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Russell Paul Smithyman

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G. S. Howell
Major professor

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CANOPY AND CROPPING INFLUENCE ON VINE GROWTH, PHYSIOLOGY, AND CLUSTER DISEASE INCIDENCE OF SEYVAL AND VIGNOLES GRAPEVINES

By

Russell Paul Smithyman

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ABSTRACT

CANOPY AND CROPPING INFLUENCE ON VINE GROWTH, PHYSIOLOGY, AND CLUSTER DISEASE INCIDENCE OF SEYVAL AND VIGNOLES GRAPEVINES

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Seyval and Vignoles grapevines were subjected to decreasing pruning severities to increase the level of fruitful (clusters) and vegetative (apical meristems) sinks during anthesis in an effort to reduce fruit-set, cluster compactness and *Botrytis* incidence. Fruit-set appears to be influenced more by cluster number than apical meristems. Due to their large cluster size, Seyval showed a significant response to greater fruitful sink competition. However, the small clusters of Vignoles were insufficient in influencing fruit-set at pruning severities that produced sufficient vegetation for fruit and wood maturity. Increased shoot numbers per vine facilitated early filling of the trellis area with foliage. However, a limit existed where vegetative sink competition adversely affected light penetration into the canopy, leaf production after veraison, and cane cold hardiness. Three canopy configurations (severely pruned, full trellis, and hedging), providing three levels of shoot production, were compared to examine their influence on shoot and leaf growth as well as leaf area formation. Both the full trellis and hedging systems increased early filling of the trellis area with foliage and yield, but canopy density became a problem in the hedged vines after veraison. A moderate pruning severity, accompanied by post-set thinning in Seyval appears to be the best method for creating a sufficient sink competition to reduce berry-set, cluster compactness, and thus, *Botrytis* infection.

Dedicated to missed days in the woods and streams of Michigan.

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Introduction

Vineyard Management Goals

The viticulturalist's objective is to manage each grapevine to produce the greatest consistent yield of high-quality fruit, while maintaining vine health. Cultural management research has increased the understanding of canopy configuration, structure, and function. However, few practices have been adopted commercially by growers because of differences in cultivars, climates, and soils. An understanding of specific circumstances of cultivar growth, localized environment and costs of production are required if the viticulturalist's objective is to be achieved.

Crop Control and Large Clustered Cultivars

Many phylloxera resistant grape cultivars are economically important in Michigan viticulture. However, because their growth and fruiting habits often differ from the widely cultivated Vitis *labruscana* Bailey grapevines, dormant-season balanced pruning, a proven method of controlling crop level and maintaining fruit quality of *V. labruscana* (11,44), can fail to provide adequate crop control for many large clustered hybrid cultivars (22,36,37,46). Some cultivars can produce three or four heavy (>500 gm) clusters per shoot as well as fruitful lateral shoots (59). Fruitful shoots can also arise from base buds that are not counted in the balanced pruning practice (46,57). For such high producing cultivars, increasing the pruning severity is insufficient to control crop load and maximize filling of the trellis space with leaves early in the growing season (46,57). Overproduction is detrimental to vegetative growth and fruit maturity (11,22,25,26,31,44,46,61,64, 90,96), but can be corrected by cluster thinning (22,26,36,37, 61,96) so that, a balance between vegetative growth and fruiting is produced. However, thinning increases labor and production expense for such cultivars. Severe pruning is presently employed to limit cluster thinning costs. Such pruning delays canopy formation early in the growing season; maximum leaf area for the trellis space is not reached until well after bloom. The potential loss of photosynthesis due to the delay in canopy formation is of concern. A more cost-effective method of crop control and canopy management that would better utilize vine capacity would be very useful.

Cluster Rot

Even with successful cropping procedures, pathogens can upset the balance achieved between vegetation and fruit, causing damage to vine health and fruit quality. Cultivars differ in their vulnerability to different pathogens. Seyval has a serious harvest season cluster rot problem due primarily to *Botrytis cinerea* Pers. The most serious infections occur post-veraison during fruit ripening after rains, when the foliage layers are fully developed and drying of the clusters is inhibited. Cluster exposure and berry contact within the cluster influence *Botrytis* rot incidence and intensity of infection (54). At present, an extensive chemical spray schedule is needed to prevent infection. However, many important fungicides are being banned or their use limited. Cultural practices are needed that would reduce cluster rot infection and decrease dependance on the use of chemicals normally applied for control.

The cultivars Seyval (S.V. 5276) and Vignoles (Ravat 51) were chosen for this study because both are of importance in Michigan's wine industry and both have serious cluster rot problems. In addition, Seyval is easily overcropped because it forms large, compact clusters. Seyval is managed using severe balanced pruning and flower cluster thinning (37). It is recommended that a 15+10 balanced pruning formula with thinning to 1.5 clusters per shoot be employed to control crop level (61).

Vignoles is by contrast, a small-clustered cultivar that also bears compact clusters susceptible to *Botrytis* infection. Because of the smaller clusters, balanced pruning alone is sufficient for crop control. A 15+15 pruning formula on a High Cordon training system is recommended (28). More practical cultural methods need to be investigated in the production of both these cultivars. Importantly, information learned on these two should provide a basis for similar problems in other cultivars such as Chancellor and Pinots noir, gris and blanc.

Literature Review

Leaf Area

The photosynthate produced during the vegetative season must drive the processes of vegetative growth, fruiting, and flower bud development for next years crop. Reserves must also be stored over the winter for cold hardiness, and initiation of growth and development, until a new canopy is producing photosynthate the following spring. Equally as significant is the mobilization and transport of assimilate between different organs of the vine in order to carry out these processes.

Leaf development is important for fruit and shoot maturity. A leaf number greater than 10 per shoot is necessary for optimal fruit ripening and shoot weight (87,93). Leaf photosynthesis is greatest when the leaf is fully expanded, and then gradually declines shortly thereafter (56). The amount of photosynthate produced by each leaf is important for the development of the subtending bud (24,79). Over 80 percent of the assimilate a cluster collects is produced by the leaves on the same side of the shoot (47,48). Buttrose (8) found that as leaf number was reduced, root dry weight decreased most severely, followed by reductions in berry development, and then trunk and shoot carbohydrate reserves. Increasing the number of leaves per shoot increases berry sugar, weight, and coloration at harvest (87). However, the production of each new leaf adds to the vine leaf area and the formation of leaf layers within the canopy.

The leaf area of the vine is critical because it produces the assimilate necessary for crop ripening and wood maturity. A minimum leaf area of 7-14 cm^2 per gram of fruit is needed for adequate fruit ripening (31,83). Smart showed that a dense canopy can reduce light levels to 1% of the solar radiation in the fruiting and renewal zone (80), and an optimal canopy has no more than three leaf layers (81). Light penetration into the canopy is important for photosynthesis (35,78), fruitfulness (27,74), flower bud formation (74,80), fruit set (15,68), fruit quality (63,65,82), yields (74), and wood hardiness (25,74,85). Thus, it is evident that a maximum leaf area exists where light penetration into the canopy is restricted to the point that vine productivity and conditions begin to diminish. The maintenance of this leaf area is important to maximize the amount of assimilate produced in the vegetative season for vine growth and development.

When this maximum leaf area to facilitate vine growth is established is of great interest. 14C-labeled assimilates move from the leaves to the perennial portions of the vine in autumn, and then reappear in the shoot growth the following spring (73). This new growth is dependent on the remobilization of stored carbohydrates from the previous year (98,99). Photosynthesis increases up to the fourth week after anthesis and then declines until harvest (53). Cluster development is slow until the leaf area is established (95). Thus, it is important to fill the trellis area with vegetative growth as early as possible to facilitate vine growth and development without creating a dense canopy later in the season.

Canopy Design

Manual labor for pruning and thinning has become increasingly scarce and costly. Much attention has been focussed on minimal pruning management techniques to reduce labor. Mechanical hedging, selective hand pruning, or no pruning, increase the number of buds retained for potential shoot production from the previous years vegetative growth compared to conventional pruning. Downton and Grant (20) showed that an increase in shoot number resulted in a change in vine morphology; smaller shoots were produced compared to spur pruned vines. Minimally pruned vines had a greater leaf area and higher photosynthetic rates before bloom, but little leaf production after, as spur pruned vines had a greater leaf area at harvest. The total amount of carbon fixed per vine was similar between treatments, but proportioned differently. Minimally pruned vines allocated more photosynthate to fruit ripening than to wood maturity. They concluded that minimally pruned vines lose less of their fixed carbon from the previous year due to pruning. This was supported by Ruhl and Clingeleffer (69), who found that minimally pruned vines stored more carbohydrates in old wood but less in their canes and roots. Without any other crop control, minimal pruning increases yield as a function of increased cluster number, but brix are usually lower (41). Increasing shoot number increases both canopy density (81) and the labor expense incurred by cluster thinning fruitful varieties.

Mechanical hedging has been suggested as an alternative to hand, balanced pruning, since it may increase labor efficiency three to six-fold (75,83). Continuous use of hedging requires the vineyard to be uniform in vine size and vigor (45) and without cane selection or shoot positioning, it has been shown to be useful for only a few years (45,55,66). It increases the amount of vegetation per foot of trellis space (43,45,55), allowing for earlier filling of the canopy. However, mechanical pruning for more than one to three years results in reduced yields, fruitfulness and fruit quality (43,45,55). Mechanical hedging may be a viable alternative when it is done in conjunction with selective hand pruning techniques (66).

Carbohydrate Sinks

The organs competing for photoassimilates are termed sinks and the control of assimilate transport is determined by the relative position of the source leaves and sink organs, and the relative strength of the sink organs to accumulate assimilates (48). From bud-burst to bloom, the rapidly expanding leaves and shoot apex are the primary sinks for stored carbohydrates (95). Flower clusters compete for carbohydrates during bloom (60). After anthesis, the shoot apex and the developing clusters become the strongest sinks (15,24,60). At harvest, the vine storage sinks compete for assimilate. Only by balancing the source to sink ratio, can productive grapevines be maintained.

