# Influence of the volume of perennial wood and vine cropping levels on pinot noir fruit composition

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## Introduction

The influence of vine age on fruit composition is the subject of much discussion. In general, it is suggested that older vines produce better fruit. However, this has not been tested in a rigorous way and any mechanisms are vague. In some cases, it is suggested that it is simply a marketing ploy invoked by vineyards with old vines!

The objective of this proposal is to test the hypothesis that:

*Old vines have greater storage reserves in the perennial parts of the vine, in particular the trunks. This provides an energy capacity in the vine, which can be drawn upon during periods of carbohydrate shortage*

## Seasonal carbohydrate physiology of grapevines

The perennial nature of grapevines means that carbohydrates are accumulated in storage organs (predominantly the roots and trunk) of vines during the growing season, which become available to the vine for growth at stages of the season when photosynthesis is insufficient to meet current demands. In general this occurs early in the season, when the leaf area has not developed sufficiently and at the end of the growing season when low temperatures or reduced leaf area results in demand by fruit exceeding the ability of leaf area to supply.

Shoot growth at the start of the season depends on the remobilization of reserves from within the vine. These reserves maintain the vine until the leaf area is sufficiently developed to be self-sustaining, generally six to eight weeks from bud break. In this period, a marked decrease in starch and sugar in the perennial parts of the vine is observed (Bennett et al 2005). Inadequate reserves at this time can result in uneven and poor bud break resulting in variation in shoot size later in the season. From veraison to harvest, while the fruit becomes the predominant sink for carbohydrates within the vine, the concentrations of starch and sugars in the trunk and roots will accumulate. Inadequate photosynthesis at this time may lead to slower rates of sugar accumulation by fruit, but probably more importantly a lack of accumulation of colour, flavour and aroma compounds within the fruit. Many of the important flavour compounds are glycosylated, needing a sugar molecule for their synthesis. Increasing the volume of perennial wood may also provide advantages for fruit ripening later in the season if the vines become source limited for CHO. In warm climates, where leaves are retained by vines in the post-harvest period, vines can recharge trunk and root reserves, however, in cool climates, where leaf senescence is often co-incident with harvest, there is little opportunity for this to occur. As a result managing crop levels to allow appropriate storage accumulation is critical.

Alternative methods of increasing the volume of reserves include:

- Vine age. As the trunk increases in volume, its capacity to store carbohydrates and nutrients also increases. These potentially become available when demand exceeds supply from current photosynthesis.
- Training system. In general, cordon pruned vines will have greater capacity than cane pruned vines. Unfortunately in cool climate growing regions low basal bud fertility prevents the adoption of spur pruning techniques in many varieties. Mid-height Sylvos has been used, but there is a cost, as yet not quantified, involved in the transfer of sugars from the leaf area on the cordon to the fruit on the hanging canes.
- Planting density. The perennial wood: fruit ratio is critical. This can be increased by close planting, thus increasing the number of trunks per hectare.

This proposal will investigate novel training systems to increase the volume of perennial wood within the vine, thus giving young vines some of the advantages of old vine in terms of their storage capacity.

## Method

A trial investigating the influence of perennial wood (grapevine reserve system) on the ripening and yield of Pinot noir (clone 777 on 3309 Couderc rootstock) grapevines was established in a cool-climate region of Marlborough (Tyntesfield Vineyard, Waihopai Valley). Vines were planted on 3m wide rows, 1.8m within row spacing and were trickle irrigated. Alternative training systems were designed and imposed on previously 2-cane guyôt trained vines in August 2001 with the aim of changing the proportion of perennial wood in the vine system relative to number of nodes per vine. The four training systems used included two conventional systems (2-cane guyôt and Spur) and two alternative systems that used a bilateral permanent cordon with two canes trained inwards or outwards from the end of the cordons (Table 1). Twenty count nodes were retained in each treatment and the training systems all utilised vertical shoot positioning during the growing season. The impact of crop load was introduced to the trial in 2004 by thinning any apical bunches approximately 2 weeks post flowering.

