Journal of Horticultural Science & Biotechnology (2005) **80** (3) 313–318

Effect of training-pruning regimes on Eutypa dieback and performance of 'Cabernet Sauvignon' grapevines

By SANLIANG GU[1*], ROBERT C. COCHRAN[1], GUOQIANG DU[1], ABDUL HAKIM[1], KENNETH C. FUGELSANG[1], JOHN LEDBETTER[2], CHUCK A. INGLES[3] and PAUL S. VERDEGAAL[4]
[1]Viticulture and Enology Research Center, Department of Viticulture and Enology, California State University, Fresno, 2360 East Barstow Avenue M/S VR 89, Fresno, California 93740, USA
[2]Vino Farms, Inc., 1377 East Lodi Avenue, Lodi, California 95240, USA
[3]University of California, Cooperative Extension, Sacramento County, 4145 Branch Center Road, Sacramento, California 95827, USA
[4]University of California, Cooperative Extension, San Joaquin County, 420 South Wilson Way, Stockton, California 95205, USA
(e-mail: sanliang@csufresno.edu) *(Accepted 10 February 2005)*

SUMMARY
The effects of training-pruning regimes on Eutypa dieback, vigour, yield and fruit composition were evaluated in 'Cabernet Sauvignon' grapevines from 1991 to 2004 in Galt, California, USA. Mechanical pruning at bud swell, and minimal pruning (trimming only in Summer) gave the least dieback. In contrast, pruning of dormant vines trained on either a bilateral cordon or a Sylvoz system increased wounding and dieback. Hand pruning of head-trained vines gave fewer cuts and less dieback, compared with vines trained as bilateral cordons or Sylvoz. Dieback reduced the extension of fruiting arms on bilateral cordon- and Sylvoz-trained vines with dormant season pruning, whereas arms were healthy after mechanical and minimal pruning. Hand-pruned vines (bilateral cordon, Sylvoz or head) had greater pruning weights, fewer shoots and clusters, heavier clusters, and lower yields than vines pruned mechanically or minimally. Despite the presence of dieback, yields did not decline over 14 years (except for Sylvoz-trained vines from 2002, and bilateral cordon-trained vines from 2003). Fruit had lower °Brix and pH, and higher titratable acidity in some years, suggesting possible delays in fruit ripening on minimally-pruned vines. Mechanical pruning at bud swell and Summer trimming can minimise Eutypa dieback while maintaining yield and fruit quality. Training-pruning regimes that require early pruning and that generate large numbers of wounds when vines are dormant should be avoided where *Eutypa* is a concern.

Eutypa dieback is one of the most destructive diseases of woody tissues in grapes. It is a chronic disease caused by infection of the vascular system by the fungus *Eutypa lata*, which enters through wounds. Eutypa dieback causes necrosis or cankers of woody tissue and also results in leaf, shoot and cluster deformities (stunting and dwarfing) and slow ripening of the berries (Moller *et al*., 1974). Infections usually do not produce symptoms for 2–3 years, during which time the mycelium colonises the xylem, cambium and the phloem (Moller and Kasimatis, 1978; 1981). The disease results in the loss of bearing surface and reduces yield by killing individual spurs and fruiting arms. Up to 90% of vines can be infected in 20 year-old vineyards (Duthie *et al*., 1991), requiring the retraining of new cordons and increasing vineyard management costs. If left unattended, the disease eventually kills the vine and shortens the economic life of the vineyard (Munkvold *et al*., 1994).

Pruning wounds are the main site of infection by *E. lata* during the rainy part of the dormant season when ascospores are released and subsequently deposited on the stems. Fungicides can protect these wounds, but the time of application is critical because all wounds must be treated shortly after pruning. The vines are more susceptible when they are dormant and pruned early (Petzolt *et al*., 1981). Because the ascospores are dispersed by rain, pruning grapevines late in the Spring when rains are less likely to occur can reduce the incidence of infection. Therefore, Eutypa dieback can be managed by delayed pruning (Moller and Kasimatis, 1980; Petsoldt *et al*., 1981), but this is not always practical in large plantings.

