Pickering, A.H., Warrington, I.J., and Woolley, D.J. Root Pruning of Cabernet Sauvignon (*Vitis vinifera* L.) Decreases Bunch stem Necrosis. Limiting factors for primary production, June, 2005, Lincoln, New Zealand. (Conference Presentation)

Root Pruning of Cabernet Sauvignon (*Vitis vinifera* L.) Decreases Bunchstem Necrosis.

Pickering, A.H., Warrington, I.J. & Woolley, D.J.

Institute of Natural Resources, Massey University, P.O.Box 11 222, Palmerston North, New Zealand

ABSTRACT

Bunch stem necrosis (BSN) is a physiological disorder in grapes, which results in unripe shrivelled berries with poor quality attributes at harvest. Vines on the high vigour rootstock, SO4, have demonstrated high incidence of BSN. Root pruning is known to reduce vigour and influence fruit quality across many species, including grapes. Field grown Cabernet Sauvignon grape vines, at 2.0 m within-row spacing, and 2.4 m between-row spacing were root pruned approximately 25 cm from the trunk on either side to a depth of 45-60 cm before bud break in either Season One or Season Three. Other Cabernet Sauvignon vines in the same vineyard, which were at 0.8 m within-row spacing, were also pruned in either Season One or Season Two. Point quadrant measures were carried out on vines to determine the characteristics of the vine canopy throughout the season. Bunches were scored to determine the onset and completion of veraison and to record BSN development. On vines at the 2 m spacing that were root pruned in Season One, wine quality aspects including Brix, acid concentrations and cation concentrations were measured at harvest along with berry size and number. Root pruning reduced canopy size at both vine spacings and this effect persisted for the three years of the study at the wider spacing. BSN incidence was reduced by root pruning. A strong positive relationship between vigour and BSN incidence was determined in the first growing season. BSN incidence was still reduced in the second and third seasons even on vines that were root pruned only in Season One. The degree to which BSN was reduced in first season root pruned vines declined as the seasons progressed. These results provide evidence that root pruning is one management practice that is available to manage this disorder.

INTRODUCTION

Bunch stem necrosis (BSN) is a complex physiological problem in grapes. It results in shrivelled unripe berries, which are detrimental to wine quality, and it reduces yield (Ureta, Boidron *et al.* 1981). Berries lack sugar and flavour, titratable acidity (TA) is higher due to an increase in tartaric acid, calcium (Ca) concentrations are higher and potassium (K) concentrations lower in affected berries (Ureta, Boidron *et al.* 1981; Morrison and Iodi 1990). Symptoms occur at any time after the onset of berry ripening (veraison) and include the appearance of dark necrotic spots on the pedicel, rachis or peduncle which can then spread and girdle the affected area. Berry appearance becomes dull and opaque, and berries are soft in texture (Ureta, Boidron et al. 1981; Morrison and Iodi 1990). Certain varieties are more susceptible than others and the severity of incidence differs from year to year (Jahnl 1983).

Results from research into this problem tend to be contradictory and therefore no one conclusive explanation for the disorder has been found. Capps and Wolf (2000) found that the application of nitrogen fertiliser reduced the incidence of BSN but other researchers has found the exact opposite response (Christensen and Boggero 1985; Brechbuhler and Meyer 1988). A magnesium (Mg) deficiency has been related to BSN incidence (Fregoni and Scienza 1976; Haub 1986) yet Nahdi et al. (1993) determined that BSN was caused by an imbalance in the K/Mg ratio, and not solely by a Mg deficiency alone. This ratio has been found to be effective only in certain locations (Boselli, Libe et al. 1987). In contrast, Kadam et al. (1995) found that BSN incidence was correlated with Ca deficiency and some studies have found that Ca application does reduce BSN (Hartmair 1977) while others have not (Rizzotto 1977). Environmental conditions such as temperature around flowering and precipitation during veraison have also been correlated with BSN incidence (Nicolli, Egger et al. 1977; Boselli, Libe et al. 1986; Holzapfel and Coombe 1995; Baldacchino-Reynaud 2000) but many of the correlations with environmental conditions differ from study to study.