An excessive crop creates a situation where the total fruiting sink is greater than any oun

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other sink. In response to excess crop, vine size decreases as shoot growth diminishes (22,25,26,61,64). Overcropping negatively effects fruit quality, berry weight, cluster weight, and berries per cluster (26,31,62). Fruit and wood maturity are delayed (25,61,92,97). The increased competition from high crop levels can influence morphological characteristics such as a decrease in shoot length, leaf size, cluster size, cluster weight, and berry weight (4,30,90). These canopy reductions improve canopy microclimate (63,64) and increase photosynthetic efficiency through reduced shading (83). Lateral shoots supply assimilate to clusters on the main shoot, but when fruitful, the mid-season clusters they produce draw assimilate from the main shoot (34). In total, an excessive crop level disrupts the source to sink balance, and is detrimental to vine growth and health.

Flower Initiation and Differentiation

Each node formed on a grapevine shoot contains three partially developed shoots with leaf and flower primordia for the following year (95). The apical buds formed late in the growing season are the least mature along the cane in the fall. Because the basal buds of a shoot are close in proximity to the storage and fruiting sinks, they accumulate carbohydrates later than the more apical nodes, and are less fruitful in most cultivars (95). The French-American hybrids have fruitful basal buds (46,57). The leaf subtending each developing bud is the main source of assimilate for that bud (24,79). Thus, the light intensity on that leaf and bud is important during flower bud development (40,79), and shading can decrease vine fruitfulness (27,74).

Flower initiation begins in early summer, when each bud begins to swell (58,84). Buds mature throughout the vegetative season. Differentiation from vegetative to fruiting primordia occurs in late summer until the vine acclimates to winter. The calyx, corolla, stamens, and pistil are differentiated the following spring (72). Two carpels makeup the pistil with two ovules in each carpel. With development of the stamens and differentiation of the pollen, the perfect inflorescence are ready to bloom.

Bloom and Fruit-Set

The basal clusters are the first to bloom, six to eight weeks after bud burst. Blooming lasts one to three weeks, with temperature being the controlling factor (95). High relative humidity and rain hamper pollination, while moisture stress decreases fruit set for up to four weeks following bloom (1). Grape flowers are either self-pollinated or aided by insects and wind (95). Fruit set is best at temperatures between 20 and 30 C (9,86).

Two theories exist as to what regulates fruit set in grape vines. One suggests that growth hormones are transported to the cluster to induce set (88,89), while the other proposes that carbohydrate supply determines fruit set (49). Intra-vine competition for carbohydrates and growth hormones by vegetative (90) and fruiting sinks (17) have been shown to have a negative effect on fruit set. Reducing sink competition and growth hormone sources by removing shoot tips, increases fruit set (15,76). Decreasing assimilate sources by leaf removal during bloom decreases fruit set (10). Thinning flower-clusters increases pollen germinability and fruit set (94). Within-cluster competition decreases fruit set (37). Mullins (49) demonstrated that fruit set can occur in flowers cultured *in vitro* on a medium of sucrose and nutrients, suggesting that fruit set is regulated by assimilate supply. Roper *et. al.* (67) suggest that competition for photosynthate may be the limiting factor in cranberry fruit set.

Strawberry fruit set and initial growth is not limited by the ability of receptacles to mobilize current source leaf assimilates; and early fruit growth is not related to pool sizes (19). Nitsh (51) removed the achenes of strawberries and the receptacle ceased to enlarge. However, if the berry was coated with a lanolin paste containing auxin, it enlarged normally. It is assumed the strawberry receptacle requires auxin for normal growth (52).

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In grapevines, a direct correlation is reported between berry size and seeds per berry (12). Seed number has little relationship with auxin or abscisic acid content (9). Coombe (14) found increased auxin levels and improved fruit set in girdled vines. Varieties that undergo normal set contain higher auxin levels and greater berry size with a full complement of developing seeds than varieties that are stimulative parthenocarpic or stenospermocarpic (95). A competition for carbohydrates and growth hormones exists, and needs further experimentation to determine optimum cultural practices.

Berry Development

When the berries become active sinks, many of their tissues become meristematic and growth begins. Those berries that have not initiated this process generally abscise. Berry development follows a double sigmoid growth curve consisting of three stages (18). Coombe (18) suggests that cell division before verasion and cell expansion after anthesis are the major determinants of the increase in weight of fleshy fruits. Some contributions are made by cell division after anthesis and an increase in concentration of solutes. Little is known about the influences upon early cell division and its differences may commonly contribute to fruit size variation. Early availability of carbohydrates and growth hormones would appear to be of great importance during this time.

Cultural Practices to Influence Fruit-Set

Manipulating the carbohydrate source/sink balance, can alter fruit set in grapevines. Shoot tipping at bloom (13,15,76), girdling (5,13), flower-cluster thinning (91,92), and the application of growth regulators (5,13,16) increase fruit set. Heavy pruning (91) or leaf removal during bloom decreases fruit set (10). Increasing the light intensity for photosynthesis promotes fruit set (68). It follows that vine training to allow more light reception into the canopy could increase fruit set (77).

Pruning is presently the most cost effective way to control crop level. Balanced pruning uses the one-year-old cane prunings as an estimate of vine size to determine the vines capacity for growth and production (3). Capacity is defined as the vines ability for total vegetative and reproductive growth (95). Vegetative growth can then be balanced with expected crop level to maintain vine size and sufficiently ripen the fruit (26).

As stated earlier, easily overcropped cultivars, such as Seyval, require thinning. Thinning increases the ratio of leaves to fruit, improving the nutrition of both the vine and fruit (95). Some cultivars are flower-cluster thinned (37). Flower-cluster thinning increases pollen germinability, fruit set (94), and shoot growth (22,37). Post-set thinning decreases fruit set by increasing the fruiting and vegetative sink competition for assimilate and growth hormone (17,90), as well as reducing pollen quality. Reduced fruit set decreases cluster compactness. Post-set thinning reduces berries per cluster in Seyval, and a compensatory increase in berry size and fruit quality follows (29). Vegetative vigor and the development of laterals decreases as thinning is delayed until after fruit set (29). The period for source/sink manipulation of fruit set is suggested to extend from bloom to two weeks post-set (10).

Chemical Influence on Fruit-Set

The use of growth regulators is an alternative to hand thinning. Both ethephon and gibberellic acid have been used as berry abscission agents (36,37,91). Ethephon's effectiveness is dependant upon environmental conditions, time of application, concentration, and cultivar (91). Gibberellic acid response has not been consistent (36,37). Chlormequat (CCC) application increases fruit set under good conditions (5,16) by diverting organic nutrients from the shoot tips to the developing ovaries (60). More partially seeded berries are set (5). Roubelakis and Kliewer (68) were unable to induce fruit set with CCC applications during poor light and temperature regimes.

Cultural Control of *Botrytis*

The control of *Botrytis cinerea Pers.* is a costly endeavor for the vineyard manager. Cluster infection usually occurs late in the growing season, decreasing yield and fruit quality. *B. cinerea* survives the winter by forming sclerotia either on the surface or within plant tissue. Clusters and dead wood retained in the vineyard from the previous season can be an important source for inoculum in the spring the following year. The fungus lives most of its life as a saprophyte, getting nutrients from dead or dying plant parts (39). It may infect grape flowers and remain latent in these tissues until the clusters begin to mature (42). The spores of *B. cinerea* require prolonged periods of free water and nutrients on the berry surface for germination (39,50). Enzymes produced by the fungus can destroy the integrity of the berry in less than 24 hours (39).

The grape berry's main protection to *Botrytis* infection is its skin. The cuticle membrane and the epicuticular wax, provide the primary physical barrier to pathogen invasion (2). For berry infection to occur, the pathogen must find a weakness on the berry surface where it can bypass the cuticle membrane, or directly penetrate the surface (6). The epicuticular wax layer influences the retention of pesticides, the water retention of the berry surface, and the adhesive ability of plant pathogens (2). Percival et al. (54) found that berries of exposed clusters and those having little berry contact, produced more epicuticular wax and cuticle. Infection can be reduced by improving the microclimate within the canopy (39,70,71).

By reducing the periods of free water within the canopy and increasing cluster exposure through canopy management, disease pressure within the vineyard can be reduced (39). Leaf removal in the fruiting zone decreases infection (21,23,33,54). Since the leaf area is the source for photoassimilate, defoliation can have a detrimental affect on fruit quality (10,25,38), vine growth (7,32), and hardiness (25,38,85). Grapevines are able to compensate for the loss in leaf area by producing lateral shoots and increasing their photosynthetic efficiency (7,10,32). However, fruitful laterals draw assimilate from the main shoot (34). Defoliation in moderation can improve the canopy microclimate at the expense of assimilate production. The canopy microclimate can be improved to decrease *Botrytis cinerea* incidence, through better design (70,71,81).

Statement of Objectives

An efficient canopy maintains enough leaf area to produce quality fruit and a sufficient number of mature buds. It allows for adequate light penetration into the fruiting zone of the canopy to ripen fruit and inhibit *Botrytis* infection. Some cultivars are more susceptible to cluster rot because they bear compact clusters. This cluster structure holds moisture within, facilitating infection. More economical practices are needed to address this problem.

Seyval and Vignoles are valuable cultivars for white wine production in the state of Michigan. However, their growth habits pose some problems in producing quality fruit. Seyval produces large, compact clusters that have a tendency to contract *Botrytis* at harvest. Presently it is recommended that Seyval be severely pruned and cluster thinned to control overcropping. This inhibits early filling of the trellis area. Vignoles is a small clustered cultivar that also has a tendency to contract *Botrytis* rot at harvest. The removal of reproductive and vegetative sinks diverts photoassimilate to retained sinks. The time of cluster and whole shoot removal influences assimilate supply per alternate sink during the critical period of fruit set.

