or Q: linear or quadratic trends, respectively.

Table 2. Yield components of 'Riesling' vines as affected by five rates of paclobistrazol, 1987 to 1990.

Paclobutrazol ($mg \cdot liter^{-1}$)	Yield ($t \cdot ha^{-1}$)				Clusters/vine (no.)				Cluster wt (g)				Berries/cluster (no.)				Berry wt (g)			
	1987	1988	1989	1990	1987	1988	1989	1990	1987	1988	1989	1990	1987	1988	1989	1990	1987	1988	1989	1990
0	12.4	13.8	1.5	13.6	86.5	68.4	12.2	67.6	47.9	67.4	48.4	68.2	41.7	57.5	37.4	53.5	1.14	1.18	1.28	1.27
1000	10.6	11.9	5.7	13.8	80.6	67.4	41.0	67.5	43.9	58.7	43.5	69.2	39.3	56.2	39.4	55.5	1.12	1.04	1.10	1.25
2000	8.6	9.6	6.9	13.5	79.0	66.8	55.0	60.3	36.2	49.0	42.7	75.2	33.8	47.9	39.0	60.0	1.07	1.03	1.08	1.26
3000	9.3	11.3	6.7	14.6	68.6	68.3	39.5	67.8	45.4	55.1	57.0	72.9	39.3	55.4	47.9	58.9	1.15	1.01	1.17	1.24
4000	8.0	10.0	7.1	12.7	69.3	66.3	57.1	61.3	40.8	50.7	42.2	68.9	35.0	48.4	37.1	56.6	1.16	1.05	1.13	1.22
Significance	L*	L**	L**	NS	NS	NS	L***, Q*	NS	NS	L**	NS	NS	NS	L**	NS	NS	Q*	NS	Q**	NS

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, and 0.001, respectively. L or Q: linear or quadratic trends, respectively.

year at harvest, with cluster weight calculated from these measurements. A random, 100-berry sample was collected from each vine at harvest for berry weight determination; an estimate of berries per cluster was calculated from cluster and berry weights. Grapes were harvested on 28 Sept. 1987, 14 Oct. 1988, 16 Oct. 1989, and 17 Oct. 1990.

Lateral shoot length was measured on the most distal five lateral shoots of one representative hedged shoot per vine on 13 Aug. 1987, 18 Aug. 1988, and 21 Aug. 1990. Leaf area of laterals was measured in 1988, along with that of the most distal main leaf on the sampled shoot, using a LI-3000 leaf area meter (LI-COR, Lincoln, Neb.). One shoot per treatment replicate was sampled in 1989 and 1990, with main leaf area and lateral shoot areas measured as in the previous season. Leaf area per vine was estimated as a product of shoot number and shoot leaf area measurements.

Vine winter injury was assessed in late May 1989, following an extremely cold February in which temperatures fell below – 25C. Vines were rated in terms of degree of trunk and cordon death on a four-point scale, where O = no injury, 1 = injury to one cordon, 2 = injury to both cordons, 3 = total top loss plus some trunk injury, and 4 = complete death of all perennial portions of the vine above soil level.

Fruit composition was assessed on the 100-berry samples that were kept frozen at – 40C until analysis. The titratable acidity (TA) of extracts prepared from 50-g subsamples was measured, according to the method of Mattick (1983), using a Brinkmann 672 Titroprocessor (Metrohm, Herisau, Switzerland). The remainder of each 100-berry sample was juiced, and °Brix and pH were measured on settled juice with an Abbé refractometer (AO Scientific, Buffalo, N. Y.) and a Fisher 825MP digital pH meter (Fisher Scientific, Vancouver, B.C.), respectively.

Four clusters per treatment replicate were sampled in 1987 for PB residue analysis and stored at – 40C. The method for PB extraction from grape tissue and its subsequent quantitation by gas chromatography-mass spectrometry (GC–MS) was adapted from Reed (1988) and Stably and Buchanan (1986). Frozen berries (25 g) were removed from their rachises, rinsed with distilled water, blended with 40 ml of 80% methanol, and filtered along with a 10-ml rinse. The residue was reextracted (40 ml plus 20 ml rinse) and the combined filtrate, diluted with 400 ml of water and 5 ml 16% NaCl, was extracted with 75 ml dichloromethane. The dichloromethane extract was passed through Na_2SO_4 and evaporated. The residue, including an internal standard (dichlobutrazol), was made up to 1.0 ml for GC–MS analysis. PB was analyzed with a Hewlett-Packard 5890A GC [Hewlett-Packard (Canada), Mississauga, Ont.] with a 5970 mass selective detector and a 25 m × 0.32-mm HP-17 capillary column. Selected ion monitoring was used for quantitation (mass : charge ratio = 125, 167, 236, and 238 for PB and 270, 272, and 274 for dichlobutrazol).