Alternative training-pruning regimes to reduce the incidence of wounding, coupled with delayed pruning and avoiding cuts during the infection period, or eliminating dormant pruning are possible methods for reducing infection. Mechanical pruning allows faster pruning late in the season when susceptibility to *E. lata* is low. Minimal pruning, on the other hand, eliminates pruning and creates no wounds when vines are dormant. It was suggested that a reduction in the exposure of wounds to disease infection, by altering training systems and pruning practices, would result in a lower incidence of Eutypa dieback while maintaining yield and fruit quality. The objective of this study was to investigate the effects of different training-pruning regimes, in the absence of fungicides, on the incidence of Eutypa dieback, vigour, yield and fruit composition in 'Cabernet Sauvignon' grapevines, where Eutypa dieback is a great concern.

*Author for correspondence.

TABLE I
Annual precipitation, degree days, irrigation and fertilisation in the vineyard

Year	Degree days (°C d, 1 Apr to 31 Oct)	Precipitation (mm)	Irrigation (mm)	Fertilisation[a] (g per vine)				
				N	P	K	Zn	B
1999	1998	289	131	31.0	15.5	46.6	3.04	–
2000	2030	433	237	12.8	6.4	19.2	3.04	–
2001	2080	354	80	12.8	6.4	19.2	–	–
2002	1903	239	114	12.8	6.4	19.2	–	0.73
2003	1982	319	143	14.6	7.3	21.9	6.09	1.46

[a]N, , and K were applied in May, June and October 1999, June 2000 and 2001, January 2002 and June 2003; Zn in October 1999, 2000 and 2003; and B in January 2002 and 2003.

MATERIALS AND METHODS

The experiment was conducted from 1991 to 2004 in a commercial vineyard in Galt, CA, USA, located in the Lodi district, a warm winegrape production area where hand-pruning is common and there is significant rainfall when the vines are dormant (Table I; Figure 1). These conditions are associated with severe infection by *E. lata* and loss of production. Results of the experiment prior to 1999 have been reported by Lake *et al*. (1996; 1998). 'Cabernet Sauvignon' vines on 'Freedom' rootstock were planted in 1991 on Columbia silt loam and San Joaquin loam soils with an east-to-west row orientation 2.13 m between vines and 3.05 m between rows. Inter-rows were planted with native grasses which were mowed during the growing season. Vines were irrigated by drip and N, P, K, Zn and B were applied as indicated in Table I. Pests were managed according to Ohlendorf *et al*. (1996). All other cultural practices were those described by Lake *et al*. (1996; 1998).

The experiment was a randomised complete block with six replications of 270 vines in three rows. Fifteen vines in the middle row of each plot were used for sampling. Treatments initiated in 1992 were bilateral cordon (BLC) with dormant pruning (DP), Sylvoz (S) with DP, head (H) with DP, mechanical pruning (MP) at bud swell (BS), and minimal pruning (MinP) with Summer trimming (ST). The vines were trained on a two-wire vertical trellis (105 and 150 cm above ground) with a stake at each vine. BLC, H and MP-trained vines had cordons on the lower wire, while S and MinP-trained vines had cordons on the higher wire. One cane was left from each side of the vine along the vine row on the H-trained vines, in addition to the spurs. Additional spurs were left on the top of the S-trained vines because of the lack of uniform budbreak on those short downward canes due to the upright growing nature of the cultivar. Vines were hand-pruned when they were dormant in December or January. Mechanical pruning was conducted at bud swell in March. In the MinP treatment, vines were only trimmed within 30 cm above the soil surface during the growing season. When the experiment began, the vines had received only one training cut and appeared free of *E. lata*.

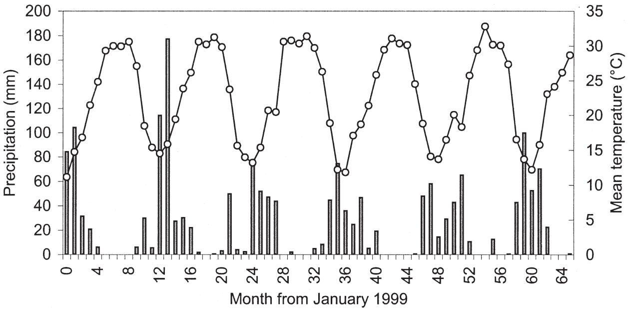

FIG. 1
Monthly precipitation (bars) and mean temperature (line) in Galt, California, USA during 1999-2004.

Stunted shoots with dwarfed, deformed, chlorotic leaves and dead spurs were counted and dead arms were measured in May, when most of the healthy shoots were 25–35 cm long. Disease incidence was expressed as the percentage of vines showing stunted shoots, dead spurs or dead arms. Disease severity was expressed as the number of stunted shoots, number of dead spurs, or length of dead arms per vine. Pruning wounds were counted and the diameter of the pruning wounds measured in 2001 to obtain each wound area. With the exception of MinP-ST, pruning weight and number of shoots were measured and recorded in each dormant season. All canes were removed and weighed for MinP-ST vines in 2004 when the experiment was terminated.