Vine vigour has also been suggested to influence BSN incidence. Treatments which increase the vigour of individual shoots or which increase vine canopy area have been found to increase BSN incidence (Theiler 1975; Theiler 1976; Theiler 1979; Redl 1984).

Root pruning is well known to reduce the vigour of the crop when it is applied (Geisler and Ferree 1984; Ferree 1990; Schupp, Ferree et al. 1992; Arzani, Wood et al. 1999) including grapes (Saayman and Huyssteen 1983; McArtney and Ferree 1999). It also has other advantageous effects such as earlier maturity (Schupp 1991), increased sugar concentration (Ferree 1992) and smaller fruit (Ferree 1992) which is beneficial in some crops. The objectives of this study were to investigate the possible positive relationship between vine vigour and BSN incidence and to determine if root pruning was a possible management tool for controlling this disorder.

MATERIALS AND METHODS

Plant material

Seven-year-old field grown Cabernet Sauvignon grape vines on SO4 root stock where used for this study. Vines were situated on a Montana vineyard at Moteo, Taradale, New Zealand. The vineyard was situated on a sandy loam soil called Poporangi.

Spacing between vines was at 2.0 m or 0.8 m within-rows, and 2.4 m between-rows. Vines were caned pruned in winter months. There was no permanent irrigation system but in dry years a travelling irrigator could be used. Common commercial practices were carried out to maintain the vines. Application of foliar fertiliser throughout the growing season which was undertaken on the rest of the vineyard was not applied to the vines used in the project.

Treatments

In the winter months prior to bud break of Season One, 2 m spaced vines were root pruned approximately 25 cm from the trunk on either side to a depth of 60 cm. A spinning wood saw blade mounted on the back of a tractor was used to cut through the soil and roots. In the winter months prior to Season Three a second group of 2 m spaced vines were root pruned 25 cm from the trunk on either side to a depth of 45 cm. In this season, a rigid blade mounted on the back of the tractor was used to tear through the soil and roots. A third group of Cabernet Sauvignon vines in the same vineyard, which were at 0.8 m within-row spacing were also pruned in either Season One or Season Two using the system used for Season One.

All three groups of vines were blocked due to a variation in soil fertility. The experimental design consisted of eight blocks. Each root pruned group also had a set of vines which were not root pruned to act as a control. Therefore there were two groups of control vines at 2 m spacing and one group of control vines at 0.8 m spacing. The overall design was a randomised block.

Measures

Vine vigour was determined using the point quadrant method as detailed by Smart and Robinson (1991). Vine canopy area was determined by counting leaf and gap numbers at 57 points within a sample area of 2 m by 2 m for 2 m spaced vines. For 0.8 m spaced vines two adjoining vines per replicate where measured with a canopy surface area of 1.6 m by 2 m. Survey points were spread evenly at 10 cm intervals horizontally and vertically at 1 m, 1.5 m and 2 m intervals above the soil surface.

Leaf layer number (LLN), percentage gaps (PG) and percent interior leaves (PI) where determined as per Smart and Robinson (1991).

Point quadrant measures began close to flowering and were repeated four times approx. one month apart in Seasons One and Two for 2 m spaced vines. In Season Three only two measures were taken - the first close to flowering and the second approximately six weeks later when it was estimated that maximum measurable vigour had occurred as indicated by Season One and Two measures. For 0.8 m spaced vines, vines were measured only in Seasons Two and Three.

Bunches were scored to determine the onset and completion of veraison and to record BSN development. Both scores were carried out non-destructively by visually estimating the progress of either veraison through the colouring of the berries, or BSN through the number of berries that were shrivelled. For 0.8 m spaced vines only BSN scores were carried out.

On vines at the 2 m spacing that were root pruned in Season One, wine quality aspects including Brix, acid concentrations and cation concentrations were measured at harvest.

Wine quality aspects were determined through juice analyses at harvest. Approximately 300 berries were included in each sample. In Season One there was no replication, in Season Two and Three, four replicates per treatment were harvested.

RESULTS

Vine spacing of two meters.