The objectives of this study are:

1. To investigate economical pruning techniques that will allow for expedient filling of the trellis for optimum fruit ripening in Seyval.

2. To explore the effect of post-set cluster thinning to find an optimum method for decreasing *Botrytis* rot and improving fruit quality in Seyval.

3. To examine the effect of post-set pruning on fruit set and *Botrytis* infection in Vignoles.

The multiple working hypotheses of this study are:

1. Hedging is a viable practice for pruning Seyval grapevines and maintaining quality yields and vine health.

2. A canopy constructed of optimally spaced shoots will have superior architecture for fruit and wood maturity.

3. Increasing the amount of fruiting sinks at fruit set will decrease the number of berries set.

4. Increasing the number of vegetative sinks at fruit set will decrease the number of berries set.

5. Decreasing the number of berries set by post-set thinning and pruning will decreases the amount of *Botrytis* rot.

6. The loss in yield in Seyval because of the decrease in fruit set can be overcome by retaining more clusters per vine during thinning.

By using the competition among fruiting and vegetative sinks, I believe that more economical and environmentally sound canopy management practices can be adopted to improve fruit quality and health of the vine.

Literature Cited

1. Alexander, D. 1965. The effect of high temperature regimes or short period of water stress on development of small fruiting Sultana vines. Austral. J. Agr. Res. 16:817-823.

2. Baker, E.L. 1982. Chemistry and morphology of plant epicuticular waxes. In: Cutler, D.F., Alvin K.L., Price, C.E. (Eds.): The Plant Cuticle, 139-161. Acedemic Press, Toronto.

3. Bell, H.K., R.P. Larson and A.L. Kenworthy. 1958. Balanced pruning of the Concord grape - another look under present-day conditions. Quarterly Bull. Mich. Agr. Exp. Station. Michigan State Univ. 40:915-919.

4. Bravdo, B., Y. Hepner, C. Loinger, S. Cohen, and H. Tabacman. 1984. Effect of crop level in a high yielding Carignane vineyard on growth, yield, and wine quality. Am. J. Enol. Vitic. 35:247-252.

5. Brown, K., D.I. Jackson, and G.F. Steans. 1988. Effects of Chlormequat, girdling, and tipping on berry set in Vitis vinifera L. Am. J. Enol. Vitic. 39(1):91-94.

6. Bulit, J., and D. Dubos. 1988. *Botrytis* bunch rot and blight. In: Pearson, R.C., Goheen, A.C. (Eds.): Compendium of grape diseases, 13-15. APS Press, St. Paul.

7. Buttrose, M.S. 1966. The effect of reducing leaf area on the growth of roots, stems, and berries of Gordo grapevines. Vitis. 5:455-464.

8. Buttrose, M.S. 1968. The effect of varying berry number on Gordo grapevines with constant leaf area. Vitis 7:299-302.

9. Buttrose, M.S. and C.R. Hale. 1973. Effect of temperature on development of the grapevine inflorescence after budburst. Am. J. Enol. Vit. 24:14-16.

10. Candolfi-Vasconcelos, M.C. and W. Koblet. 1990. Yield, fruit quality, bud fertility and starch reserves of the wood as a function of leaf removal in Vitis vinifera - Evidence of compensation and stress recovering. Vitis. 29:199-221.

11. Cawthon,D.L. and J.R. Morris. 1977. Yield and quality of Concord grapes as affected by pruning severity, nodes per bearing unit, training system, shoot positioning, and sampling date in Arkansas. J. Amer. Soc. Hort. Sci. 102:760-767.

12. Cawthon, D.L. and J.R. Morris. 1982. Relationship of seed number and maturity to berry development, fruit maturation, hormonal changes, and uneven ripening of Concord grapes. J. Amer. Soc. Hort. Sci. 107(6):1097-1104.

13. Coombe, B.G. 1959. Fruit set and development in seeded grape varieties as affected by defoliation, topping, girdling, and other treatments. Am. J. Enol. Vitic. 10:85-100.

14. Coombe, B.G. 1960. Relationship of growth and development to changes in sugar, auxin, and gibberellins in fruit of seeded and seedless varieties of Vitis vinifera. Plant Physiol. 35:241-250.

15. Coombe, B.G. 1962. The effect of removing leaves, flowers and shoot tips on fruit set of Vitis vinifera L. J. Hort. Sci. 37:1-15.

16. Coombe, B.G. 1970. Fruit set in grapevines: The mechanism of the CCC effect. J. Hort. Sci. 45:415-425.

17. Coombe, B.G. 1973. Regulation of set and the development of the grape berry. Acta. Horticulture 34:261-273.

18. Coombe, B.G. 1976. The development of fleshy fruits. Ann. Rev. Plant Physiol. 27(2):507-528.

19. Darnell, R.L. and G.C. Martin. 1988. Role of assimilate translocation and Carbohydrate accumulation in fruit set of strawberry. J. Amer. Hort. Sci. 113(1):114-118.

20. Downton, W.J.S. and W.J.R. Grant. 1992. Photosynthetic physiology of spur pruned and minimal pruned grapevines. Aust. J. Plant Physiol. 19:309-316.

21. English, J.T., C.S. Thomas, J.J. Marois, and W.D. Gubler. 1989. Microclimates of grapevine canopies associated with leaf removal and control of *Botrytis* bunch rot. Phytopathology. 79(4):395-401.

22. Fisher, K.H., O.A. Bradt, J. Wiebe and V.A. Dirks. 1977. Cluster thinning 'de Chaunac' French hybrid grapes improves vine vigor and fruit quality in Ontario. J. Amer. Soc. Hort. Sci. 102(2):162-165.

23. Gubler, W.D., J.J. Marois, A.M. Bledsoe, L.J. Bettiga. 1987. Control of *Botrytis* bunch rot of grape with canopy management. Plant. Dis. 71(7):599-601.

24. Hale, C.R., and P.J. Weaver. 1962. The effect of developmental stage on direction of translocation of photosynthate in *Vitis vinifera* . Hilgardia 33:89-131.

25. Howell, G.S., B.S. Stergios and S.S. Stackhouse. 1978. Interrelation of productivity and cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 29:187-191.

26. Howell, G.S., T.K. Mansfield and J.A. Wolpert. 1987. Influence of training system, pruning severity, and thinning on yield, vine size and fruit quality of Vidal blanc grapevines. Am. J. Enol. Vitic. 38(2):105-112.

27. Howell, G.S., D.P. Miller, C.E. Edson and R.K. Streigler. 1991. Influence of training system and pruning severity on yield, vine size, and fruit maturity of Vignoles grapevines. Amer. J. Enol. Vitic. 42(3):191-198.

28. Howell, G.S. May 1992. Pruning and training Vignoles grapevines in Michigan. Vintner & Vineyard. Coop. Ext. Serv. Pub. 6(1):1-6.

29. Hunter, D.M. and J.T.A. Proctor. 1985. Effects of timing of thinning influence on Seyval blanc fruit yields and quality. Presented at 10th Annual meeting of the American Society for Enology and Viticulture/Eastern section, Mississauga, Ont. (August 1985).

30. Kaps, M.L. and G.A. Cahoon. 1989. Berry thinning and cluster thinning influence on vegetative growth, yield, fruit composition, and net photosynthesis of Seyval blanc grapevines. J. Amer. Soc. Hort. Sci. 114(1):20-24.

31. Kliewer, W.M. and R.J. Weaver. 1971. Effect of crop level and leaf area on growth, composition and correlation of 'Tokay' grapes. Am. J. Enol. Vitic. 23:172-177.

32. Kliewer, W.M and R.D. Fuller. 1973. Effect of time and severity of defoliation on growth of roots, trunk and shoots of Thompson Seedless grapevines. Am. J. Enol. Vit. 24:59-64.

33. Kliewer, W.M. and A.M. Bledsoe. 1987. Influence of hedging and leaf removal on canopy microclimate, grape composition, and wine quality under California conditions. Acta. Hort. 206:157-168.

34. Koblet, W. 1977. Translocation of photosynthate in grapevines. In: Proc. OIV symp. on the quality of the vintage. pp.45-51. OVRI, Stellenbosch, South Africa.

35. Kriedemann, P.E., B.R. Loveys, and W.J.S. Downton. 1975. Internal control of stomatal physiology and photosynthesis. 2. Photosynthetic responses to phaseic acid. Aust. J. Plant Physiol. 2:553-567.

36. Looney, N.E. and D.F. Wood. 1977. Some cluster thinning and gibberellic acid effects on fruit set, berry size, vine growth, and yield of DeChaunac grapes. Canadian J. Plant Sci. 57:653-659.

37. Looney, N.E. 1981. Some growth regulator and cluster thinning effects on berry set and size, berry quality, and annual productivity of 'De Chaunac' grapes. Vitis 20:22-35.

38. Mansfield, T.K. and G.S. Howell. 1981. Response of soluble solids accumulation, fruitfulness, cold resistance, and the onset of bud growth to different defoliation stress at verasion in Concord grapevines. Am. J. Enol. Vitic. 32:200-205.

39. Marios, J.J. 1987. *Botrytis* bunch rot of grapes. Oregon Dpt. of Agr.: The Wine Advisory Board Research Report. June (5):1-6.

40. May, P. and A.J. Antcliff. 1963. The effect of shading on fruitfulness and yield of the Sultana. J. Hort. Sci. 38:85-94.

41. McCarthy, M.G., and R.M. Cirami. 1990. Minimal pruning effects on the performance of selections of four *Vitis vinifera* cultivars. Vitis 29:85-96.