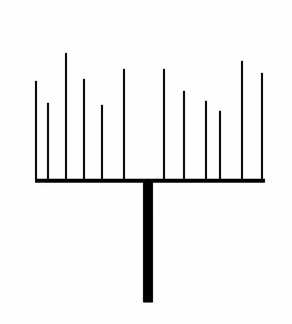
Table 1
Pruning system descriptions

| | Treatment | Training description |
|---|---|---|
| 1 | 2 cane: | Double guyôt: Two head spurs and two canes. |
| 2 | Spur: | Bilateral permanent cordon, 2 node spurs evenly spaced along the cordons. |
| 3 | Trought: Fistonich | Bilateral permanent cordon, two canes trained inwards from spurs at the end of the cordon. |
| 4 | Trought:Gandell : | Bilateral permanent cordon, two canes trained outwards over the adjacent vine from spurs at the end of the cordon. |

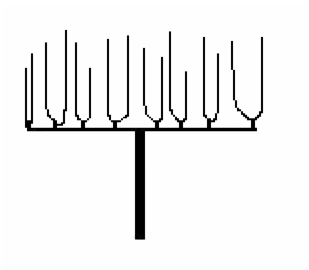
The trial was established on three rows of vines, using a split-plot randomized block design (crop load as the main plot and training system as sub-plots) Six replicates were used per treatment (48 bays in total), each plot consisted of four vines in a single bay, which were evaluated for uniformity at the start of the trial. Bays with missing or non-uniform vines were discarded from the trial.

Figure 1
Training systems

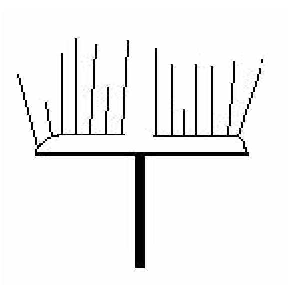
Double guyôt (2-cane guyôt)



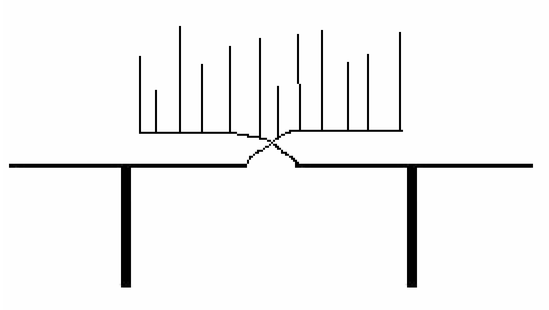
Spur



Trought: Fistonich



Trought:Gandell



Vintages 2002 and 2003 (Trial managed by Mike Trought, while working for Villa Maria)
No thinning treatments were imposed in these years. Resources were not provided in 2002. Ffrosts in October and November 2002 limited fruit yields in 2003.

Vintage 2004
Pre-veraison, a crop thinning treatment was imposed on 10th February 2004, by removing the apical bunch from all shoots on the appropriate plots. Carbohydrate reserves of the double guyôt and Trought:Fistonich training systems were measured. These treatments were chosen as they both used cane pruning, and the second training system had a cordon, capable of increasing the vine reserves. Soluble sugars and starch were measured in the trunk and canes (internodes three), with samples taken in mid-August.

Vintage 2005
As a result of low temperatures and poor fruit set in December 2004, no fruit thinning was undertaken this year.

Vintage 2006
The 2006 season proved to be one of the earliest on record. Thinning was undertaken by removing the apical bunch on all shoots on 17th January 2006.

Results 2002

Spur pruning resulted in slightly higher yield and lower pruning weights when compared to the other treatments (Table 1). Spur pruning resulted in a slightly, non- significant lower soluble solids lower.

Table 2
Influence of pruning on yield and fruit composition: 2002 harvest

| | 2 cane guyôt | Spur | Trought: Fistonich | Trought: Gandell | LSD 5% |
|---|---|---|---|---|---|
| | | | | | |
| Yield (kg/vine) | 1.93 | 2.42 | 1.86 | 1.94 | 0.43 |
| Soluble solids | 23.3 | 23.0 | 23.3 | 23.1 | 0.7 |
| Pruning weight (kg/vine) | 1.81 | 1.54 | 1.67 | 1.69 | 0.13 |
| Yield/pruning wt ratio | 1.07 | 1.61 | 1.11 | 1.56 | 0.30 |

Results 2003

Frosts in October and November 2002 caused some damage to vines, and limited yields. Damage was most severe at the North end of the trial, with an average bunch number per vine of 25.5 compared to 30.3 at the south end. However, slightly heavier bunches in the north bays when compared to south bays (68.4 v 62.7 g respectively) minimized differences in vine yield and there were no effects of frost on fruit composition.