Samples of 100–120 berries were taken every 7–10 d during berry maturation and analysed for total soluble solids (ºBrix), pH, and titratable acidity (TA) with a refractometer (PR-32 Palette, ATAGO Co., Ltd., Japan), a pH meter (Accumet AB-15, Fisher Scientific, Pittsburgh, PA, USA) or an autotitrator (DL 50 Graphix, Mettler-Toledo GmbH, Analytical, Schwerzenbach, Switzerland), respectively. Cluster number and yield were measured at harvest, and cluster weights were calculated. Data were analysed using analysis of variance for treatment effect on each variable according to the experimental design. Means were separated by Tukey-Kramer multiple comparison test at the P = 0.05 level. Regression procedures were applied to analyse the relationship of dieback measures to yield or pruning weight.

RESULTS AND DISCUSSION

Stunted shoots with small, deformed and chlorotic leaves were first noted on the BLC-DP and S-DP vines 6 years after planting (Lake *et al*., 1996). This was delayed for 2, 3 and 5 years with H-DP, MP-BS and MinP-ST intervention, respectively (Figure 2). This is consistent with the observation that grapevines younger than 8 years seldom have symptoms of Eutypa dieback (Carter, 1988; Gubler and Leavitt, 1992). Dieback, expressed as stunted shoots on BLC-DP and S-DP vines, increased over time, with more than 90% of vines affected in 2001. H-DP vines had much less disease. The lowest incidence of dieback occurred with MP-BS and MinP-ST (Figure 2A).

Dead spurs were first recorded in 2000 on BLC-DP, S-DP and H-DP vines, and were more severe with the first two canopy management strategies (Figure 2B).

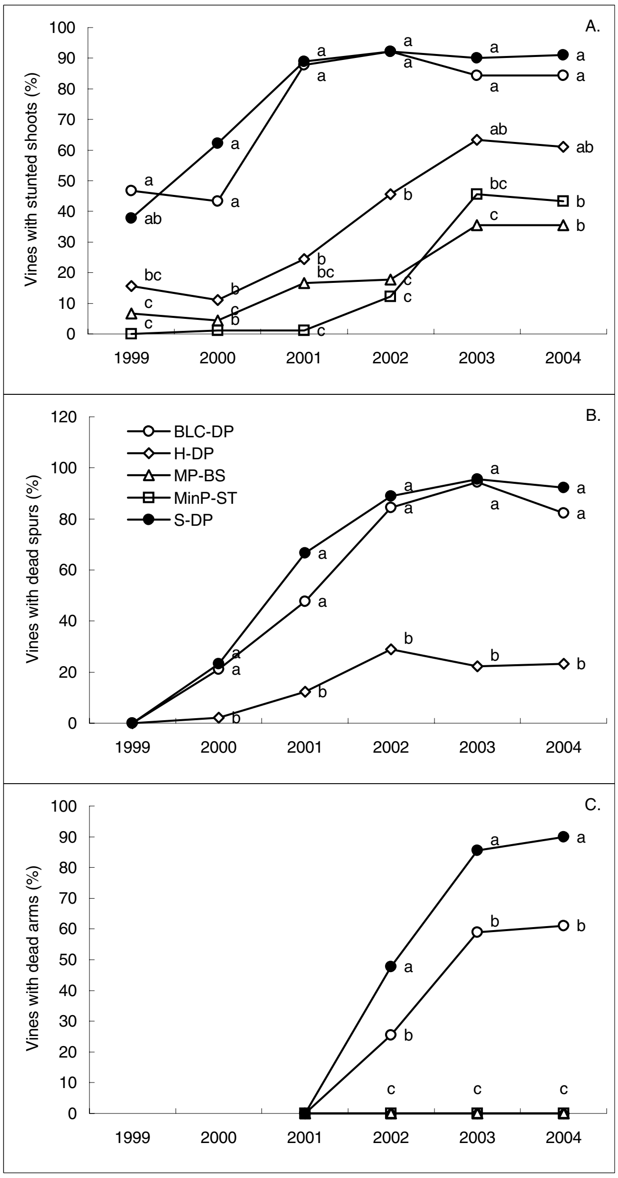

Fig. 2

Incidence of Eutypa dieback in 'Cabernet Sauvignon' grapevines trained to bilateral cordon (BLC), head (H) or Sylvoz (S) with dormant pruning (DP), mechanical pruning (MP) at bud swell (BS), and minimal pruning (MinP) with Summer trimming (ST). Means within each year with different letters are significantly different by Tukey-Kramer multiple comparison test at $P = 0.05$ level. Vines were planted in 1991 and trained in 1992. No data available for dead spurs in MP-BS and MinP-ST. Data are means of 6 replications of 15 vines per treatment.