All analyses of variance were performed using the SAS statistical package (SAS Institute, Cary, N. C.) with the aid of the General Linear Models procedure. Linear, quadratic, cubic, and quartic trends were ascertained by single-degree-of-freedom contrasts. Significant cubic and quartic trends are not reported.

Results

Vines used in this experiment were small, averaging 0.19 kg of cane prunings per vine (0. 14 kg/m of row) in the 3 years during which PB was applied. There was no significant effect of PB on vine size in the three application years (1987–89), but there was a significant linear reduction in vine size relative to PB concentration in the carryover year (1990) (Table 1). The mean number of shoots retained per vine did not vary significantly with PB concentration during the course of the trial, but did in 1990 (Table 1); 1989 data reflect only those vines not injured severely during the previous winter. Vine winter injury was apparently reduced linearly by increasing PB concentration, wherein greatest trunk and cordon injury occurred with PB at 0 and 1000 $mg \cdot liter^{-1}$ and, to a lesser extent, at 3000 $mg \cdot liter^{-1}$. Entire yield loss (<0.5 kg/vine) was observed on 13 vines out of 20 with the 0-mg-liter^{-1} treatment. Only six, two, three, and one vine out of 20, respectively, lost crop with PB at 1000, 2000, 3000, and 4000 mg·liter^{-1}.

Yield was reduced linearly by increasing PB level in 1987 and 1988 (Table 2). Cluster weight and berries per cluster were also reduced in a similar fashion in 1988. Berry weight was affected by PB in 1987 and 1989 in a predominately quadratic fashion, with the 2000 mg PB/liter resulting in the lowest berry weight. Winter injury in 1989 reversed many previously observed PB-induced trends in yield components; thus, yield and clusters per vine increased linearly with increasing PB level in 1989. There were no effects of PB on any yield components in 1990, except a quartic trend (not shown) for clusters per vine.

Lateral shoot length was reduced linearly by PB at the most distal position in 1987, at the five most distal nodes in 1988, and at the "fifth node below the shoot terminus in 1990 (Fig. la-c). The lack of a large response to PB in 1987 may have been due to the hot, dry conditions that prevailed during that season, which limited extension and lateral shoot growth throughout the entire vineyard. Leaf area on the five most distal lateral shoots was similarly reduced in 1988 by increasing PB concentration, as was the leaf area of the most distal main leaf (Fig. 2). In 1989, PB reduced main shoot leaf area and lateral shoot leaf area on a per leaf, per shoot, and per vine basis in a predominantly linear fashion (Table 3). Total leaf area per vine and the lateral shoot leaf area : main shoot leaf area ratio also decreased linearly in 1989 relative to increasing PB concentration (Table 3). These patterns were similar in 1990 (Table 4), but variability in the data was great, and the trends were not as strong as in 1989.

PB was associated with increased fruit soluble solids concentration (°Brix) in 1987–89, as well as a linear decrease in TA and a linear increase in pH in 1987 (Table 5). This trend in °Brix was reversed in 1990, but there were no effects on TA or pH. Residue levels of PB in fruit tissue in 1987 responded linearly to applied PB (Fig. 3). There was considerable variation within and between replicates.