42. McClellan, W.D. and W.B. Hewitt. 1973. Early *Botrytis* rot of grapes: Time of infection and latency of *Botrytis cinerea* Pers. in *Vitis vinifera* L. Phytopathology. 63:1151-1157.

43. Morris, J.R., D.L. Cawthon, and J.W. Flemming. 1975. Effect of mechanical pruning on yield and quality of Concord grapevines. Ark. Farm Res. pub. 24(3):1-12.

44. Morris, J.R. and D.L. Cawthon. 1980. Yield and quality responses of Concord grapes to training systems and pruning severity in Arkansas. J. Amer. Soc. Hort. Sci. 105:307-310.

45. Morris, J.R. and D.L. Cawthon. 1981. Yield and quality responses of Concord grapes to mechanized pruning. Am. J. Enol. Vitic. 32(4):280-282.

46. Morris, J.R., C.A. Sims, J.E. Bourque and J.L. Oakes. 1984. Influence of training system, pruning severity and spur length on yield and quality of six French-American hybrid grape cultivars. Am. J. Enol. Vitic. 35:23-27.

47. Motomura, Y. 1990. Distribution of 14C-assimilates from individual leaves on clusters in grape shoots. Am. J. Enol. Vitic. 41:306-312.

48. Motomura, Y. 1993. 14C-assimilate partitioning in grapevine shoots: Effects of shoot pinching, girdling of shoot, and leaf-halving on assimilate partitioning from leaves into clusters. Am. J. Enol. Vitic. 44:1-7.

49. Mullins, M. G. 1967. Regulation of fruit set in the grapevine. Aust. J. Biol. Sci. 20:1141-1147.

50. Nelson, K.E. 1951. Factors influencing the infection of table grapes by *Botrytis cinerea* (Pers). Phytopathology. 41:319-326.

51. Nitsch, J.P. 1950. Growth and morphogenesis of the strawberry as related to auxin. Amer. J. Bot. 37:211-215.

52. Nitsch, J.P. 1953. The physiology of fruit growth. Ann. Rev. Plant Physiol. 4:199-236.

53. Pandey, R.M. and H.L. Farmahan. 1977. Changes in the rate of photosynthesis and respiration in leaves and berries of Vitis vinifera grapevines at various stages of berry development. Vitis. 16:106-111.

54. Percival, D.C., J.A. Sullivan, and K.H. Fisher. 1993. Effect of cluster exposure, berry contact and cultivar on cutical membrane formation and occurrence of bunch rot (*Botrytis cinerea* Pers.:Fr.) with 3 *Vitis vinifera* L. cultivars. Vitis 32:87-97.

55. Pollock, J.G., E.S. Shepardson, N.J. Shaulis, and D.E. Crowe. 1977. Mechanical pruning of American hybrid grapevines. Trans. ASAE 20(5):817-821.

56. Poni, S., C. Intrieri, and O. Silvestroni. 1994. Interactions of leaf age, fruiting and exogenous cytokinins in Sangiovese grapevines under non-irrigated conditions. 1. Gas exchange. Am. J. Enol. Vitic. 45(1):71-78.

57. Pool, R.M., C. Pratt, and H.D. Hubbard. 1978. Structure of base buds in relation to yield of grapes. Amer. J. Enol. Vit. 29:36-41.

58. Pratt, C. 1971. Reproductive anatomy of grapes - A review. Amer. J. Enol. Vitic. 22:92-109.

59. Pratt, C. 1974. Vegetative anatomy of cultivated grapes-A review. Amer. J. Enol. Vit. 25:131-150.

60. Quinlan, J.D. and R.J. Weaver. 1970. Modification of pattern of the photosynthate movement within and between shoots of *Vitis vinifera* L. Plant Physiol. 46:527-530.

61. Reynolds, A.G., R.M. Pool and L.R. Mattick. 1986a. Effect of shoot density and crop control on growth, yield, fruit composition and wine quality of 'Seyval blanc' grapevines. J. Amer. Soc. Hort. Sci. 111(1):55-63.

62. Reynolds, A.G., R.M. Pool and L.R. Mattick. 1986b. Influence of cluster exposure on fruit composition and wine quality of 'Seyval blanc' grapes. Vitis 25:85-95.

63. Reynolds, A.G., and D.A. Wardle. 1989a. Impact of various canopy management techniques on growth, yield, fruit composition and wine quality of Gewurtztraminer. Am. J. Enol. Vitic. 40:121-129.

64. Reynolds, A.G. and D.A. Wardle. 1989b. Effects of timing and severity of summer hedging on growth, yield, fruit composition, and canopy characteristics of 'De Chaunac' 1. Canopy characteristics and growth parameters. Am. J. Enol. Vitic. 40:109-120.

65. Reynolds, A.G. and D.A. Wardle. 1989c. Effects of timing and severity of summer hedging on growth, yield,fruit composition, and canopy characteristics of 'De Chaunac' 2. Yield and fruit composition. Am. J. Enol. Vitic. 40:299-308.

66. Reynolds, A.G. and D.A. Wardle. 1993. Yield component path analysis of Okaagan Reisling vines conventionally pruned or subjected to simulated mechanical pruning. Am. J. Enol. Vitic. 44(2):173-179.

67. Roper, T.R., E.J. Stang, and G.M. Hawker. 1992. Early season leaf removal reduces fruit set and size in cranberry (Vaccinium macrocarpon Ait.). Hort. Science. 27(1):75.

68. Roublelakis, K.A. and W.M. Kliewer. 1976. Influence of light intensity and growth regulators on fruit set and ovule fertilization in grape cultivars under low temprature conditions. Am. J. Enol. Vitic. 27(4):163-167.

69. Ruhl,E.H. and P.R. Clingeleffer. 1993. Effect of minimal pruning and virus inoculation on the carbohydrate and nitrogen accumulation in Cabernet franc vines. Am. J. Enol. Vitic. 44(1):81-85.

70. Savage, S.D. and M.A. Sall. 1983. *Botrytis* bunch rot of grapes: The influence of selected cultural practices on infection under California conditions. Plant Dis. 67:771-774.

71. Savage, S.D. and M.A. Sall. 1984. *Botrytis* bunch rot of grapes: Influence of trellis type and canopy microclimate. Phytopathology. 74:65-70.

72. Scholefield, P.B. and R.C. Ward. 1975. Scanning electron microscopy of the developmental stages of the Sultana inflorescence. Vitis. 14:14-19.

73. Scholefield, P.B., T.F. Neales, and P. May. 1978. Carbon balance of the Sultana vine (*Vitis vinifera* L.) and the effects of autumn defoliation by harvest-pruning. Aust. J. Plant Physiol. 5:561-570.

74. Shaulis, N., and R. Smart. 1974. Grapevine canopies: management microclimate and yield responses. In: Proc. XIXth International Hort. Congress. pp. 255-265. 11-18 Sept., Warsaw.

75. Sims, C.A., R.P. Johnson, and R.P. Bates. 1990. Effects of mechanical pruning on the yield and quality of Muscadine grapes. Am. J. Enol. Vitic. 41(4):273-276.

76. Skene, K.G.M. 1969. A comparison of the effects of "Cycocel" and tipping on fruit set in *Vitis vinifera* . Austr. J. Biol. Sci. 22:1305-1311.

77. Smart, R.E. 1973. Sunlight interception by vineyards. Am. J. Enol. Vitic. 24(4):141-147.

78. Smart, R.E. 1974a. Photosynthesis by grapevine canopies. J. Applied Ecology 11:997-1006.

79. Smart, R.E., N.J. Shaulis, and E.R. Lemon. 1982b. The effect of Concord vineyard microclimate on yield. 2. The interrelations between microclimate and yield expression. Am. J. Enol. Vitic. 33:109-116.

80. Smart, R.E. 1984. Some aspects of climate canopy microclimate, vine physiology and wine quality. In: Proc. First Intl. Symp. Cool Climate Vitic. Enol. D.A. Heatherbell, P.B. Lombard, F,W. Bodyfelt, and S.F. Price (eds.). pp 1-18. June 1984, Eugene, Oregon. Oregon State Univ.

81. Smart, R.E. 1985. Principles of grapevine canopy microclimate manipulation with implications for yield and quality. A review. Am. J. Enol. Vitic. 36(3):230-239.

82. Smart, R.E. 1987. Influences of light on composition and quality of grapes. Acta Horticulture. 206:37-47.

83. Smart, R.E., J.K. Dick, I.M. Gravett and B.M. Fisher. 1990. Canopy management to improve grape yield and wine quality - principle and practices. S. Afric. J. Enol. Vitic. 11:3-17.

84. Srinivasan, C. and M.G. Mullins. 1981. Physiology of flowering in the grapevine: A review. Am. J.Enol. Vitic. 32(1):47-63.

85. Stergios, B.G. and G.S. Howell. 1977. Effects of defoliation, trellis height, and cropping stress on the cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 28(1):34-42.

86. Tukey, L.D. 1957. Effects of controlled temperature following bloom on berry development of the Concord grape. Proc. Am. Soc. Sci. 71:157-166.

87. Weaver, R.J. 1958. Effect of leaf to shoot ratio on fruit quality and shoot development in Carignane and Zinfandel wine grapes. Am. Soc. Enol. Vitic. 14:1-12.

88. Weaver, R.J., S.B. McCune, and C.R. Hale. 1962. Effect of plant regulators on fruit set and berry development in certain seeded and seedless varieties of *Vitis vinifera*. Vitis 3:84-96.

89. Weaver, R.J., W. Shindy, and W.M. Kliewer. 1969. Growth regulator induces movement of photosynthate products into fruits of 'Black Corinth' grapes. Plant. Physiol. 44:183-188.

90. Weaver, R.J. and R.M. Pool. 1968. Effect of various levels of cropping on *Vitis vinifera* grapevines. Am. J. Enol. Vitic. 19:185-193.