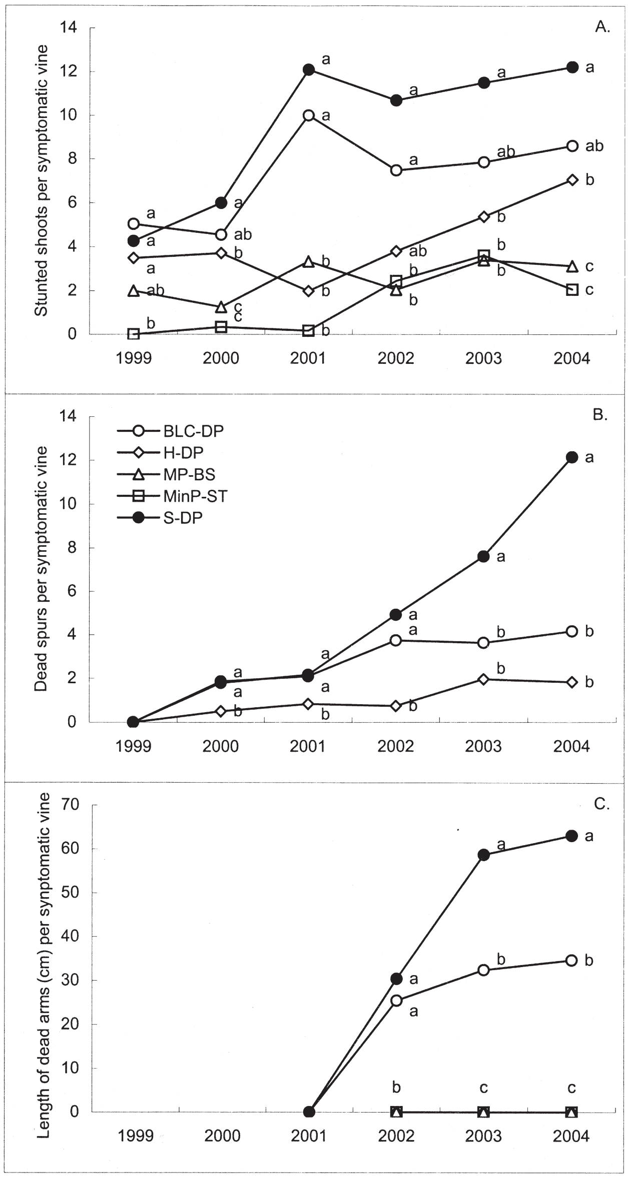

Fig. 3

Severity of Eutypa dieback in 'Cabernet Sauvignon' grapevines trained to bilateral cordon (BLC), head (H) or Sylvoz (S) with dormant pruning (DP), mechanical pruning (MP) at bud swell (BS), and minimal pruning (MinP) with Summer trimming (ST). Means within each year with different letters are significantly different by Tukey-Kramer multiple comparison test at $P = 0.05$ level. Vines were planted in 1991 and trained in 1992. No data available for dead spurs in MP-BS and MinP-ST. Data are means of 6 replications of 15 vines per treatment.

There were dead spurs on MP-BS and MinP-ST vines, but it was impossible to determine if they were due to *Eutypa*. On BLC-DP and S-DP, dead arms were first noted in 2002, and their number increased over time. No dead arms occurred with MP-BS and MinP-ST (Figure 2C).

The trend in disease severity was similar to that shown for the incidence of disease (Figure 3). However, S-DP had a greater severity of dieback than BLC-DP (Figure 3B).