Root pruning in Season One dramatically reduced the vigour of the vines in all three seasons compared to the control (Figure 1). There was a lower percentage of interior leaves, a higher percentage of gaps and a lower leaf layer number for root pruned vines for all seasons. Vines root pruned in Season Three began the season less vigorously than the vines root pruned in Season One. However, by the last measure Season Three root pruned vines had caught up to Season One root pruned vines for all three measures (Figure 1). This difference in vigour between the two root pruned groups may have been due to the different root pruning depths and/or the different techniques which were used to carry out the root pruning. In Season Three, the two groups of control vines were not significantly different to each other.

Season Two was a more vigorous season overall when compared to the other two seasons. Final vigour measures where higher than in the other two seasons (Figure 1) and trimming was carried out weekly from one week after flowering. In contrast, in Season One it commenced three weeks after full bloom and was carried out two weekly during the remainder of the season (data not shown). In Season Three, vines began much more vigorously than the other two seasons (Figure 1). The first trim was carried out two weeks before flowering in this season, but was not repeated until three weeks after full bloom and then continued at two weekly intervals (data not shown). This is probably due to the amount of rain experienced early in the season. This demonstrates that while early season vigour was much higher in Season Three, the growth of the vines had reduced by the time of flowering and then continued at a less vigorous rate than had occurred in Season Two.

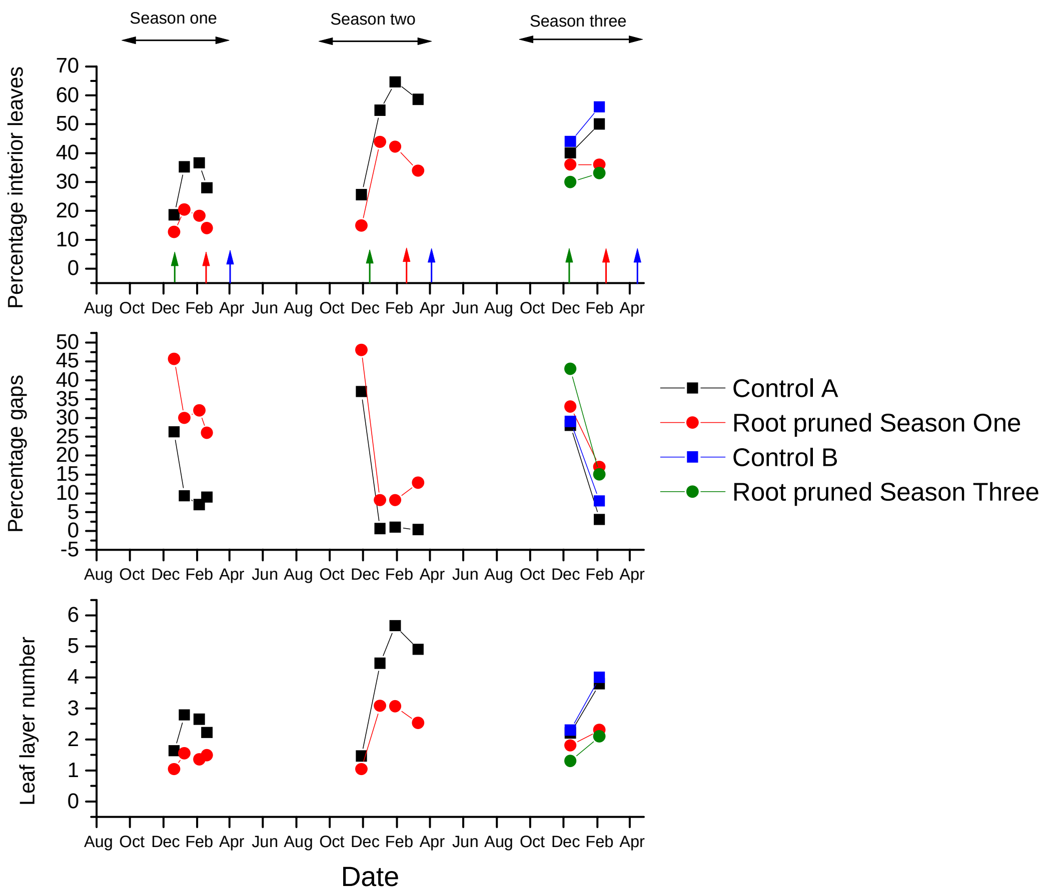

Figure 1: Point quadrant analyses of 2 m spaced vines. Percentage interior leaves, percentage gaps and leaf layer number. Black arrows indicate seasons, green arrows indicate flowering, red arrows indicate 50% veraison, blue arrows indicate harvest.