91. Weaver, R.J. and R.M. Pool. 1971b. Chemical thinning of grape clusters (*Vitis vinifera* L.). Vitis. 10:201-209.

92. Winkler, A.J. 1929. The effect of dormant pruning on the carbohydrate metabolism of the vine. Hilgardia. 4:153-173.

93. Winkler, A.J. 1930. The relation of number of leaves to size and quality of table grapes. Proc. Am. Soc. Hrt. Sci. 27:158-160.

94. Winkler, A.J. 1958. The relation of leaf area and climate to vine performance and grape quality. Amer. J. Enol. 9:10-23.

95. Winkler, A.J., J.A. Cook, W.M. Kliewer and L.A. Lider. 1981. General Viticulture. University of California Press, Berkeley.

96. Wolpert, J.A., G.S. Howell, T.K. Mansfield. 1983. Sampling Vidal blanc grapes: 1. Effect of training system, pruning severity, shoot exposure, shoot origin, and cluster thinning on cluster weight and fruit quality. Amer. J. Enol. Vit. 34:72-76.

97. Wolpert, J.A. and G.S. Howell. 1985. Cold acclimation of Concord grapevines. I. Variation in cold hardiness within the canopy. Am. J. Enol. Vitic. 41:330-341.

98. Yang, Y.S. and Y. Hori. 1979. Studies on retranslocation of accumulated assimilates in 'Delaware' grapevines. I. Retranslocation of 14C-assimilates in the following spring after 14C feeding in summer and autumn. Tohoku J. of Agr. Res. 30(2):43-56.

99. Yang, Y.S., Y. Hori, and R. Ogata. 1980. Studies on retranslocation of accumulated assimilates in 'Delaware' grapevines. II. Retranslocation of assimilates accumulated during the previous growing season. Tohoku J. of Agr. Res. 31(2):109-119.

CHAPTER I

INFLUENCE OF CANOPY CONFIGURATION ON CANOPY DEVELOPMENT, YIELD, FRUIT COMPOSITION, AND CANE QUALITY OF SEYVAL GRAPEVINES

Abstract

Seyval grapevines were trained to three canopy configurations in 1988. One treatment filled the trellis (Full Trellis) early by spacing 45 buds along the cordon. Another simulated a hedge (Hedge) by hand pruning four inches around the cordon. A control was used where vines were balanced pruned to 8 nodes per 454 g. cane prunings. All vines were flower cluster thinned to 15 clusters per 454 g. cane prunings. Vine size and yield indices, as well as fruit quality, were evaluated each year. Canopy development was measured using point quadrat analysis taken during the 1991-1993 growing seasons. Cold hardiness evaluations were made in March of 1992-1994. The full trellis and hedge treatments had a larger number of nodes retained and earlier filling of the trellis area with foliage. However, hedging produced poorly spaced shoots that were less winter hardy. The full trellis treatment increased yield as a function of increased berries per cluster and cluster weight, as well as cane cold hardiness. Hedging increased yield by developing more clusters after thinning, but produced a higher incidence of *Botrytis* rot. There were no other differences in fruit quality between treatments. A canopy structure that fills the trellis early with properly spaced shoots appears to be the best canopy configuration for Seyval grapevines.

Introduction

Seyval is an important white wine grape cultivar across the Eastern United States. It is cold hardy, disease resistant, and phylloxera resistant. It does, however, form large, compact clusters susceptible to cluster rot under Michigan conditions and the large clusters can lead to overcropping. Crop levels are usually maintained by severe balance pruning and flower-cluster thinning. Reynolds et al. (12) suggested an optimal cropping level of 17 clusters per 500 grams of cane prunings in New York state. Severe pruning reduces the thinning expense incurred by the grower, but results in a later filling of the canopy and thus potential loss of photosynthesis. The current suggested balanced pruning formula is 15+10 (15 nodes retained for the first 454 gm of dormant one year cane prunings, and 10 nodes retained for each additional 454 gm). This results in a canopy that does not fill the trellis area until after fruit set.

Grapevine canopy development and density have been areas of recent interest and research. Spring shoot growth is dependant on the remobilization of carbohydrates stored in roots, trunks, cordons, and canes from the previous year (31,32), and cluster development is slow until leaf area is established (30). Shoots become net exporters of carbohydrates during anthesis (11). Cell division before anthesis and cell expansion after anthesis are the major determinants of the increase in weight of grape berries (3). Thus, it seems important to fill the trellis area with vegetative growth and leaf surface as early as possible to facilitate vine growth and fruit development.

Increasing the number of nodes retained at pruning is the most common method used to establish an early full canopy (22). There are potential negatives. Increased shoot numbers can form a dense canopy that reduces light levels to 1% of the solar radiation in the fruiting zone (21,22). Light penetration into the canopy is important for photosynthesis

(20), fruitfulness (6,18), flower bud formation (18,21), fruit set (2,16), fruit quality (13,15,23), yields (18), and wood hardiness (5,18,26). It appears that an optimum leaf area exists above which light penetration into the canopy is restricted to the point that vine productivity begins to diminish, and below which the canopy is ineffective as a light trap for photosynthesis. A method to quickly establish and maintain this optimum leaf area to maximize the amount of assimilate produced in the vegetative season, and maximize vine productivity, fruit quality, and composition, plus insure vine growth and cold hardiness needs to be investigated for a large fruited, overproducing cultivar such as Seyval.

Mechanical hedging, selective hand pruning, or no pruning at all, increase the number of nodes retained for potential shoot production from the previous years vegetative growth, but, increasing shoot number increases canopy density (4). These minimally pruning management techniques also change vine morphology. They increase the leaf area before and decrease leaf production after bloom (4). Minimally pruned vines partition fixed carbon differently than conventionally pruned vines (4). They store more carbohydrates in old wood and less in their canes and roots (17). However, some of these methods have increased labor efficiency (19,25).

Mechanical hedging has received increasing attention in the United States, since the pioneering efforts of the Australian researchers. This is suggested to be a cost effective alternative to hand pruning. Hedging leaves more nodes in the canopy area, increasing the amount of vegetation per foot of row and per square foot of canopy space (8,9,10). With no further crop control, increasing shoot number produces more clusters per vine, and thus greater sink competition. This in turn results in morphological characteristics such as reduced shoot length, leaf size, cluster size, cluster weight, and berry weight (1,7,29). This improves canopy microclimate (13,14) and increases photosynthetic efficiency through reduced shading (25). However, hedging alone has shown only to be useful for a few years before yields, fruitfulness, and fruit quality diminishes (8,9,10). Given the differences in climate and limitations of sunlight and carbon assimilation between the North Eastern United States and Australia, an objective evaluation of the limitations of this technology deserves effort particularly for Seyval. Since thinning is required to control overcropping in Seyval, the crop level can be managed so that the influence of canopy configuration and decreasing pruning severity on canopy development, can be further investigated. Reducing labor expenses by mechanical hedging would greatly decrease the cost of producing this variety.

Experimental Objectives:

1. To evaluate alternative pruning techniques that may allow expedient filling of the trellis for optimum fruit ripening in Seyval.

2. To determine the results of increasing bud numbers and balanced cropping (based on the previous years vine size) on canopy development, yield, fruit composition and quality in Seyval.

3. To evaluate balanced cropping with a set pruning number of buds retained, designed to space shoots at optimal distances from each other along the cordon in Seyval.

4. To analyze the impacts of hedging in conjunction with balanced cropping by cluster thinning in Seyval.

Materials and Methods

Plant Material

The experiment was established in March of 1988, 4.5 miles East of Lake Michigan (42-15' latitude) at Fenn Valley vineyards in Fennville Mi. Mature, bearing Seyval grapevines planted in 1975 on an Oshtemo sandy-loam soil were used in the experiment. Rows were spaced 3.0 meters apart with vines 2.4 meters apart within rows. The vines were trained to a bilateral cordon on the top wire, 1.8 meters high (Hudson River Umbrella training system).

Pruning Treatments

The three canopy configurations initiated in 1988 consisted of: 1) a full trellis treatment (FT) spacing 45 buds along the cordon with five-node canes and two-node spurs; 2) a mechanically pruned hedge (SH) was simulated by hand pruning four inches around the cordon; and 3) a control (C) (the current standard cultural method) was employed to ensure a typical rate of canopy development. In all cases an 8+8 balance pruning formula (8 buds retained for every 454 grams of dormant one year cane prunings) was used.

The control and full trellis vines were pruned to 45-nodes and the live one-year cane prunings weighed to estimate the previous year's vine size. The node number for the control vines was then set for the duration of the growing season following the procedures stated above. Because hedged vines retained a larger number of nodes, a method was devised to estimate the weight of retained wood. After pruning the hedge treatment, the live canes were weighed and nodes counted. The remaining live nodes of canes on the vine were counted. A weight was assigned to the number of nodes over 45 retained on the vine, based on a node weight calculated in 1992 (113 gm per 52 nodes) and 1993 (113 gm per 50 nodes). This weight and the weight of cane prunings were added producing the vine size estimate for each (SH) vine.

Since pruning is not sufficient for optimal crop control in Seyval, cluster thinning was also required. The weight of live one-year-old canes at pruning (vine size) was used to determine cluster number after thinning. All vines were flower-cluster thinned just prior to or during bloom to 15-clusters per 454 grams of dormant cane prunings.

At bud burst, nodes that did not produce a shoot (shootless nodes) were counted. Percent blind nodes, vegetativeness (vine size (gm) per shoot), count shoots (nodes retained at pruning minus blind nodes), and non-count shoots (total shoots minus count shoots) were calculated for each vine. Treatment comparisons of pruning data were analyzed each year and over years for the years applicable.