S-DP vines had the greatest number of pruning wounds and larger wound surface areas, while H-DP

Table II

Details of training-pruning treatments and their impact on the number and surface area of pruning wounds in 'Cabernet Sauvignon' grapevines in 2001

		Pruning wounds	
Treatment	Time of pruning	Number per vine	Surface area (cm^2 per vine)
Sylvoz – dormant pruning (S-DP)	December or January	59 a[z]	106 a
Bilateral cordon – dormant pruning (BLC-DP)	December or January	50 b	105 a
Head – dormant pruning (H-DP)	December or January	33 c	54 b
Mechanical pruning at bud swell (MP-BS)	March	–	–
Minimal pruning – summer trimming (MinP-ST)	June	0	0

[z]Means within columns followed by different letters are significantly different by Tukey-Kramer multiple comparison test at $P = 0.05$ level. Data are the means of 6 replications of 15 vines each per treatment.

TABLE III
Effect of training-pruning treatment on vigour in 'Cabernet Sauvignon' grapevines

Treatment[y]	1999	2000	2001	2002	2003
	Shoots per vine				
BLC-DP	61 c[z]	71 b	67 c	79 c	72 b
H-DP	45 c	48 b	45 c	57 c	61 b
MP-BS	117 b	109 b	156 b	144 b	108 a
MinP-ST	164 a	227 a	269 a	217 a	–
S-DP	54 c	63 b	59 c	74 c	70 b
	Pruning weight (kg per vine)				
BLC-DP	2.22 a	2.15 a	1.52 ab	1.46 a	1.47 a
H-DP	1.89 a	1.78 ab	1.62 a	1.21 ab	1.71 a
MP-BS	0.57 b	0.57 c	0.64 c	0.5 c	0.51 c
MinP-ST	–	–	–	–	0.42 c
S-DP	1.72 a	1.44 b	1.03 bc	0.94 b	0.98 b

[y]See Table I for details.
[z]Means within each year with different letters are significantly different by Tukey-Kramer multiple comparison test at $P = 0.05$ level.
All vines were planted in 1991 and trained in 1992.
No data available for shoots per vine in 2003 and pruning weight in 1999–2002 for MinP-ST. Data are means of 6 replications of 15 vines each per treatment.

vines had the fewest wounds among those pruned by hand when dormant (Table II). Pruning wound surface area was larger in BLC-DP and S-DP vines than that in H-DP vines. There appeared to be a large number of pruning wounds on MP-BS vines. However, these pruning wounds were made at bud swell. The relationship between Eutypa dieback and the number and surface area of pruning wounds agrees with previous studies (Chapuis *et al*., 1998; Munkvold and Marois, 1995; Trese *et al*., 1980). That is, the earlier the pruning and the greater the number of pruning wounds, the greater the level of dieback.

Pruning at bud swell reduced dieback, but did not eliminate it. Summer trimming alone (no wounds when the vines were dormant) also did not fully protect the vines from infection. This suggests that vines can be infected by *E. lata* even when they are pruned at bud swell or just trimmed during the growing season. The pathogen can enter vines by other routes and methods. Infection can occur after bud swell if it rains. However, damage is minimal since no arms were killed when pruning was delayed or minimised (Figures 2C and 3C).

Time of pruning had a dramatic effect on the incidence of infection by *E. lata*, even though its effect can not be separated from that of vine training. S-DP and BLC-DP vines had the most pruning and the highest level of dieback. H-DP vines require fewer cuts and are less prone to *Eutypa* infection. MP-BS vines had even lower levels of disease because the numbers of airborne ascospores were low (Petzoldt *et al*., 1983a, b; Ramos *et al*., 1975), the wounds were less susceptible at the time of pruning (Petzoldt *et al*., 1981), and the wounds were exposed to *E. lata* for a shorter period of time. MinP-ST vines suffered the least infection because they were not pruned during Winter.

MinP-ST vines had the greatest number of shoots per vine (Table III). There were also significant differences between MP-BS and the other treatments in 4 out of 5 years. Pruning weight per vine was least in MP-BS (Table III). In contrast, there were only a few cases when the other treatments were significantly different. Pruning weight was inversely correlated with the length of dead arms in BLC and S-trained vines (Figure 4) and other Eutypa dieback measurements, including the number of dead spurs for S-DP vines, number of vines with dead arms, and number of dead spurs for BLC-DP vines in 2003 (data not shown). This indicates that dieback can reduce vine vigour by killing fruiting arms of the vine.

Yield was lower in S-DP, H-DP and BLC-DP compared with MinP-ST and MP-BS in 1999 (Table IV). H-DP also had lower yields than MinP-ST in 2000. Yields in the other 5 years were similar. The number of clusters per vine was lower in S-DP, H-DP and BLC-DP than in the other two treatments in 1999 (Table IV). There were also differences between MinP-ST and MP-BS. S-DP, H-DP, BLC-DP and MP-BS were lower in 2001, and BLC-DP and H-DP lower than MinP-ST in 2003. Cluster weight generally declined over time (Table IV). Values varied across the different treatments. However, the differences between treatments varied from year to year. Cluster weight was lowest in MinP-ST vines.