There was little difference in veraison development between the control and root pruned vines in Season One (Figure 2). However, in Season Two, vines which were root pruned appeared to progress through veraison quicker than the control vines, even though the onset of veraison was similar between treatments. By Season

Three this difference had been reduced, but vines root pruned in Season One were still slightly more advanced in veraison development than the other treatments. There was no difference in the time of 50% veraison between the control group for Season One, the control group for Season Three and vines root pruned in Season Three. However, Season Three control vines and vines root pruned in Season Three did appear to have a slower early stage of veraison development (Figure 2).

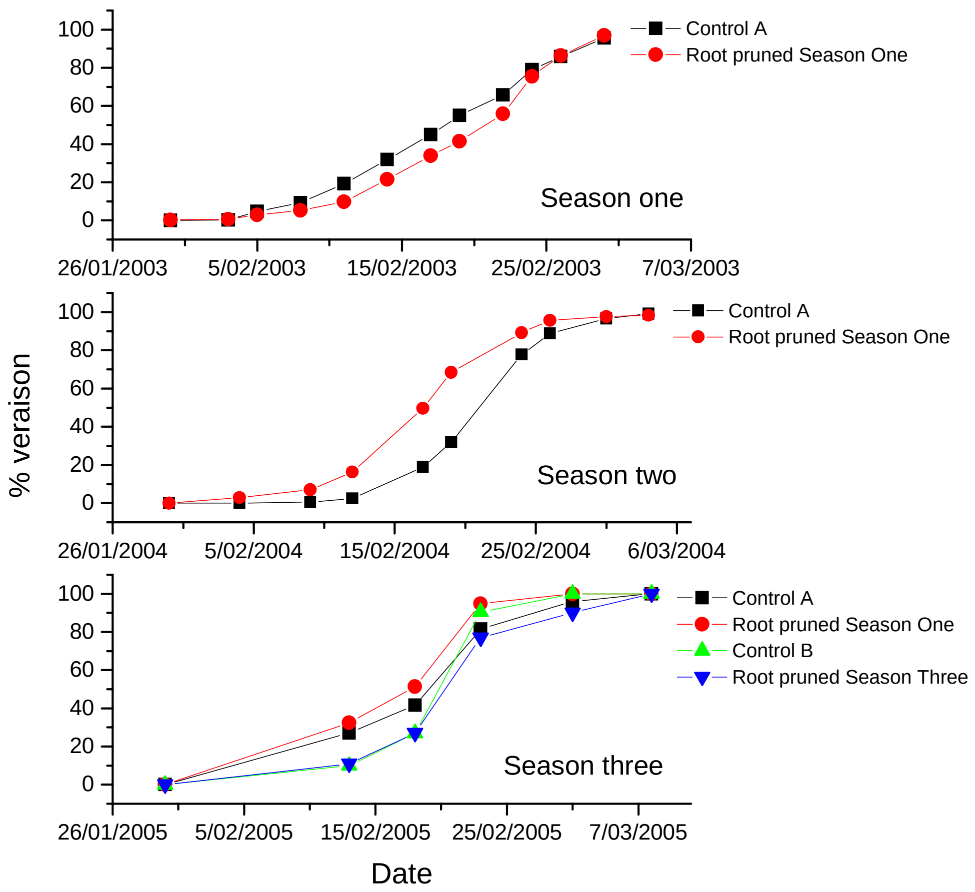

Figure 2: Veraison development for Season One, Two and Three for 2 m spaced vines.

Although in Seasons One and Three there appeared to be little difference in veraison development, by harvest in Season One, the root pruning treatment had more mature berries compared to the control - Brix concentrations tended to be higher and TA concentrations lower resulting in a higher maturity ratio for the root pruned treatment (Table 1). This was also evident in Season Two where the root pruning treatment tended to progress through veraison quicker. These results agree with those found by Stone (2000). However, Stone also concluded that, although the controls were still behind the root pruned vines in berry maturity, they had begun to catch up nearer to harvest.