The cordon cane pruning (Trought: Fistonich and Trought: Gandell) systems produced higher yields of fruit of similar composition to other treatments (Table 3). The increase in yield was a reflection of a greater bunch number rather than an effect of treatment on bunch weight (Table 3). Crop load appeared to have no influence on fruit soluble solids either within or between treatments (Figure 2).

Table 3
Influence of pruning on vine yield and fruit composition: 2003 harvest

| | 2 cane guyôt | Spur | Trought: Fistonich | Trought: Gandell | LSD 5% |
|---|---|---|---|---|---|
| | | | | | |
| Yield (kg/vine) | 1.38 | 1.32 | 2.11 | 2.05 | 0.22 |
| Bunch number/vine | 21.5 | 21.3 | 32.7 | 32.1 | 3.1 |
| Bunch weight (g) | 65.8 | 62.2 | 65.1 | 63.7 | ns |
| Soluble solids | 21.4 | 21.0 | 21.4 | 21.4 | ns |
| Titratable acidity (g/L tartaric acid) | 7.89 | 7.75 | 7.81 | 7.06 | ns |
| pH | 3.55 | 3.49 | 3.55 | 3.56 | ns |

## Results 2004

Pruning treatments resulted in significant differences in bunch number per bay pre-thinning (Table 4 ). However, the thinning protocol removed the same percentage from each treatment. At harvest, bunch weight was not significantly affected by either pruning or thinning treatments, although thinning caused a small (1.70 v 1.78 g) but significant (P=0.004) increase in average berry weight. This may have been the result of shriveling of the slightly earlier ripening fruit (22.7 v 22.4 $^{o}$Brix; 3.47 v 3.44 pH) on unthinned and thinned treatments respectively. Titratable acidity was unaffected by thinning or training.

Pruning weight was not significantly affected by pruning or thinning treatments, although double guyôt gave the lowest (2.28) yield to pruning ratio and the cordon:cane treatments the highest (3.22 and 2.77 Trought:Fistonich and Trought:Gandell respectively).

Table 4
Influence of training system and crop load on yield and fruit composition: 2004 harvest

| | 2 cane (double guyôt) | | Spur pruned | | Trought: Fistonich | | Trought: Gandell | | LSD 5% |
|---|---|---|---|---|---|---|---|---|---|
| | thin | unthin | thin | unthin | thin | unthin | thin | unthin | |
| | | | | | | | | | |
| Bunch number per vine pre-thinning | | 38 | | 40 | | 50 | | 46 | 4 |
| Bunches removed at thinning | 16 | - | 17 | - | 22 | - | 19 | - | 3 |
| Percentage removed /vine | 39 | - | 38 | - | 42 | - | 39 | - | 3 |
| | | | | | | | | | |
| Yield (Kg) | 2.91 | 4.10 | 3.34 | 3.90 | 3.83 | 5.73 | 3.38 | 5.12 | 0.52 |
| Bunch wt (g) | 118 | 116 | 120 | 109 | 126 | 122 | 117 | 115 | 11 |
| Berry weight (g) | 1.69 | 1.82 | 1.74 | 1.84 | 1.67 | 1.71 | 1.70 | 1.72 | 0.12 |
| Pruning wt (g/vine) | 1.70 | 1.66 | 1.52 | 1.55 | 1.47 | 1.52 | 1.59 | 1.51 | 175 |
| Fruit composition at harvest (21/04/04) | | | | | | | | | |
| Soluble solids (°Brix) | 23.2 | 22.4 | 21.9 | 22.1 | 22.9 | 22.7 | 22.7 | 22.7 | 0.8 |
| pH | 3.50 | 3.48 | 3.51 | 3.42 | 3.46 | 3.45 | 3.47 | 3.43 | 0.06 |
| Titratable acidity (g/L) | 6.27 | 6.37 | 6.16 | 6.37 | 6.34 | 6.46 | 6.23 | 6.54 | 0.50 |
| Pruning data | | | | | | | | | |
| Pruning weight (g/vine) | 1.70 | 1.66 | 1.52 | 1.55 | 1.47 | 1.52 | 1.59 | 1.51 | 0.17 |
| Yield : pruning weight ratio | 1.75 | 2.52 | 2.20 | 2.57 | 2.67 | 3.77 | 2.13 | 3.40 | 0.48 |

## Over-wintering reserves

The over-wintering carbohydrate reserves of 2-cane guyôt and Trought:Fistonich systems were measured in early August 04. Training and crop load had a significant effect on trunk starch concentrations, with thinned and 2-cane guyôt vines having higher reserves (Table 5). Soluble sugar and total CHO were the same in both systems. Although no differences in the concentration of CHO reserves were evident in vine system (shoots and trunks) between 2-cane guyôt and Trought: Fistonich, its likely there was more CHO reserve potentially available in the Trought: Fistonich vines because of the presence of permanent cordons.