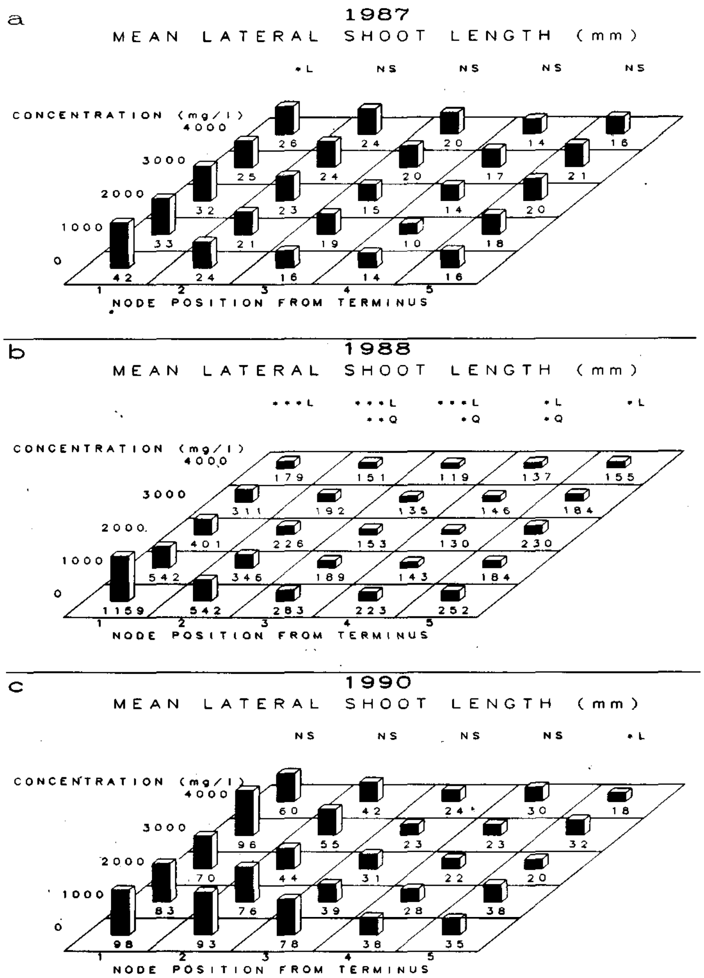

Fig. 1. Lateral shoot length on 'Rieling' vines at each of the five most distal nodes in response to PB concentration: **(a)** 1987, **(b)** 1988, **(c)** 1990.
*,**, ***, NSSignificant at P ≤ 0.05, 0.01, 0.001, or nonsignificant, respectively. L, Q: linear or quadratic trends, respectively.

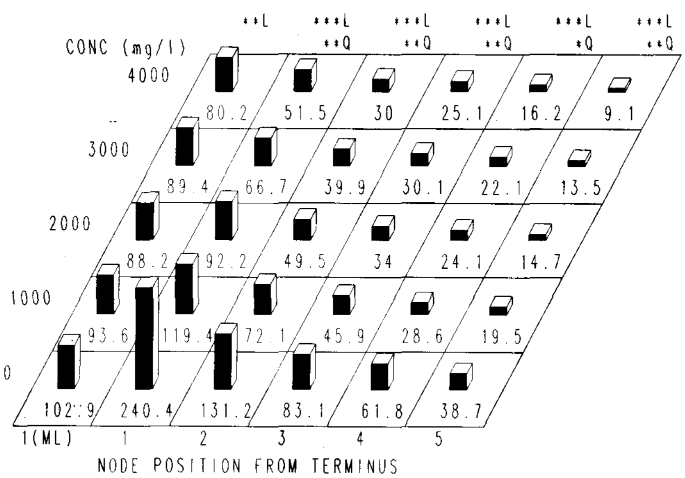

Fig. 2. Mean leaf area of the most distal main leaf and per lateral shoot at each of the five most distal nodes on 'Riesling' vines in response to PB concentration, 1988.
*,**,***Significant at P ≤ 0.05, 0.01, or 0.001, respectively. L, Q: linear or quadratic trends, respectively.

Discussion

PB had no apparent overall impact on vine size except for a slight linear reduction relative to PB concentration in 1990. This result confirms those reported by Ahmedullah et al. (1986) and Reynolds (1988b) for trunk-applied PB on 'Concord' and 'Okanagan Riesling', respectively, as well as those of Reynolds (1988a) and Reynolds and Wardle (1989b) for foliar-applied PB on 'Riesling' and 'Gerwürztraminer', respectively, all of whom found no vine size reductions resulting from PB application. Williams et al. (1989) showed that PB applied to soil at rates of 0.55 to 2.20 kg a.i./ha reduced vine size, but found that such reductions were short lived. Our study used ≈2.5 liters of solution per five-vine treatment replicate, or 0.5 to 2.0 g a.i./vine (1.51 to 6.05 kg a.i./ha). The lack of vine size response in this study may be due to the small initial vine size (0.20 kg) compared to the relatively large size (2.10 to 4.56 kg) reported by Williams et al. (1989). The fact that PB moves mostly acropetally (Sterrett, 1985) also helps explain why a single foliar application might be less successful for overall vigor control. Williams et al. (1984) indicated that soil application of PB to deciduous fruit trees generally was more effective for vegetative growth control than foliar application. However, our objective was not overall vine size reduction, but specifically the restriction of the lateral shoot growth that typically occurs after vines are hedged.