Cation concentrations were also higher in root pruned vines than the control vines except for ammonium concentrations where they were lower (Table 1). Though various studies have determined differing results in nutrient uptake by root pruned plants, and Ferree et al. (2000) found no improvement in grape juice quality from root pruning, several studies have found an increase in nutrient uptake by root pruned plants (eg., Geisler and Ferree 1984).

Table 1: Juice analyses for Seasons One, Two and Three for Season One root pruned vines and the control at 2 m spacing.

	Season One		Season Two		Season Three	
	Control	**Root prune**	**Control**	**Root prune**	**Control**	**Root prune**
Brix (°)	19.7	20.2	19.3	20.1	20.2	20.5
TA (g/l)	7.8	6.4	10.8	10.2	9.3	8.0
Maturity ratio	2.5	3.2	1.8	3.0	2.2	2.5
pH	3.25	3.38	3.2	3.2	3.34	3.43
Malic (ppm)	2.71	2.04	6.1	5.4	3.04	2.21
Tartaric (ppm)	6.11	5.90	6.7	6.5	7.88	6.35
Potassium (ppm)	1489	1683	1754	1785		
Magnesium (ppm)	48	52	56	59		
Calcium (ppm)	31	35	28	35		
Ammonium (ppm)	98	74	211	181		

Root pruning significantly reduced the incidence of BSN compared to the control. This reduction continued for the two seasons after root pruning although the incidence of BSN began to increase for each additional year after root pruning (Figure 3). Root pruning reduced BSN incidence by 80% in Season One, 35% in Season Two and 45% in Season Three. Vines root pruned in Season Three did not demonstrate as much of a reduction in BSN incidence in the first season after root pruning as the Season One root pruned vines did in their first season. This may have been due to the different environmental conditions experienced up to veraison between Seasons One and Three as discussed previously. Season Three root pruned vines reduced BSN incidence by 60%.

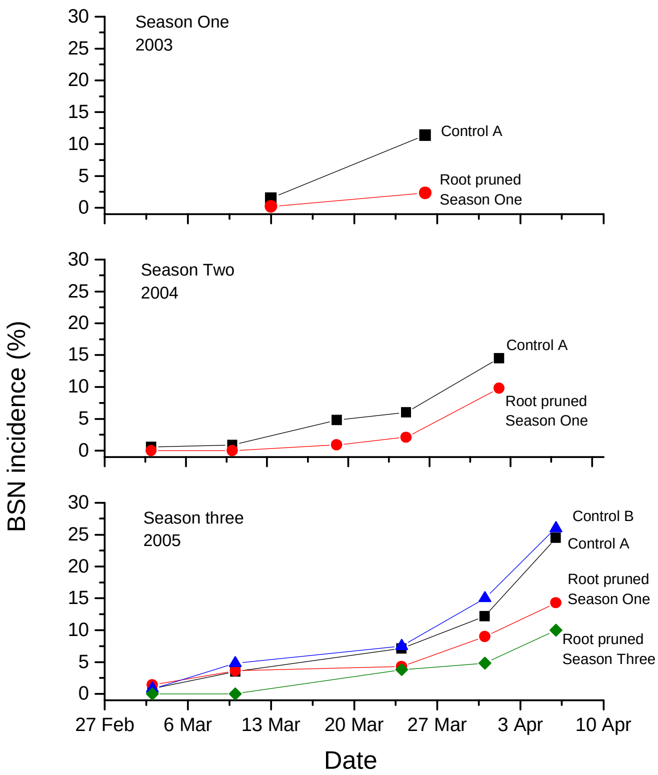

Figure 3: BSN incidence for Seasons One, Two and Three for 2 m spaced vines.

Values were adjusted so that they could be compared at 40 days after 50% veraison and at a maturity ratio of 1.8 in order to compare results amongst years (Figure 4). Raw data suggests that Season Three was the worst season of the three. However, this is only due to BSN measures being carried out for a longer period following veraison. When results were veraison adjusted, the controls indicate that all three seasons were similar in the incidence of the disorder. However, when adjusted for maturity, which is the basis in which the crop is harvested, Season Two clearly had the highest incidence of all seasons for the control vines and the incidence in both Seasons One and Three was similar (Figure 4). In Season Three, the second group of control vines had a similar incidence to the first group of control vines which indicates that there was little difference between the groups.