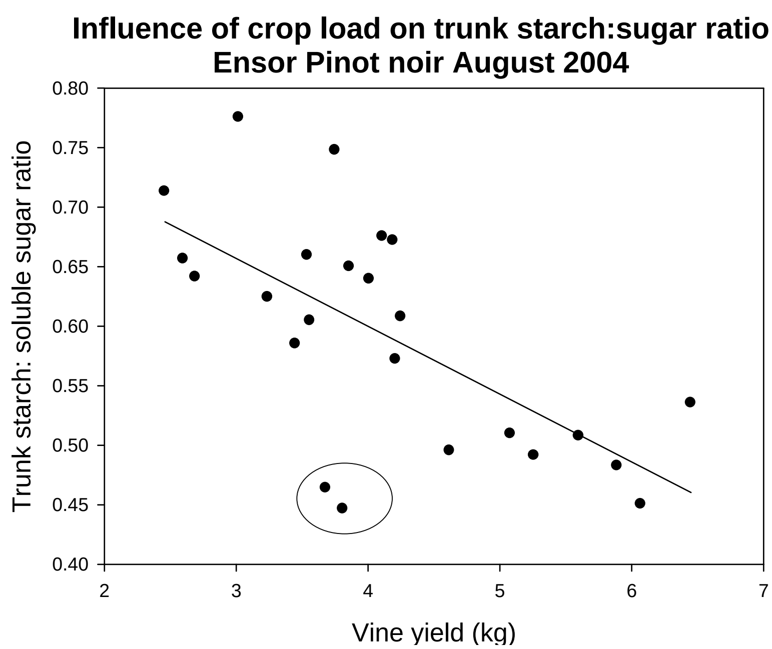
Trunk reserves appear more sensitive to crop load and training than the cane reserves. It is interesting to note that the higher crop load also had a soluble sugar concentration which appeared potentially higher (P= 0.07) than the low crop. Over the whole trial, vines with higher crop loads appear to have lower trunk starch: sugar ratio, which would appear to be the most sensitive means of assessing the carbohydrate stress of vines (Figure 2), although two outliers (circled) are unexplained). Similar increases in soluble sugar:starch ratio were noted in vines subjected to leaf removal (lower leaf : fruit ratio) [Bennett, J. Relationship between carbohydrate supply and reserves and the reproductive growth of grapevines. PhD thesis, Lincoln University 2002]; which in turn was related to the number of flowers per inflorescence. The mechanism and timing of the increase in sugar : starch ratio still has to be determined, but it may be a useful tool in assisting growers with pruning decisions.

Table 5: Influence of training system and crop load on starch and sugar concentrations August 2004

| Treatment | Crop load | Trunk samples | | |
|---|---|---|---|---|
| | | Starch (% Dwt)[1] | Sugar (%Dwt) | Total (%Dwt) |
| 2-cane guyôt | Thinned | 8.18 | 12.32 | 20.48 |
| | Unthinned | 7.32 | 12.70 | 20.02 |
| Trought:Fistonich | Thinned | 7.70 | 12.37 | 20.08 |
| | Unthinned | 6.37 | 12.85 | 19.20 |
| | | | | |
| Main effects | P training | 0.04 | 0.66 | 0.15 |
| | P crop load | 0.004 | 0.07 | 0.11 |
| | | | | |
| | | Cane samples | | |
| | | Starch | Sugar | Total |
| 2-cane guyôt | Thinned | 8.68 | 13.6 | 22.3 |
| | Unthinned | 7.90 | 13.8 | 21.7 |
| Trought:Fistonich | Thinned | 8.73 | 13.7 | 22.5 |
| | Unthinned | 8.45 | 13.7 | 22.1 |
| | | | | |
| Main effects | P training | 0.16 | 0.90 | 0.23 |
| | P crop load | 0.018 | 0.71 | 0.078 |

[1] CHO concentration expressed as percent dry weight

Figure 2



## Results 2004-05

### Yield and pruning results

Vine yields across all training systems were very low. This was the consequence of a very poor fruit set during the unfavourable weather conditions over the flowering/ fruit set period and as a consequence no thinning treatments were imposed. Despite the low yields there were small but significant differences between training systems. Spured vines had more bunches than any other treatment, but did not yield more than either Trought:Fist or Trought:Gand systems (Table 6). Two cane vines had a similar bunch number to Trought:Fist and Trought:Gand systems, but a lower yield. This appeared to be the result of a lighter bunch weight (Table 6). Heavier bunches on the Trought:Fistonich vines, compared with 2-cane guyôt, may be related to the increased amount of perennial wood, and hence the amount of CHO reserves in the vine system.