Yield was inversely correlated with the length of dead arms for S-DP vines in 2002, BLC-DP vines in 2003, number of vines with dead arms, symptomatic shoots and dead spurs for S-DP vines in 2002, number of vines with

TABLE IV
Effect of training-pruning treatment on yield components in 'Cabernet Sauvignon' grapevines

Treatment[y]	1999	2000	2001	2002	2003
	Yield (kg per vine)				
BLC-DP	11.2 b[z]	15.9 ab	11.5	8.2	9.6
H-DP	12.8 b	13.1 b	11.0	7.9	8.1
MP-BS	19.9 a	17.6 ab	8.1	8.5	13.2
MinP-ST	23.0 a	19.9 a	12.5	8.9	15.9
S-DP	14.5 b	16.0 ab	13.8	9.3	–
	Clusters per vine				
BLC-DP	92 c	146 c	114 b	178 c	146 b
H-DP	102 c	119 c	96 b	142 c	120 b
MP-BS	206 b	263 b	105 b	291 b	322 ab
MinP-ST	279 a	383 a	207 a	389 a	461 a
S-DP	123 c	158 c	132 b	203 c	–
	Cluster weight (g)				
BLC-DP	122 ab	109 a	108 a	92 a	66 a
H-DP	126 a	112 a	97 ab	111 a	69 a
MP-BS	97 bc	67 bc	70 ab	57 b	42 b
MinP-ST	86 c	57 c	51 b	46 b	36 b
S-DP	118 ab	101 ab	91 ab	93 a	–

[y]See Table I for details.
[z]Means within each year with different letters are significantly different by Tukey-Kramer multiple comparison test at $P = 0.05$ level.
All vines were planted in 1990 and trained in 1991.
No data for S-DP in 2003. Data are means of 6 replications of 15 vines each per treatment.

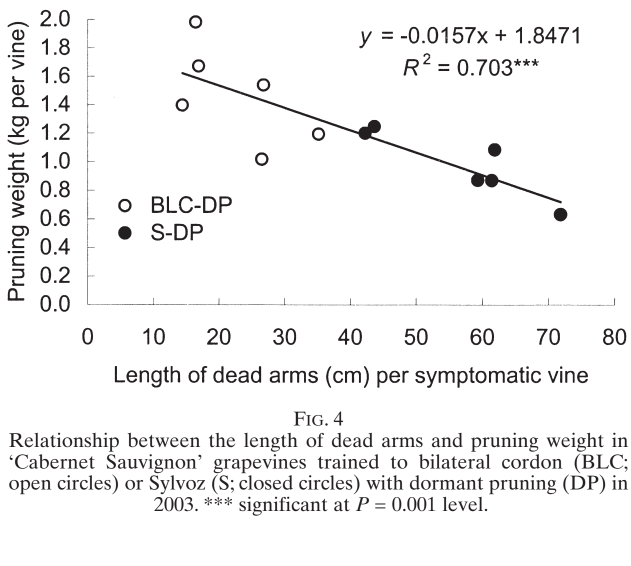

FIG. 4
Relationship between the length of dead arms and pruning weight in 'Cabernet Sauvignon' grapevines trained to bilateral cordon (BLC; open circles) or Sylvoz (S; closed circles) with dormant pruning (DP) in 2003. *** significant at $P = 0.001$ level.

TABLE V
Effect of training-pruning treatment on berry size and juice pH at harvest in 'Cabernet Sauvignon' grapevines

Treatment[y]	1999	2000	2001	2002	2003
			Berry weight (g)		
BLC-DP	1.39 a[z]	1.19	1.07 ab	0.78 ab	0.87 a
H-DP	1.28 ab	1.07	1.22 a	0.84 ab	0.88 a
MP-BS	1.16 b	0.93	0.96 ab	0.66 b	0.75 ab
MinP-ST	1.00 b	0.94	0.83 b	0.58 b	0.70 b
S-DP	1.35 a	1.23	1.14 ab	0.88 a	–
			Juice pH		
BLC-DP	3.73 a	3.56	3.53 ab	3.54 a	3.42 a
H-DP	3.73 a	3.55	3.61 a	3.53 a	3.39 b
MP-BS	3.62 b	3.51	3.54 ab	3.47 c	3.40 ab
MinP-ST	3.45 b	3.43	3.46 b	3.52 ab	3.39 c
S-DP	3.67 ab	3.52	3.51 b	3.49 bc	–