Both the raw data and veraison adjusted data indicate that absolute BSN incidence was increasing each year after root pruning for the Season One root pruned vines (Figure 4). When adjusted for veraison, root pruning reduced BSN incidence by 75% in Season One, 60% in Season Two and 45% in Season Three. The maturity adjusted data indicates that Season Three had, in fact, the same absolute incidence as Season Two. However, when adjusted for maturity, root pruning reduced BSN incidence from the control by 90% in Season One, 75% in Season Two and 65% in Season Three. Clearly there was a marked reduction of BSN where vines had been root pruned.

Maturity adjustment of Season Three root pruned vines was unable to be carried out due to the absence of compositional results from this treatment. However, both the raw data and the veraison adjusted data show that BSN incidence was less than the incidence for Season One root pruned vines. Veraison adjusted data indicate a BSN incidence reduction of 65%. As maturity adjusted data for Season One root pruned vines was always less than either the raw or the veraison adjusted data, it can be assumed that this would also be the case in for the Season Three root pruned vines.

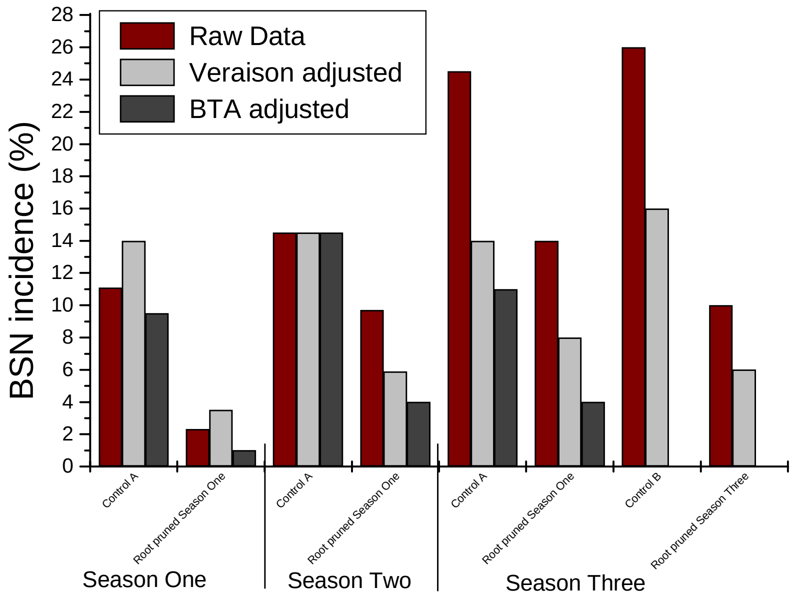

Figure 4: BSN incidence adjusted for 40 days after 50% veraison, and maturity ratio (BTA) of 1.8 for Seasons One , Two and Three for 2 m spaced vines.

There was a strong positive correlation between vigour (LLN) and BSN incidence for all three seasons. This correlation was more significant when using maturity adjusted data (Figure 5).