Table 5 The effect of grapevine training system on fruit and yield components: 2005 harvest

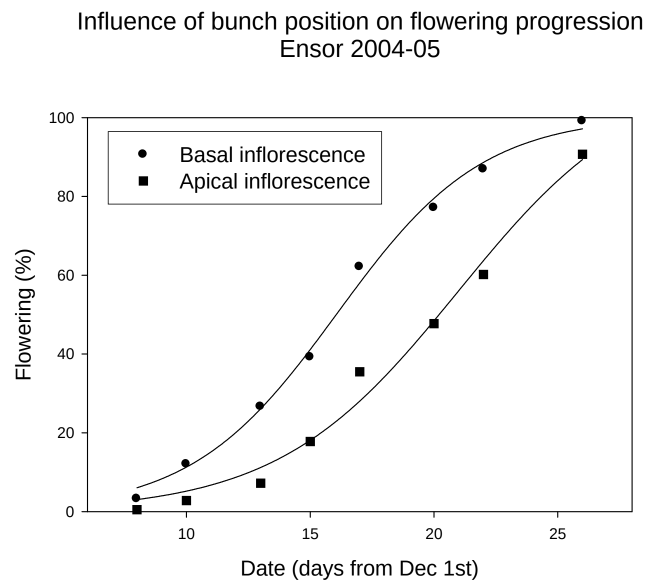
| | 2-cane guyôt | Spur | Trought:Fistonich | Trought:Gandell |
|---|---|---|---|---|
| *Bunch samples (11/4/2005):* | | | | |
| Basal bunch weight (g) | 28.8 | 31.0 | 34.1 | 31.3 |
| Apical bunch weight (g) | 23.8 | 25.6 | 26.7 | 25.7 |
| Mean berry weight | 1.00 | 1.05 | 1.08 | 1.07 |
| Soluble solids ($^o$Brix) | 21.8 | 22.1 | 22.0 | 21.9 |
| Berry sugar content (mg) | 221.0 | 231.9 | 237.2 | 232.9 |
| *Harvest samples (24/4/2005):* | | | | |
| Bunches per vine | 40 a[1] | 47 b | 41 a | 40 a |
| Yield per vine (Kg) | 0.92 a | 1.14 b | 1.08 b | 1.02 ab |
| Mean Bunch weight (g) | 22.6 a | 24.2 ab | 26.5 b | 25.5 b |
| Pruning weights (g/vine) | | | | |
| New wood | 1845 b | 1965 b | 1613 a | 1683 a |
| Old wood | 262 c | 212 b | 181 a | 192 a |

[1] Means within the same row with the same letter are not significantly different at $LSD_{(5\%)}$

### Flowering and fruit development

Flowering duration was extended over ~20 days with basal bunches approximately 5 days ahead of the apical inflorescence. Training system had no influence on flowering progression

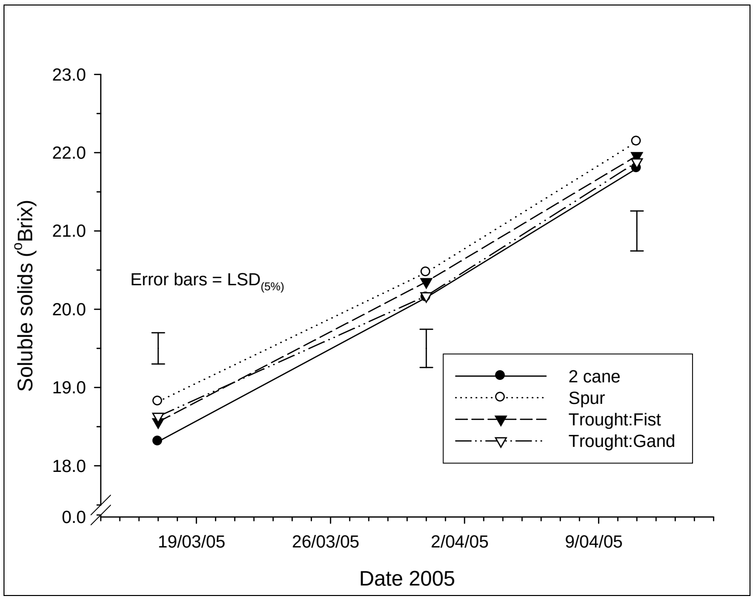
Figure 3



A sub sample of bunches on 11/4/05 found that basal bunches were slightly heaver than apical bunches, 32g vs. 25g respectively. Training systems had no effect on these bunch weights nor mean berry weight or berry sugar content (Table 6).