Table 3. Leaf area components of 'Riesling' vines as affected by five rates of paclobutrazol, 1989.

Concn (mg·liter⁻¹)	Main shoot leaf area (cm²) per Leaf	Main shoot Shoot (1000s)	Main shoot Vine (1000s)	Lateral shoot leaf area (cm²) per Leaf	Lateral Shoot (1000s)	Lateral Vine (1000s)	L : M ratio[z]	Total (cm²)[y] (1000s)
0	158	2.67	63.3	43.9	4.02	67.6	1.51	131
1000	121	1.76	48.6	28.3	1.08	28.2	0.62	76.8
2000	95.5	1.40	42.6	19.5	0.41	12.8	0.27	55.4
3000	97.3	1.47	42.7	21.2	0.44	12.3	0.28	55.0
4000	87.6	1.29	38.3	19.6	0.30	9.3	0.23	47.6
Significance	L***, Q**	L***, Q**	L***	L***, Q**	L**, Q*	L***	L**, Q*	L***

[z]L : M ratio = leaf area on lateral shoots : leaf area on main shoots.
[y]Total = leaf area per vine on main shoots + leaf area per vine on lateral shoots.
*, **, *** , [NS]Significant at P ≤ 0.05, 0.01, or 0.01, or nonsignificant, respectively. L or Q: linear or quadratic trends, respectively.

Table 4. Leaf area components of .'Riesling' vines as affected by five rates of paclobutrazoi, 1990.

Concn (mg·liter⁻¹)	Main shoot leaf area (cm²) per Leaf	Main shoot Shoot (1000s)	Main shoot Vine (1000s)	Lateral shoot leaf area (cm²) per Lateral shoot	Lateral Main shoot (1000s)	Lateral Vine (1000s)	L : M ratio[z]	Total (cm²)[y] (1000s)
0	127	2.02	55.4	79.8	1.29	35.2	0.62	90.7
1000	109	1.97	58.2	63.7	1.17	34.7	0.58	92.9
2000	102	1.80	54.1	81.8	1.44	43.5	0.81	97.6
3000	112	1.83	53.8	64.9	1.07	31.8	0.60	85.6
4000	91.5	1.37	40.8	46.2	0.68	20.2	0.42	61.0
Significance	L**	L***	L**	NS	L*	NS	Q*	L*

[z]L : M ratio = leaf area on lateral shoots : leaf area on main shoots.
[y]Total = leaf area per vine on main shoots + leaf area per vine on lateral shoots.
*,**, ***[NS]Significant at P ≥ 0.10, 0.05, or 0.01, or nonsignificant, respectively. L or Q: linear or quadratic trends, respectively.

Table 5. Composition of 'Riesling' fruit as affected by five rates of paclobutrazol, 1987 to 1990.

Paclobutrazol (mg·liter⁻¹)	°Brix 1987	°Brix 1988	°Brix 1989	°Brix 1990	Titratable acidity (g·liter⁻¹) 1987	TA 1988	TA 1989	TA 1990	pH 1987	pH 1988	pH 1989	pH 1990
0	20.3	21.2	21.2	19.8	11.4	12.2	10.9	13.6	3.02	2.99	3.14	2.86
1000	20.9	22.2	22.7	19.8	10.9	12.1	10.5	13.9	3.03	3.04	3.17	2.85
2000	21.3	22.6	23.3	19.4	10.6	12.1	10.3	14.2	3.07	3.07	3.17	2.84
3000	21.3	21.9	23.1	19.2	10.3	12.4	10.4	13.8	3.08	3.02	3.16	2.85
4000	21.0	22.9	23.4	18.8	10.3	11.6	10.8	14.4	3.07	3.07	3.20	2.84
Significance	L*	L*	L**	L**	L**	NS	NS	NS	L*	NS	NS	NS

[NS,*,**]Nonsignificant or significant at $P \leq 0.05$ and 0.01, respectively. L: linear trend.