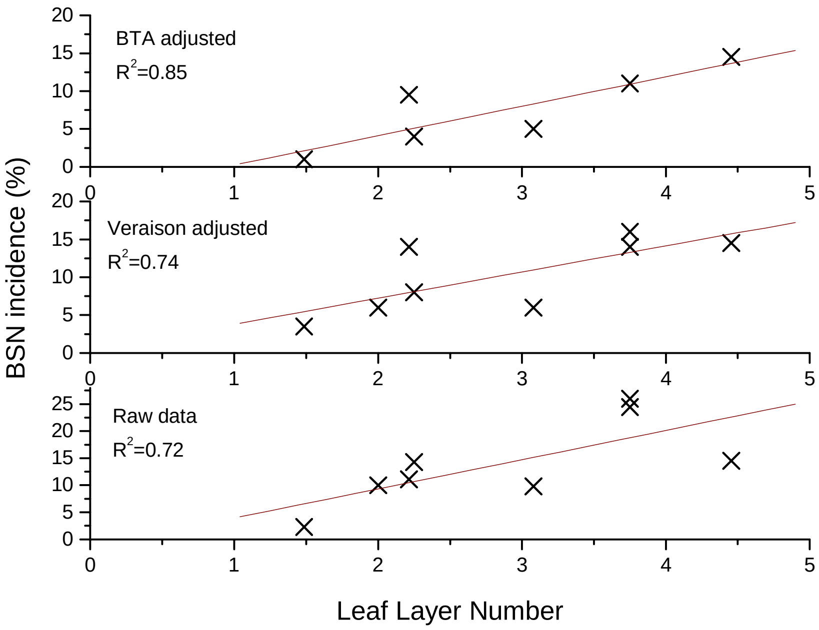

Figure 5: Raw, veraison adjusted and maturity adjusted correlations between BSN and LLN using all three seasons mean data for root pruning Season One, root pruning Season Three and controls at 2 m spacing. Maturity adjusted correlation does not include data for Season Three root pruning.

Vine spacing of 0.8 meters

The vigour of vines at the 0.8 m within-row spacing was also dramatically reduced by root pruning. Point quadrant measures were not taken in the first season for the vines root pruned in that season. However, in the second season, the difference in vigour was still obvious with both the LLN and PI being much lower for vines root pruned in Season One than for those of the control (Figure 6). Vines root pruned in Season Two did have slightly lower LLN and PI values than those of the Season One root pruned vines, but by the third season these differences had disappeared.

PG did not appear to differ greatly amongst treatments for either the second or third season. These measures demonstrate that while all treatment canopies may fill in the allocated area, root pruned canopies are not as dense as that of the control, and therefore more light may be able to penetrate into the canopy (Figure 6).

Vines at the 0.8 m spacing also demonstrated a higher vigour in Season Two compared to Season Three (as in the 2 m spaced vines) (Figure 6).

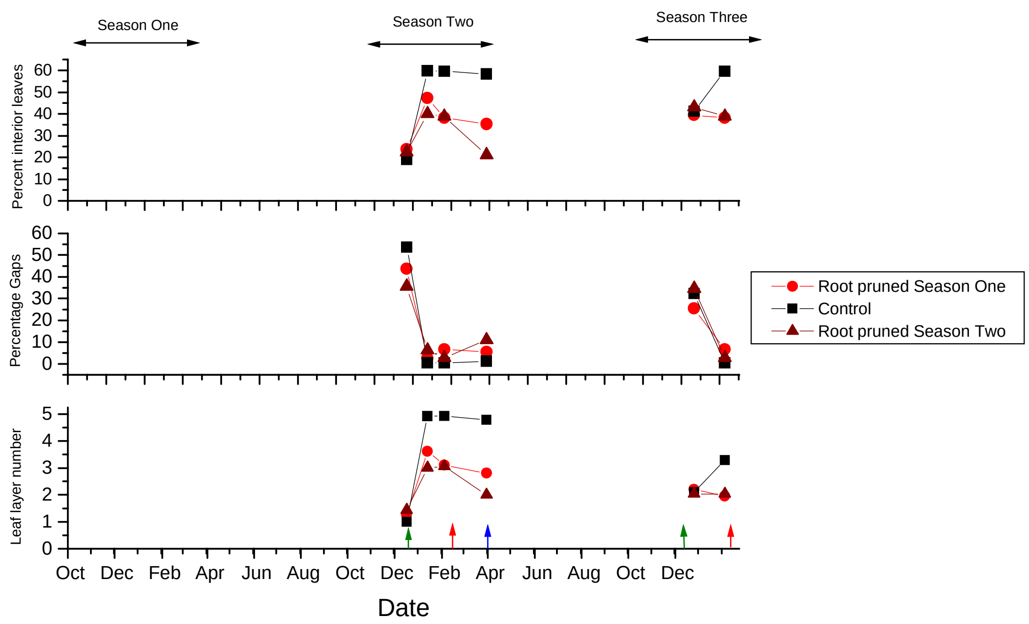

Figure 6: Point quadrant analyses of 0.8 m spaced vines. Percentage interior leaves, percentage gaps and leaf layer number. Black arrows indicate seasons, green arrows indicate flowering, red arrows indicate 50% veraison, blue arrows indicate harvest.