The effect of training system on berry soluble solids accumulation was minimal in 2005. There were only small significant differences between Spur and 2-cane guyôt on 17/3/05. After that date there was no difference (Figure 4).

Figure 4
Influence of training system of soluble solids accumulation 2005 harvest




*Results 2005-06 season:*

## Yield components

Retaining two node spurs on the spur pruned systems resulted in a higher count node number and overall increased number of shoots per vine when compared to double guyôt pruned vines. The cordon-caned vines had similar node number to cane pruned, but higher shoot number (largely a reflection of non-count shoots arising from non-count positions on the vine). Spur pruning was most efficient in bud burst from retained count nodes, while the two alternative systems produced more non-count shoots and hence a high vine per cent bud break (Table 6). Pre- and post-thinning bunch number shoot was lower on spur pruned vines, probably reflecting the selection of less fruitful basal buds. As a consequence both training system and crop load had significant impact on yields and fruit composition (Table 7). At harvest Spur-pruned and cordon-cane pruned vines had higher overall yield, reflecting greater bunches/vine. Bunch and berry weights were unaffected by training system or thinning.

## Fruit composition

Flowering duration was ~15 days, with no significant differences between training systems and only 1 day between the basal and apical inflorescences (Figure 5). Despite the lower crop load on the 2-cane guyôt pruned vines, fruit maturity (Brix, PH and TA) were unaffected by training system. In contrast thinning vines in January had a significant, albeit small, effects on berry maturation and ripeness at harvest (Table 7). Removing apical bunches may advance ripeness in two ways:

- By removing the less ripe apical bunches, the overall mean ripeness will be advanced.

- By reducing crop load on individual shoots, the ripeness of the basal bunch may be advanced. Comparing the development of basal bunches alone suggests that removal of the apical bunch advanced veraison by approximately a day (Figure 6).

The effects of training system and crop load on other juice composition parameters such as organic acids and skin colour pigments (anthocyanin concentrations) will be investigated in the future.

Shoots, Pruning and vine Balance

Two-cane vines were more vigorous vegetatively than the other systems with higher mean cane weights, this was also indicated by a lower yield to pruning weight ratio. Crop thinning had little influence on vegetative growth, but did reduce the yield to pruning ratio (Table 7).

Table 7 The main effect of grapevine training system and thinning on Pinot noir (777) yield components, fruit composition and vine balance: 2006 harvest.

| Training system | 2-cane guyôt | Spur | Trought - Fistonich | Trought - Gandell | Crop load | |
|---|---|---|---|---|---|---|
| Perennial wood volume | Low | High | High | High | Thin | No thin |
| *Yield components:* | | | | | | |
| Bunches/vine pre-thin | 40 b | 48 a | 48 a | 51 a | 48 a | 45 b |
| Bunches/vine harvest | 29 b[1] | 35 ab | 35 ab | 37 a | 28 b | 40 a |
| Yield/vine (kg) | 3.3 b | 4.0 a | 3.9 a | 4.0 a | 3.2 b | 4.5 a |
| Mean bunch weight (g) | 115.2 | 116.2 | 113.8 | 109.3 | 114.4 | 112.9 |
| Mean berry weight (g) | 1.50 | 1.52 | 1.49 | 1.53 | 1.51 | 1.51 |
| *Harvest fruit composition:* | | | | | | |
| Brix | 23.9 | 23.7 | 23.7 | 23.8 | 24.0 a | 23.5 b |
| Juice pH | 3.30 | 3.30 | 3.29 | 3.29 | 3.32 a | 3.28 b |
| Titratable acidity (g/L) | 8.3 | 8.1 | 8.4 | 8.3 | 8.2 | 8.4 |
| *Pruning and vine balance:* | | | | | | |
| Count nodes/vine | 21 c | 30 a | 23 bc | 24 b | 25 | 24 |
| Shoots/vine | 25 c | 33 a | 30 b | 31 b | 30 | 30 |
| % non-count shoots | 22.5 b | 15.1 c | 33.8 a | 33.4 a | 27.9 | 24.5 |
| % Count node Bud break | 90.3 b | 94.0 a | 86.5 c | 88.3 bc | 89.7 | 89.9 |
| % Overall Vine Bud break | 116.6 b | 115.5 b | 131.2 a | 133.1 a | 128.2 | 120.0 |
| Bunches/shoot pre-thin | 1.6 a | 1.4 b | 1.6 a | 1.6 a | 1.6 a | 1.5 b |
| Bunches/shoot harvest | 1.4 a | 1.2 c | 1.3 b | 1.4 a | 0.9 b | 1.3 a |
| Old cane wt/vine (g) | 280 a | - | 210 b | 220 b | 240 | 230 |
| Cane weight/vine (kg) | 1.6 b | 1.8 a | 1.5 b | 1.6 b | 1.7 | 1.6 |
| Mean cane weight (g) | 63.6 a | 54.5 b | 49.3 b | 52.9 b | 56.4 | 53.7 |
| Yield prune ratio | 2.2 b | 2.3 b | 2.7 a | 2.5 ab | 2.0 b | 2.9 a |