Harvest Procedures and Fruit Quality Assessments

Prior to harvest each year, *Botrytis* incidence assessments of each sample vine were taken. Vine rot and within cluster rot were subjectively evaluated using a one to five ranking where 1=0-20%; 2=21-40%; 3=41-60%; 4=61-80%; and 5=81-100% of the clusters on the vine or berries within the cluster were rotten. Treatment vines were harvested each year within ten days of October 1. Each sample vine was hand harvested with the cluster number noted and the fruit placed into an individual bin. Each bin was then weighed in the field and a cluster weight calculated. Apical berries were taken from clusters of all sample vines within a treatment replication to create a 100 berry sample. From these samples pH, titratable acidity, soluble solids, and a berry weight were measured and the number of berries per cluster calculated. The number of non-count clusters per vine was calculated from the number of clusters harvested minus the number retained after bloom thinning. Treatment comparisons of harvest data were analyzed each year and over the years 1989,1991, 1992, and 1993. Using the harvest and pruning data, shoots per cluster (total shoots/ harvest cluster number), productivity (yield per previous year's vine size), and crop load (yield per current season's vine size) were calculated for every sample vine and analyzed each year and over years. Fruitfulness (gm fruit per shoot) was calculated and analyzed during 1991-1993.

Canopy Measurements: Point Quadrat Analysis

Point quadrat assessments were taken at three times during the growing season in 1991-1993. A thin metal rod was inserted into the canopy to determine the number of leaves above the fruiting zone (24). Five insertions along the cordon were made on each treatment vine at bloom, veraison, and harvest. Insertions were always made from the West side of the canopy. A frequency distribution of the number of contacts and a seasonal history of leaf layer formation were developed.

Cold Hardiness Evaluations

Prior to pruning in 1993-1994, a cold hardiness evaluation was taken of the previous season's vegetative growth. Previous work with Seyval (28) and a re-evaluation of that work (Appendix 1) has led to a definition of Seyval cane characteristics closely associated with cold hardiness. Classifications were created from hardiness analyses done on Dec 19, 1991 and Jan 22, 1992 on Seyval canes (Appendix 1). Periderm and primary bud T50's were determined for variations within four cane characteristics, and over node positions along the cane. Canes having a medium diameter (7-10 mm), medium internode length (6-8 cm), and dark brown periderm were found to have superior cane and primary bud cold hardiness. Persistent laterals and node position (2-9) did not have any influence on cold hardiness. Total one-year-old canes were counted on each treatment vine and each cane given an excellent, acceptable, or poor classification. Excellent canes consisted of ten or more live nodes with the optimal characteristics stated above. Acceptable canes had five or more living nodes but failed in one of the optimal characteristics. Canes with less than five live nodes or failing at least two optimal characteristics were placed in the poor cold hardiness category. Samples of Seyval canes within the three classifications were collected in December, January, and March. Periderm and primary bud cold hardiness were significantly different among the treatments at the 0.01 level over the three dates. Excellent canes were superior while poor canes were inferior to acceptable canes. Using the three classifications was a rapid and effective way to evaluate the relative cold hardiness of each treatment vine.

Experimental Design and Analysis

A randomized complete block design was used with four blocks. Two rows, containing two blocks each, of self-rooted Seyval grapevines were utilized. Within each block, the treatments consisted of five sample vines. A guard row was situated outside and between the two treatment rows, and a guard vine separated each treatment. Comparisons between treatments were done using the MSTAT-C statistical computer package. Analysis was by ANOVA, with mean separations calculated using Duncan's Multiple Range Test (27). Comparisons over years were made where applicable. Point quadrat frequency distributions were calculated using the MSTAT-C computer package. In the spring of 1990 a portion of the experiment was accidentally pruned by the grower, and thus, the treatments were analyzed using only two replications that year, and were not considered in the analysis over years. The experiment was terminated after pruning in March of 1994.

Results and Discussion

Vine Yield and Fruit Composition Response

Vine yield was favored by increased node number retained. Both (FT) and (SH) vines had improved yields (25-30 percent; over a ton per acre) over the control (Table 1).

While (C) and (SH) yields fluctuated among years, the (FT) consistently produced 7 kg or more fruit per vine. Normally, these differences in yield might be the result of increased cluster number or cluster weight, composed of berry weight and number. Although large differences in nodes retained provided conditions favorable for large variations in cluster number, this variable was eliminated by the process of cluster thinning based on vine size. As a result, no significant differences were observed in cluster number at harvest (Table 2). The yield differences are, therefore, due to cluster weight and must be a result of variations in berry weight and/or the number of berries per cluster (Table 3). The (FT) system improved the components of yield compared to the other two treatments. Its average weight per cluster was the highest every year and 50 g heavier over years. Although occasional years (1989 and 1993) show a berry weight response, the major response is berry number per cluster. The (FT) treatment produced 10 percent more berries per cluster over years. Importantly, when both berry weight and berry number per cluster were significant, it was always for the (FT) treatment.

It was surprising to note minimal differences in cluster weight of (C) and (SH) vines, contrasting previous work (1,7,29). Since the vines were flower cluster thinned near bloom each year, many more shoots per cluster existed in the (SH) canopy than the (C) at that stage. The greater leaf area at bloom may explain this response. The fruitfulness data suggest a reduced yield per node, but that was expected based on the thinned treatment response.

Treatments did not affect soluble solids , pH, or titratable acidity (Table 4). The (C) berries appeared to accumulate the highest percent of soluble solids in each year, but were significantly greater only in 1989. The grams sugar per vine data are highly significant, but vary from year to year. Early, the best treatment is the (SH). However, over time it becomes clear that the better choice is the (FT) treatment. It produces the most sugar per vine over years. Interestingly, the (FT) also was the best at vegetative production and yield.

Botrytis cinerea infection of the clusters was the most noticeable fruit quality variant among canopies (Table 5). Subjective ratings on the day of harvest, showed that the amount of *Botrytis* rot was severe across treatments every year. The average loss of crop was nearly 25 percent. Severe pruning produced adventitious shoots from secondary and tertiary buds, as well as vigorous laterals from basil nodes. This created dense microclimates immediately surrounding clusters of control canopies during fruit ripening. A dense canopy inhibits air flow and chemical penetration to the clusters. In 1989 and 1993 the higher amount of rot incidence in (C) clusters influenced yield. Rot within clusters was significantly lower for (FT) and (SH) in 1989, and for (FT) compared with (C) in 1991. The number of clusters with vine rot was significantly lower for (FT) and (SH) in 1989 and 1993. The (FT) treatment showed the least amount of vine rot in 1993. Over years, vine and cluster rot incidence were significantly lower for (FT) compared to (C). Clusters on the (FT) canopy consistently had less *Botrytis* rot infection. Proper shoot spacing created an optimal canopy density limiting *Botrytis* rot infection in years of high incidence.

Vine Vegetative Growth Response

Canopy configurations were achieved in the second year (1989). Although all the vines began the study at about 250-275 grams of cane prunings per meter of row, and yield varied by 30 percent, vine size differences were very small and seldom significant (Table 6). Vine size was similar among treatments in all of the years except in 1992. In that year, (FT) produced an average of 200 more grams of cane prunings per vine than the other two treatments. Averaged over years, the (FT) produced 60 grams more than (C) and 100 gm more than (SH). The (FT) treatment had the largest vine size and was also the treatment with the highest consistent yield.

There was a strong vegetative response by the vine to varying node number at the same cluster number. The full trellis and hedged systems increased node numbers within the canopy 4 and 10 fold, respectively from the control. Control vines produced the most vegetative growth as measured by both kilograms of cane prunings per node or shoot retained (Table 6). This supports Ruhl and Clingeleffer's (17) findings on carbohydrate partitioning of reserves, but was more likely due to two factors: 1) the stimulation of non-count shoot production by (C) vines, which resulted in two-thirds of the total shoot number per vine, from non-count positions; and 2) the competition for stored reserves, nutrients and water, among the large number of primary shoots arising from count positions in the other treatments, resulting in shootless nodes on (SH) vines.

Shoot numbers among treatments did not vary as widely as the number of nodes retained due to adventitious shoot growth and shootless nodes. Adventitious shoots comprised much of the (C) canopy. These non-count shoots formed either along the cordon, or from secondary and tertiary buds when a primary shoot was present. Over years, (C) vines produced twice as many shoots from non-count sites as they did from count positions (Table 7). Less than ten were produced each year by (FT) vines and very few produced by (SH). Whatever was gained by adventitious shoots on (SH) vines, was negated by the loss of count shoots during the growing season. Even taking into account the non-count shoot contribution, total shoot number was highly significant among treatments over years. The (C) vines produced the least amount of shoots and hedging the most. The large number of non-count shoots exemplifies the severe pruning practice of the (C) treatment.

Another response to the differing bud populations per vine was the cane maturation and acclimation to cold. Cane quality varied with the number of nodes retained in the canopy (Table 8). Hedging produced the fewest number of excellent and the most poor quality canes each year. In 1993 (FT) vines matured significantly more excellent and acceptable quality canes than the other two treatments. Over years, the treatments each matured significantly different numbers of excellent quality canes. The (FT) vines had the most (11) and (SH) vines the least (4) excellent quality canes. The (FT) vines had a greater number of acceptable canes and (SH) vines had a greater number of poor quality canes over the other two treatments. These data are significant whether expressed as direct data (Table 8) or as percentage of total canes per vine (data not shown). Whether data derived from canes can express accurately characteristics of older vine tissues is not known. However, this does pose a concern (not heretofore defined) about vine culture with systems of large bud numbers. With the canopies fully developed in the later years of the study, competition between shoots became evident. Nearly half of the (SH) buds failed to produce a shoot in 1992 and 1993 (Table 9), supporting the position that excess shoots can weaken a vine's cold resistance.