The incidence of BSN was reduced by root pruning in both of the seasons that were scored (Figure 7). In Season Two, vines root pruned in Season One did not have a much higher incidence than vines root pruned in Season Two. The BSN incidence early in this season for vines root pruned in Season One was the same as that for the control, but the subsequent rate of increase in the incidence for control vines was much stepper than that for vines root pruned in Season One (Figure 7).

In Season Three both groups of root pruned vines were similar in their incidence of BSN. Though not significantly different from the control, incidence was still less for root pruned vines (Figure 7).

When comparing BSN incidence between seasons at particular dates, it appears that both seasons were similar for BSN incidence (Figure 7). However, the last BSN scores were carried out just prior to harvest in both seasons, and harvest occurred at similar maturity levels in both seasons. Therefore, when comparing BSN incidence for maturity level, Season Two had a higher incidence of BSN than Season One.

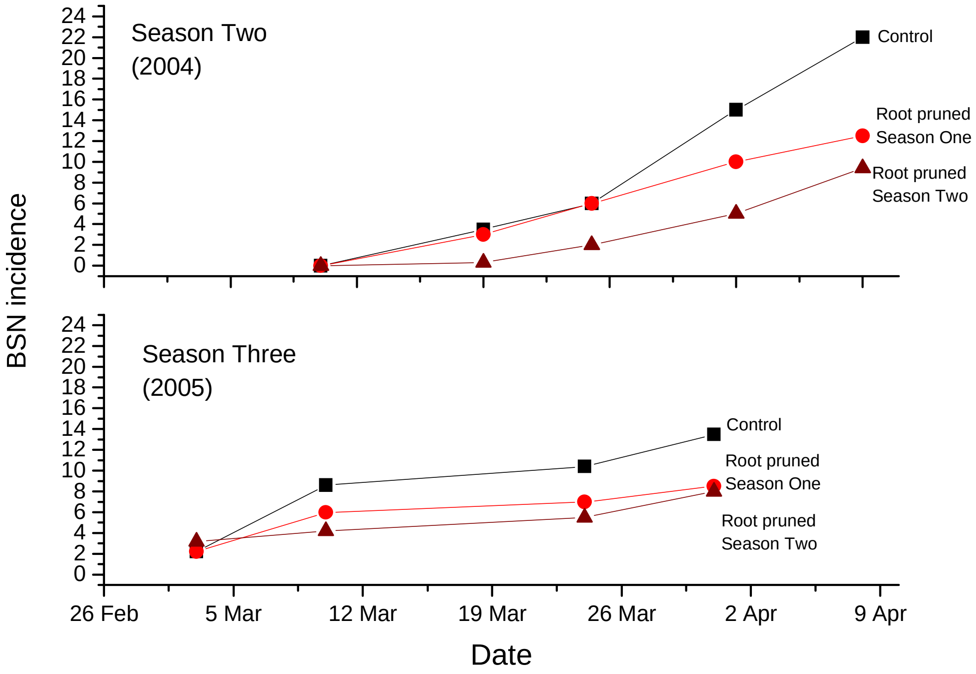

Figure 7; BSN incidence for vines at 0.8 m spacing in Seasons Two and Three.

CONCLUSIONS

Root pruning reduced the vigour of vines compared to the controls for at least three seasons after the root pruning was carried out. This occurred at both the 0.8 m and 2 m spacing. Coincidentally, BSN incidence was considerably reduced in root pruned vines. This effect carried over for at least two seasons after the root pruning had been carried out, and had a similar effect on both 2 m and 0.8 m with-in row vine spacings.

There was a strong positive correlation between LLN and BSN incidence for 2 m spaced vines across all of the three seasons for which measurements were taken.

Not only did root pruning reduce the incidence of BSN, but other quality aspects were also improved and maturity was accelerated. This may be an advantage in some areas of New Zealand where reaching maturity in Cabernet Sauvignon can be a problem.

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