[y]See Table I for details.
[z]Means within each year with different letters are significantly different by Tukey-Kramer multiple comparison test at $P = 0.05$ level.
All vines were planted in 1991 and trained in 1992. No data available for S-DP in 2003. Data are means of 6 replications of 15 vines each per treatment.

dead arms and number of dead spurs for BLC-DP vines in 2003 (data not shown). Reductions in yield caused by *Eutypa* are primarily due to fewer clusters per vine, with pruning weight also lowered (Munkvold *et al*., 1994). In the present experiment, yield was not reduced in BLC-DP and S-DP vines due to *Eutypa* until 2003. Lower yields in the last few years reflected the adoption of deficit irrigation (Table II), with the number of shoots and clusters per vine not reduced (Tables III and IV).

Berry weight showed similar pattern as with regard to cluster size (Table V). Notable differences in fruit composition included lower pH in 4 out of 5 years (Table V), and lower °Brix and higher TA in MinP-ST vines in 1 out of 5 years (data not shown). Fruit sampling prior to harvest revealed a possible delay in fruit ripening on MinP-ST in some years. There were no significant differences in fruit composition between other training-pruning regimes (data not shown).

MP-BS and MinP-ST increased yield, but reduced the size of berries. Smaller berries are popular for making red wines due to their increased surface area to volume ratio and higher concentrations of anthocyanin, tannin and aroma compounds (Roby and Matthews, 2004; Roby *et al*., 2004). This is advantageous when mechanical or minimal pruning is conducted in warm regions with little delay in fruit ripening. It is also well-documented that mechanical and minimal pruning can produce fruit with lower °Brix, lower pH, and higher acidity (McCarthy and Cirami, 1990; Studer and Kliewer, 1988). Longer delays in ripening would be expected if mechanical, and especially minimal pruning were adopted in cooler regions.

Both mechanical and minimal pruning offer the advantages of mechanisation and lower costs while maintaining or improving yield (Morris and Cawthon, 1981; Reynolds, 1988). As demonstrated in this study, these regimes can be used to minimise Eutypa dieback while maintaining yield and fruit quality. However, less dieback after mechanical and minimal pruning was primarily due to pruning timing in the growing season, when the vines were no longer dormant, rather than mechanical pruning *per se*. If vines were mechanically pruned at the same time as they were hand-pruned (when vines were dormant), more disease may have been expected due to the greater total surface area of pruning sites. Training-pruning regimes that require early pruning and generate large numbers of wounds when vines are dormant should be avoided where *E. lata* is a concern.

We thank Dr. Keith Striegler for establishing the experiment; the Lodi-Woodbridge Winegrape Commission, American Vineyard Foundation and California State University – Agricultural Research Initiative for financial support; Vino Farms, Inc. for vineyard management and data collection; and staff and students at the Viticulture and Enology Research Center for administrative and technical assistance. We also thank Drs. Robert Wample, Sanjun Gu, Mark Greenspan and Clifford Ohmart for reviewing the manuscript.

REFERENCES

CATER, M. V. (1988). Eutypa Dieback. In: *Compendium of Grape Diseases*. (Pearson, R. C. and Goheen, A. C., Eds.). The American Phytopathological Society Press, MN, USA. 32–4.

CHAPUIS, L., RICHARD, L. and DUBOS, B. (1998). Variation in susceptibility of grapevine pruning wound to infection by *Eutypa lata* in south-western France. *Plant Pathology*, **47,** 463–72.

DUTHIE, J. A., MUNKVOLD, G. P., MAROIS, J. J., GRANT, R. S. and CHELLEMI, D. O. (1991). Relationship between vineyard age and incidence of Eutypa dieback. (Abstract). *Phytopathology*, **81,** 1183.

GUBLER, W. D. and LEAVITT, G. M. (1992). Eutypa dieback of grapevine. In: *Grape Pest Management*. 2nd Edition. (Flaherty, D. L., Jensen, F. L., Kasimatis, A. N., Kido, H. and Moller, W.J., Eds.). University of California, Oakland, CA, USA. 71–5.