According to Smart (22), an optimal canopy has no more than three leaf layers. Point quadrat assessments taken during the 1991-1993 growing seasons, showed that increased shoot number per vine increased leaf layer number each year (Figs. 1, 2, and 3). The (SH) vines produced a greater average leaf layer number throughout the growing season each year. The (SH) canopies averaged 2 layers at bloom, and over 3 layers from veraison to harvest. The (C) and (FT) canopies never obtained an average of 3 layers in any year. The (FT) canopies were also superior to (C) canopies each year. They continually had nearly half a leaf layer advantage. Most leaf layer production for (SH) canopies occurred between bloom and veraison, while (C) and (FT) canopies increased their rate of leaf layer production from veraison to harvest.

The (C) vines never completely filled the canopy with foliage during any of the growing seasons (Figs. 4-12). Gaps in the canopy still existed at harvest. The (SH) and (FT) vines filled the trellis area by veraison each year (Figs. 4-12). However, (SH) canopies formed shaded areas at bloom each year. Hedging improved canopy formation early in the growing season, consistent with prior work on hedging systems (8,9,10). However, increased shading occurred after veraison each year, contradictory to previous results with hedging systems (13,14,25). The upright growth of small shoots in hedged canopies caused the added leaf layer formation. The long, well developed shoots of control and full trellis canopies angled below the cordon later in the growing season exposing fruit and older leaves, and avoided leaf layer formation above the fruiting zone. The full trellis canopy was superior because it increased filling of the trellis with vegetation early in the growing season and allowed for further leaf development during ripening without substantial shading.

Conclusions

The treatments established three unique canopy architectures. Severe pruning and hedging were compared with a constant pruning level created to optimally space shoots along the cordon. Cluster number was consistent among treatments due to balanced cropping based on vine size. Thus, yield responses reflected differences in cluster weights. The full trellis and hedged systems increased yield by increasing cluster weight resulting from greater numbers of berries per cluster. Although the hedged canopies contained greater node numbers, the response of increased berry number was greatest in the full trellis treatment.

Retaining more nodes than currently recommended at pruning, increased shoot number within the canopy. With more shoots, canopies filled the trellis area with foliage earlier in the growing season. Creating a canopy that spaced shoots at optimum distances, increased light penetration and cane maturity, resulting in greater cane cold hardiness and deterrence to rot. Hedging increased canopy formation before bloom, but shading became a problem after veraison. With poor light levels within the canopy, hedged vines ripened fruit at the expense of vegetation and poor cane cold hardiness resulted. Dead wood accumulated in the canopy area and optimal spacing declined each year. Because of poor wood maturity, hedged vines would also be more susceptible to environmental stresses and disease. If hedging is the preferred method of pruning in Seyval, then cordon renewal is suggested for maintenance of vine health after four to five years. No advantages to vine growth were observed in the hedging system compared to the full trellis canopy. Thus, optimal shoot spacing should be the major consideration during pruning.

Literature Cited

1. Bravdo, B., Y. Hepner, C. Loinger, S. Cohen, and H. Tabacman. 1984. Effect of crop level in a high yielding Carignane vineyard on growth, yield, and wine quality. Am. J. Enol. Vitic. 35:247-252.

2. Coombe, B.G. 1962. The effect of removing leaves, flowers and shoot tips on fruit set of Vitis vinifera L. J. Hort. Sci. 37:1-15.

3. Coombe, B.G. 1976. The development of fleshy fruits. Ann. Rev. Plant Physiol. 27(2):507-528.

4. Downton, W.J.S. and W.J.R. Grant. 1992. Photosynthetic physiology of spur pruned and minimal pruned grapevines. Aust. J. Plant Physiol. 19:309-316.

5. Howell, G.S., B.S. Stergios and S.S. Stackhouse. 1978. Interrelation of productivity and cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 29:187-191.

6. Howell, G.S., D.P. Miller, C.E. Edson and R.K. Streigler. 1991. Influence of training system and pruning severity on yield, vine size, and fruit maturity of Vignoles grapevines. Amer. J. Enol. Vitic. 42(3):191-198.

7. Kaps, M.L. and G.A. Cahoon. 1989. Berry thinning and cluster thinning influence on vegetative growth, yield, fruit composition, and net photosynthesis of Seyval blanc grapevines. J. Amer. Soc. Hort. Sci. 114(1):20-24.

8. Morris, J.R., D.L. Cawthon, and J.W. Flemming. 1975. Effect of mechanical pruning on yield and quality of Concord grapevines. Ark. Farm Res. pub. 24(3):1-12.

9. Morris, J.R. and D.L. Cawthon. 1981. Yield and quality response of Concord grapes to mechanized pruning. Am. J. Enol. Vitic. 32(4):280-282.

10. Pollock, J.G., E.S. Shepardson, N.J. Shaulis, and D.E. Crowe. 1977. Mechanical pruning of American hybrid grapevines. Trans. ASAE 20(5):817-821.

11. Quinlan, J.D. and R.J. Weaver. 1970. Modification of pattern of the photosynthate movement within and between shoots of *Vitis vinifera* L. Plant Physiol. 46:527-530.

12. Reynolds, A.G., R.M. Pool and L.R. Mattick. 1986a. Effect of shoot density and crop control on growth, yield, fruit composition and wine quality of 'Seyval blanc' grapevines. J. Amer. Soc. Hort. Sci. 111(1):55-63.

13. Reynolds, A.G., and D.A. Wardle. 1989a. Impact of various canopy management techniques on growth, yield, fruit composition and wine quality of Gewurtztraminer. Am. J. Enol. Vitic. 40:121-129.

14. Reynolds, A.G. and D.A. Wardle. 1989b. Effects of timing and severity of summer hedging on growth, yield, fruit composition, and canopy characteristics of 'De Chaunac' 1. Canopy characteristics and growth parameters. Amer. J. Enol. Vitic. 40:109-120.

15. Reynolds, A.G. and D.A. Wardle. 1989c. Effects of timing and severity of summer hedging on growth, yield,fruit composition, and canopy characteristics of 'De Chaunac' 2. Yield and fruit composition. Am. J. Enol. Vitic. 40:299-308.

16. Roublelakis, K.A. and W.M. Kliewer. 1976. Influence of light intensity and growth regulators on fruit set and ovule fertilization in grape cultivars under low temprature conditions. Am. J. Enol. Vitic. 27(4):163-167.

17. Ruhl,E.H. and P.R. Clingeleffer. 1993. Effect of minimal pruning and virus inoculation on the carbohydrate and nitrogen accumulation in Cabernet franc vines. Am. J. Enol. Vitic. 44(1):81-85.

18. Shaulis, N., and R. Smart. 1974. Grapevine canopies: management microclimate and yield responses. In: Proc. XIXth International Hort. Congress. pp. 255-265. 11-18 Sept., Warsaw.

19. Sims, C.A., R.P. Johnson, and R.P. Bates. 1990. Effects of mechanical pruning on the yield and quality of Muscadine grapes. Am. J. Enol. Vitic. 41(4):273-276.

20. Smart, R.E. 1974a. Photosynthesis by grapevine canopies. J. Applied Ecology 11:997-1006.

21. Smart, R.E. 1984. Some aspects of climate canopy microclimate, vine physiology and wine quality. In: Proc. First Intl. Symp. Cool Climate Vitic. Enol. D.A. Heatherbell, P.B. Lombard, F,W. Bodyfelt, and S.F. Price (eds.). pp 1-18. June 1984, Eugene, Oregon. Oregon State Univ.

22. Smart, R.E. 1985. Principles of grapevine canopy microclimate manipulation with implications for yield and quality. A review. Am. J. Enol. Vitic. 36(3):230-239.

23. Smart, R.E. 1987. Influences of light on composition and quality of grapes. Acta Hortic. 206:37-47.

24. Smart, R.E., C.M. Seaver. 1988. Handbook for Canopy Management Workshop. Pesented at 2nd International Cool climate Viticulture and Oenology Symposium, Matua Valley Vineyard Kumeu, New Zealand. (Jan. 1988). pg. 1-20.

25. Smart, R.E., J.K. Dick, I.M. Gravett and B.M. Fisher. 1990. Canopy management to improve grape yield and wine quality - principle and practices. S. Afric. J. Enol. Vitic. 11:3-17.

26. Stergios, B.G. and G.S. Howell. 1977. Effects of defoliation, trellis height, and cropping stress on the cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 28(1):34-42.

27. Steel,R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometric Approach. McGraw-Hill Book Company, New York, NY.

28. Striegler, R.K., and G.S. Howell. 1991. The influence of rootstock on the cold hardiness of Seyval grapevines: 1. Primary and secondary effects on growth, canopy development, yield, fruit quality and cold hardiness. Vitis. 30:1-10.

29. Weaver, R.J. and R.M. Pool. 1968. Effect of various levels of cropping on *Vitis vinifera* grapevines. Am. J. Enol. Vitic. 19:185-193.

30. Winkler, A.J., J.A. Cook, W.M. Kliewer and L.A. Lider. 1981. General Viticulture. University of California Press, Berkeley.

31. Yang, Y.S. and Y. Hori. 1979. Studies on retranslocation of accumulated assimilates in 'Delaware' grapevines. I. Retranslocation of 14C-assimilates in the following spring after 14C feeding in summer and autumn. Tohoku J. of Agr. Res. 30(2):43-56.

32. Yang, Y.S., Y. Hori, and R. Ogata. 1980. Studies on retranslocation of accumulated assimilates in 'Delaware' grapevines. II. Retranslocation of assimilates accumulated during the previous growing season. Tohoku J. of Agr. Res. 31(2):109-119.

TABLE 1. Influence of pruning treatments on vine yield from 1988-1993 of Seyval grapevines at Fenn Valley vineyards.