[1] Means within the same row for either training system or crop load with the same letter are not significantly different at $LSD_{(5\%)}$

Figure 5

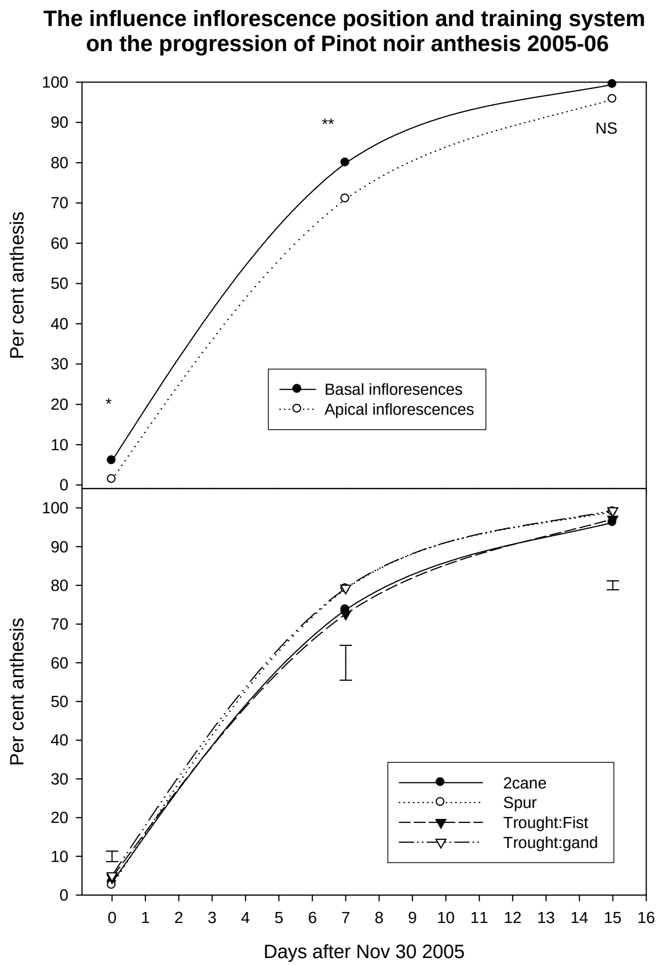
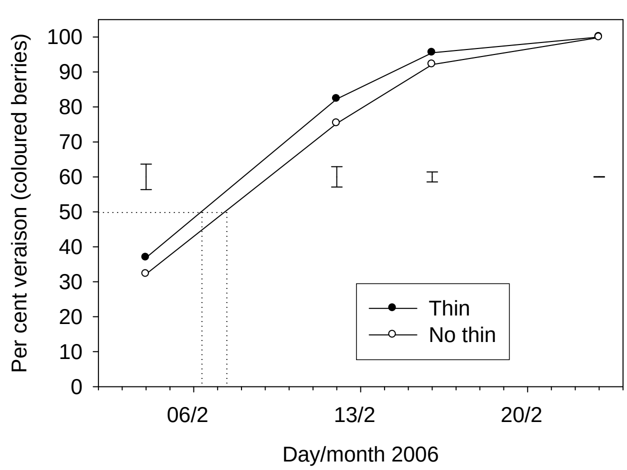



Figure 6:
The effect of crop load (thinning) on veraison progression in Pinot noir fruit.