Yield reductions associated with PB in 1987 and 1988 may have been partly due to an apparent trend toward reductions in clusters per vine, cluster weight, berries per cluster, and berry weight, although some of these trends were not significant statistically. The trend toward a reduction in clusters per vine in 1988 may have been due to death of some of the primary bud primordia as a result of the 1987 PB application. Williams et al. (1989) observed that soil-applied PB resulted in death of the primary bud, accompanied by growth of the less-fruitful secondary and tertiary buds. Ahmedullah et al. (1986) found no effects of trunk-applied PB on 'Concord' yield components, but Reynolds (1988b) observed a persistent berry weight increase with a single trunk application of PB on 'Okanagan Riesling'. Foliar-applied PB on 'Riesling' (Reynolds, 1988a) enhanced berry size during one season of a 3-year trial, but no effects of foliar-applied PB were observed on yield components of 'Gewürztraminer' (Reynolds and Wardle, 1989b). Overall, there appears to be little previous evidence of significant reductions in yield components of grapes in response to trunk- or foliar-applied PB. Williams et al. (1989), however, demonstrated significant yield reductions in 'Thompson Seedless' vines in the first and second years following a PB soil application.

Many features of shoot growth and leaf area were impacted by PB in this study. Reynolds (1988a) and Reynolds and Wardle (1989b) reported PB-induced reductions in lateral shoot length in hedged 'Riesling' and 'Gewurztraminer' vines, respectively, in response to foliar applications. Williams et al. (1989) noted that PB applied to soil at 2.2 kg·ha⁻¹ increased the proportion of short (O to 50 cm) shoots. To our knowledge, no previous research has documented PB-induced reductions in leaf area of field-grown grapevines, although many (Intrieri et al., 1986; Reynolds and Wardle, 1990; Wample et al., 1987) have reported on leaf area reductions in potted vines in response to foliar-, trunk-, and soil-applied PB, respectively.

An apparent advance in fruit maturity in response to PB is consistent with previous results with trunk applications to 'Okanagan Riesling' (Reynolds, 1988b) and foliar applications to 'Riesling' (Reynolds, 1988a) and 'Gewürztraminer' (Reynolds and Wardle, 1989b). Ahmedullah et al. (1986) found no effect of PB trunk applications on 'Concord' fruit composition,

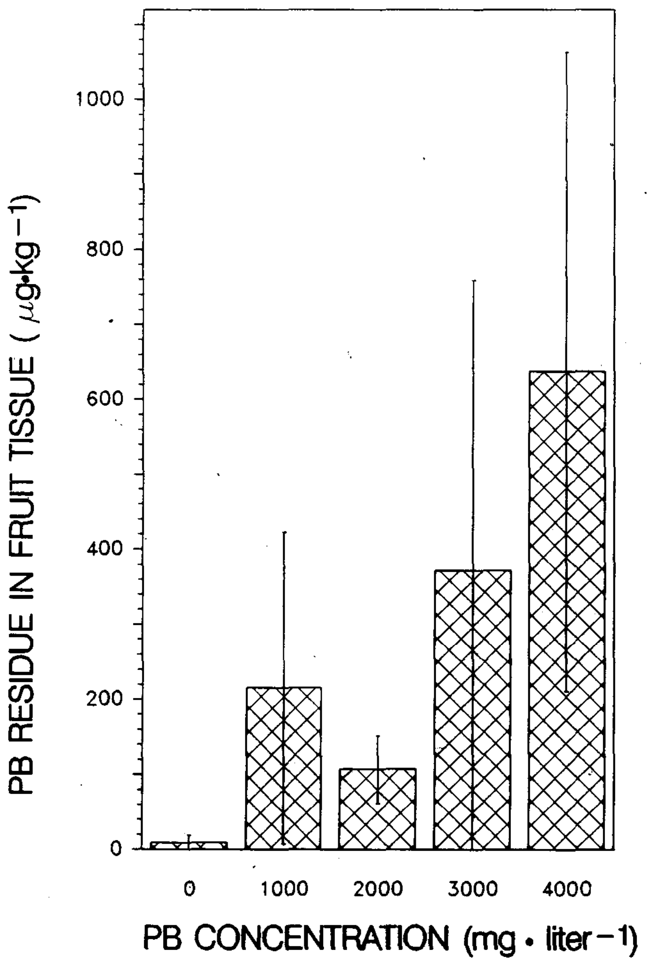

Fig. 3. PB residues in 'Riesling' fruit tissue in response to PB foliar sprays, 1987. Linear trend, $P \leq 0.01$. Vertical bars represent **SD.** Limit of detection was 10 μg·kg^{-1}.