LAKE, C. B., STRIEGLER, R. K., VERDEGAAL, P. S., BERG, G. T. and WOLPERT, J. A. (1996). Influence of training system on growth, yield, fruit composition and *Eutypa* incidence of 'Cabernet Sauvignon' grapevines. *Proceedings of the 4th International Symposium on Cool Climate Viticulture and Enology*. Rochester, New York, USA. III-19-26.

LAKE, C. B., STRIEGLER, R. K., VERDEGAAL, P. S., BERG, G. T., WOLPERT, J. A. and INGELS, C. A. (1998). Cabernet Sauvignon grapevines. How training system and soil type influence yield and quality. *American Vineyard*, (July), 27–31.

MCCARTHY, M. G. and CIRAMI, R. M. (1990). Minimal pruning effects on the performance of selections of four *Vitis vinifera* cultivars. *Vitis*, **29,** 85–96.

MOLLER, W. J. and KASIMATIS, A. N. (1978). Dieback of grapevines caused by *Eutypa armeniacae*. *Plant Disease Reporter*, **62,** 254–8.

MOLLER, W. J. and KASIMATIS, A. N. (1980). Protection of grapevine pruning wounds from Eutypa dieback. *Plant Disease*, **64,** 278–80.

MOLLER, W. J. and KASIMATIS, A. N. (1981). Eutypa dieback of grapevines. In: *Grape Pest Management*. (Flaherty, D. L., Jensen, F. L., Kasimatis, A. N., Kido, H. and Moller, W. J., Eds.). University of California, Berkeley, CA, USA. 57–61.

MOLLER, W. J., KASIMATIS, A. J. and KISSLER, J. J. (1974). A dying arm disease of grape in California. *Plant Disease Reporter*, **58,** 869–71.

MORRIS, J. R. and CAWTHON, D. L. (1981). Yield and quality response of Concord grapes to mechanized vine pruning. *American Journal of Enology and Viticulture*, **32,** 280–2.

MUNKVOLD, G. P. and MAROIS, J. J. (1995). Factors associated with variation in susceptibility of grapevine pruning wounds to infection by *Eutypa lata*. *Phytopathology*, **85,** 249–56.

MUNKVOLD, G. P., DUTHIE, J. A. and MAROIS, J. J. (1994). Reductions in yield and vegetative growth of grapevines due to Eutypa dieback. *Phytopathology*, **84,** 186–92.

Ohlendorf, B., Flint, M. L. and Bush, M. (1996). *UC IPM Pest Management Guidelines: Grape*. Publication 3339. DANR Publications, University of California, Oakland, CA, USA.

Petzoldt, C. H., Moller, W .J. and Sall, M. A. (1981). Eutypa dieback of grapevines: seasonal differences in infection and duration of susceptibility of pruning wounds. *Phytopathology*, **71,** 540–3.

Petzoldt, C. H., Sall, M. A. and Moller, W. (1983a). Eutypa dieback of grapevines: ascospore dispersal in California. *American Journal of Enology and Viticulture*, **34,** 265–70.

Petzoldt, C. H., Sall, M. A. and Moller, W. (1983b). Factors determining the relative number of ascospores releases by *Eutypa armeniacae* in California. *Plant Disease*, **67,** 857–60.

Ramos, D. E., Moller, W. J. and English, H. (1975). Production and dispersal of ascospores of *Eutypa armeniacae* in California. *Phytopathology*, **65,** 1364–71.

Reynolds, A. G. (1988). Response of Okanagan Riesling vines to training system and simulated mechanical pruning. *American Journal of Enology and Viticulture*, **39,** 205–11.

Roby, G. and Matthews, M. A. (2004). Relative proportions of seeds, skin and flesh, in ripe berries from Cabernet Sauvignon grapevines grown in a vineyard either well irrigated or under water deficit. *Australian Journal of Grape and Wine Research*, **10,** 74–82.

Roby, G., Harbertson, J. F., Adams, D. A. and Matthews, M. A. (2004). Berry size and vine water deficits as factors in winegrape composition: anthocyanins and tannins. *Australian Journal of Grape and Wine Research*, **10,** 100–7.

Studer, H. and Kliewer, M. (1988). Mechanical vine pruning in California. *Proceedings of the Second International Seminar on Mechanical Pruning of Vineyards*. Villanova di Motta di Livenza (Treviso), Association Italiana di Genio Rurale (AIGR), Italy. 24–30.

Trese, A. T., Burton, C. L. and Ramsdell, D. C. (1980). *Eutypa armeniacae* in Michigan vineyards: ascospore production and survival, host infection, and fungal growth at low temperature. *Phytopathology*, **70,** 788–93.