Error bars = $LSD_{(5\%)}$.

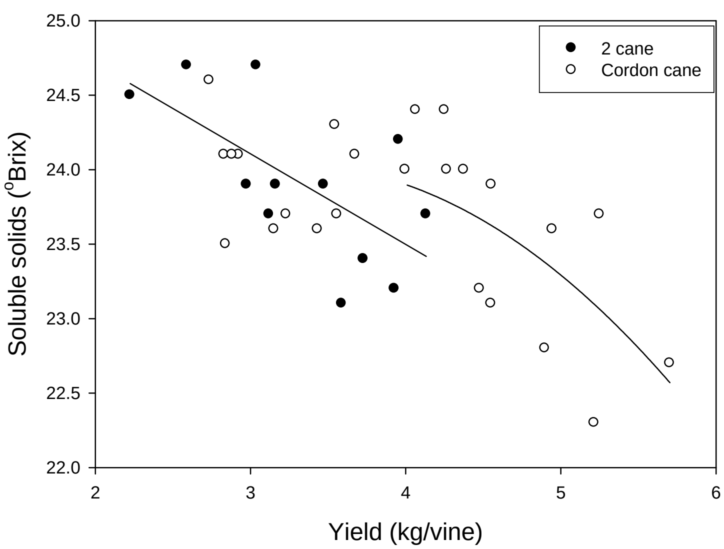
Summary
Spur pruning produced less fruitful shoots than the cordon-cane pruning treatments, however this was offset by the retention or more nodes per vine and hence shoots resulting in bunch numbers and yields similar to the two alternative cordon-cane- systems. The latter two systems yielded more than the 2-cane guyôt system, but this was a consequence of more nodes and shoots per vine rather than any inherent effect of increased perennial wood volume (cordon). Likewise, extra perennial wood did convey any advantage to fruit ripeness in terms of Brix. However, it has to be appreciated that the 2005-06 season was early and warm and hence there was little impediment to fruit maturation. Under a cool season regime the extra perennial wood may be advantageous to fruit maturation. Crop thinning, which was estimated to remove approximately 40% of the bunches per vine (less by weight because they were smaller apical bunches) could only bring forward 50% veraison by one day and improve fruit ripeness by 0.5 Brix at harvest.

## Conclusion

Koblet et al (1994) suggested that small increases (10%) in perennial wood volume could have a marked influence on fruit yields and quality, allowing stored reserves to be remobilized in the spring to improve shoot development and/or as fruit matured to ripen berries. The additional reserves are likely to have a greater beneficial effect when vines are under some degree of stress. Data from this trial suggests that following the spring frosts in 2003, the cordon-cane pruned treatments had greater yield capacity. Likewise in 2006, the fruit soluble solids of vines cropping up to 4 kg / vine, were little affected by the additional perennial wood volume, although at higher crop levels data suggests that higher brix might be expected on the cordon-cane pruning systems (Figure 7).

**Figure 7**

**Influence of yield and pruning on soluble solids at harvest: Ensor 2006**




Trunk starch to sugar ratio appears to provide the most sensitive method of assessing potential reserves in the vine and the carbohydrate stress that was experienced by the vine in the previous season. Further research investigating the extent to which sugar: starch ratio in the over-wintering trunk may be used to assess spring vine development (bud break, shoot and inflorescence development may provide a useful tool to assist growers with pruning decisions.

## Recommended development of the trial

To date the crop loading treatments have been imposed by thinning post flowering, but pre-veraison. The interaction of thinning, bunch position and perennial wood makes interpretation of some of the data difficult. Thinning pre-flowering, by removing apical inflorescences may be a better means of assessing the impact of crop load on vine responses. Potential cropping of the cane pruned treatment needs to be extended to impose a greater photosynthates sink to source ratio. An alternative treatment may be to remove a proportion of the leaves.

Fruit anthocyanin analysis is yet to be undertaken.

As the vines mature, differences in perennial wood storage between treatments will increase, and treatment responses should become greater.

Further research on the impact of crop load and perennial wood volume on trunk starch: sugar ratio may provide a useful tool in managing pruning strategies in vineyards.

References

Koblet, W. et al 1994. Influence of leaf removal, rootstock and training system on yield and fruit composition of Pinot noir grapevines. American Journal Enology and Viticulture 45, 181-187.

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