while Williams et al. (1989) found that soil applications of 2.2 kg PB/ha at budbreak tended to lower °Brix by 1.8° relative to the untreated control. In this study, consistent increases in °Brix in fruit from PB-treated vines are attributed to a favorably altered source–sink relationship in the vines, resulting from the significant reduction in lateral shoot length. According to Koblet (1977), lateral shoots are net importers of photosynthate, unless (or until) leaves are fully expanded or if they bear no second crop. Many of the lateral shoots treated with 0 or 1000 mg PB/liter contained partially expanded leaves and second crop clusters, but few, if any, fully expanded leaves, hence those laterals might have been strong sinks. Vines treated with higher concentrations of PB had, in many cases, minimal lateral shoot growth, so presumably their primary clusters were stronger sinks than those borne on untreated vines.

Other features of the PB-treated vines in this study may have affected fruit composition. Leaf area reductions, estimated at 41% to 63% for 1000 to 4000 mg PB/liter in 1989 (23% to 39% of main leaf area), obviously led to reduced canopy shade and higher fruit exposure. Exposed clusters usually are higher in °Brix and lower in TA (Crippen and Morrison, 1986; Reynolds et al., 1986; Reynolds and Wardle, 1989c). It might also be argued that the lower yields of PB-treated vines could have increased °Brix; however, a linear increase in °Brix with increasing PB level was still apparent in 1989, despite a reversal in this yield trend. Nonetheless, the effects of crop load on fruit composition cannot be discounted, because significant reductions in yield in the absence of vine size reductions were associated with increased PB concentration in 1987 and 1988. The observation in 1990 of °Brix decreasing with increased PB levels may have been due to carryover effects of the chemical; leaf areas were still reduced relative to increasing PB concentration, but yields were similar. Lateral shoot growth was not appreciably reduced, thus lateral shoots probably were strong photosynthetic sinks. Vines previously sprayed with high levels of PB had relatively low main leaf areas but carried the same crop level as untreated vines. Both the yield and lateral shoot length relative to main leaf area were likely contributors to reductions in °Brix relative to increasing PB level in 1990.

Reduced vine winter injury by PB following Winter 1988-89 may also have been explained by a combination of lower yields in 1988, advanced fruit maturity, and an improvement in cane exposure. The possibilities of altered root anatomy or water relations impacting winter hardiness also cannot be ruled out. Wample et al. (1987) reported that PB increased root cortical cell counts and root diameter, compared to untreated controls. They suggested that modified root growth might indirectly impact water use and CO_2 assimilation. Increased carbohydrate levels have also been found in leaves, buds, wood, and fruit of PB-treated 'Spartan' apple *(Malus domestics* Borkh.) trees (Steffens et al., 1985); such a phenomenon may have occurred in the PB-treated 'Riesling' vines used in this study and may have led to the observed improvement in vine hardiness.

Perhaps of greatest importance are the residue levels found in the fruit. Canadian tolerance levels for unregistered chemicals, established by Health and Welfare Canada, are set at 100 μg·liter^{-1} (0.1 ppm) (G. Orriss, personal communication). Levels found in fruit sampled from the 1000-mg PB/liter treatments averaged 215.8 μg·kg^{-1} or more than double the established tolerance level. To our knowledge, this is the first evidence of PB translocation into fruit from foliar applications. Although PB accumulation in the fruit may be attributed to other mechanisms (root uptake of runoff from foliage or direct absorption into young berries from foliar runoff), most of the PB in the fruit likely came from direct translocation from the leaves. This assumption is not entirely consistent with the results of Sterrett (1985), who indicated that PB moves primarily acropetally.

Although PB led to consistent reductions in lateral shoot growth, advanced fruit maturity, and reduced winter injury, the excessive residue levels found in fruit tissue may prohibit its use in viticulture. Also, these residues were found less than 90 days after application of the chemical, thus leaving little time for accumulation in the soil and subsequent uptake in the xylem. Although future research may still be warranted, it appears that the levels of PB required to elicit consistent and positive vine responses may be regarded as excessive from a residue standpoint.

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