Treatment (pruning formula)	1988 Yield (Kg/vine)	1989 Yield (kg/vine)	1990 Yield (kg/vine)	1991 Yield (kg/vine)	1992 Yield (kg/vine)	1993 Yield (kg/vine)	$\bar{X}$ (kg/vine) v
Control (8+8) w	7.79	3.57 b	10.3	6.49	7.12	4.52 b	5.35 b
Full Trellis (45) x	7.12	6.24 a	9.1	9.5	6.93	8.12 a	7.69 a
Hedge (4" radius) y	7.98	6.78 a	4.8	7.48	7.47	6.97 a	7.15 a
Sig. F	ns	**	z	ns	ns	*	**

v These means are based on the years 1989 and 1991-1993.

w Control vines pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

x Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

y Hedge treatment was accomplished using hand hedging shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

z Data incomplete due to partial pruning of plot in March of 1990. These data are based on only two replicates.

F values significant at 5% (*); 1% (**); or not significant (ns).

Means separation within columns using Duncan's New Multiple Range Test.

TABLE 2. **Influence of pruning treatments on node number at pruning and cluster number at harvest from 1988-1993 of Seyval grapevines at Fenn Valley vineyards.**

	Control v		Full Trellis w		Hedge x		
	Node #	Cluster #	Node #	Cluster #	Node #	Cluster #	Sig. F
1988	20		49		18		ns
		27		25		29	ns
1989	9 c		45 b		85 a		**
		18		20		23	ns
1990	25		41		121		z
		41		33		23	z
1991	9 c		45 b		79 a		**
		18		22		20	ns
1992	16 c		45 b		141 a		**
		19		17		25	ns
1993	11 c		45 b		129 a		**
		24		33		33	ns
$\bar{X}$ y	11 c		45 b		109 a		**
		21		23		26	ns

v Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

w Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

x Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

y These means are based on the years 1989 and 1991-1993.

z Data incomplete due to partial pruning of plot in March of 1990. These data are based on only two replicates.

F values significant at the 5% (*), 1% (**), or not significant (ns).

Mean separation within rows using Duncan's New Multiple Range Test.

TABLE 3. ***Influence of pruning*** **treatments on cluster wt., berry wt., and berries/cluster at harvest from 1989-1993 of Seyval grapevines at Fenn Valley vineyards.**

	Control v			Full Trellis w			Hedge x			
	Cluster wt (gm)	Berry wt (gm)	Berries/ Cluster	Cluster wt (gm)	Berry wt (gm)	Berries/ Cluster	Cluster wt (gm)	Berry wt (gm)	Berries/ Cluster	Sig. F
1989	208 b			314 a			300 a			*
		2.38 a			2.04 b			2.19 ab		*
			89 b			154 a			138 ab	**
1990	255			277			209			z
		1.80			2.00			2.00		z
			141			139			114	z
1991	353 b			436 a			363 b			*
		2.01			1.99			1.98		ns
			180 b			209 a			184 b	*
1992	386 b			417 a			327 c			*
		1.98			2.15			1.99		ns
			195			194			166	ns
1993	188 b			256 a			212 ab			**
		1.96 b			2.25 a			1.97 b		*
			96			114			108	ns
$\bar{X}$ y	282 b			346 a			296 b			**
		2.08			2.10			2.03		ns
			140 b			168 a			149 ab	**

v Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.
w Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.
x Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.
y These means are based on the years 1989 and 1991-1993.
z Data incomplete due to partial pruning of plot in March of 1990. These data are based on only two replicates.
F values significant at the 5% (*), 1% (**), or not significant (ns).
Mean separation within rows using Duncan's New Multiple Range Test.

TABLE 4. ***Influence of pruning*** **treatments on fruit composition and vine sugar production at harvest from 1989-1993 of Seyval grapevines at Fenn Valley vineyards.**

	Control u				Full Trellis v				Hedge w				
	%SS	pH	TA	Gm. Sugar x	%SS	pH	TA	Gm. Sugar x	%SS	pH	TA	Gm. Sugar x	Sig. F
1989	16.7 a				15.5 b				15.4 b				*
		3.02				3.06				3.08			ns
			1.63				1.46				1.53		ns
				59.6 b				96.7 a				105.8 a	**
1990	20.8				18.9				19.4				z
		3.11				3.04				3.06			z
			0.70				0.78				0.74		z
				214.2				172.0				93.1	z
1991	20.7				19.6				20.7				ns
		3.38				3.37				3.45			ns
			0.62				0.63				0.61		ns
				134.3 b				186.2 a				154.8 ab	**
1992	16.2				16.0				153				ns
		3.03				3.09				2.85			ns
			0.94				0.89				0.87		ns
				115.3				110.8				114.3	ns
1993	18.5				18.4				17.8				ns
		3.21				3.27				3.21			ns
			0.59				0.61				0.62		ns
				83.6 c				149.4 a				124.1 b	**
$\bar{X}$ y	18.0				17.4				17.3				ns
		3.16				3.20				3.15			ns
			0.94				0.90				0.91		ns
				96.0 c				133.8 a				123.7 b	**

u Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.
v Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.
w Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon.
Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.
x Grams sugar per vine = %SS (gm yield/vine).
y These means are based on the years 1989 and 1991-1993.
z Data incomplete due to partial pruning of plot in March of 1990. These data are based on only two replicates.
F values significant at the 5% (*), 1% (**), or not significant (ns). Mean separation within rows using Duncan's New Multiple Range Test.

TABLE 5. Influence of pruning treatments on incidence of Botrytis rot within and among clusters at harvest from 1989-1993 of Seyval grapevines at Fenn Valley vineyards.

	Control t		Full Trellis u		Hedge v		
	Cluster Rot w	Vine Rot x	Cluster Rot w	Vine Rot x	Cluster Rot w	Vine Rot x	Sig. F
1989	4.3 a		2.5 b		2.4 b		**
		4.6 a		2.7 b		2.5 b	**
1990	1.7		3.0		2.4		z
		1.9		3.8		3.1	z
1991	2.0 a		1.2 b		1.5 ab		*
		2.2		1.4		1.5	ns
1992	2.5		2.6		3.1		ns
		3.6		3.2		4.1	ns
1993	2.6		2.2		2.6		ns
		3.2 a		1.9 c		2.6 b	**
$\bar{X}$ y	2.8 a		2.1 b		2.4 ab		*
		3.4 a		2.3 b		2.7 ab	*

t Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

u Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

v Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

w Within cluster rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of berries within the clusters were rotten.

x Vine rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of clusters on the vine were rotten.

y These means are based on the years 1989 and 1991-1993.

z Data incomplete due to partial pruning of plot in March of 1990. These data are based on only two replicates.

F values significant at the 5% (*), 1% (**), or not significant (ns).

Mean separation within rows using Duncan's New Multiple Range Test.

TABLE 6. Influence of pruning treatments on vine size and growth per node retained at pruning from 1988-1993 in Seyval at Fenn Valley Vineyards. Growth per shoot was calculated from 1991-1993.

	Control v			Full Trellis w			Hedge x			
	Vine Size (kg/vine)	Veg. Growth per node (g)	Veg. Growth per shoot (g)	Vine Size (kg/vine)	Veg. Growth per node (g)	Veg. Growth per shoot (g)	Vine Size (kg/vine)	Veg. Growth per node (g)	Veg. Growth per shoot (g)	Sig. F
1988	0.41			0.51			0.36			ns
		21			28			21		ns
1989	1.16			0.64			0.61			z
		129			14			7		z
1990	0.33			0.45			0.39			ns
		35 a			11 b			3 c		**
1991	0.62			0.44			0.50			ns
		73 a			10 b			6 b		**
			20			14			16	ns
1992	0.56 b			0.76 a			0.51 b			*
		56 a			16 b			5 c		**
			16 a			17 a			7 b	**
1993	0.53			0.49			0.47			ns
		51 a			11 b			4 c		**
			18 a			10 ab			7 b	*
$\bar{X}$ y	0.48 ab			0.54 a			0.44 b			*
		47 a			15 b			8 c		**
			18 a			14 ab			10 b	**

v Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

w Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

x Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

y These means are based on the years 1988 and 1990-1993.

z Data incomplete due to partial pruning of plot in March of 1990. These data are based on only two replicates.

F values significant at the 5% (*), 1% (**), or not significant (ns).

Mean separation within rows using Duncan's New Multiple Range Test.

TABLE 7. **Influence of pruning treatments on shoot population measured after veraison from 1991-1993 in Seyval at Fenn Valley vineyards.**

	Control x			Full Trellis y			Hedge z			
	Count	Non-Count	Total	Count	Non-Count	Total	Count	Non-Count	Total	Sig. F
1991	10 b			38 ab			44 a			**
		18 a			7 ab			0 b		**
			28			30			42	ns
1992	14 b			39 ab			70 a			**
		21 a			4 b			0 c		**
			35 b			43 ab			65 a	**
1993	9 c			40 b			72 a			**
		25 a			9 b			0 c		**
			34 b			49 b			72 a	**
$\bar{X}$	11 c			40 b			71 a			**
		23 a			6 b			0 b		**
			34 c			46 b			68 a	**

x Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

y Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

z Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

F values significant at the 5% (*), 1% (**), or not significant (ns).

Mean separation within rows using Duncan's New Multiple Range Test.

TABLE 8. Influence of pruning treatments on cane quality as assessed after leaf fall from 1991-1993 in Seyval at Fenn Valley vineyards.

	Control u			Full Trellis v			Hedge w			
	Excellent x	Acceptable y	Poor z	Excellent x	Acceptable y	Poor z	Excellent x	Acceptable y	Poor z	Sig. F
1991	9 a			6 b			3 c			*
		8			10			8		ns
			7 c			14 b			31 a	**
1992	9 a			11 a			4 b			**
		11			12			10		ns
			15 b			19 b			51 a	**
1993	8 b			14 a			4 b			**
		14 b			20 a			16 b		*
			12 b			14 b			51 a	**
$\bar{X}$	8 b			11 a			4 c			**
		11 b			14 a			11 b		**
			13 b			15 b			41 a	**

u Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

v Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

w Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

x Excellent quality canes consisted of 10 or more live nodes with optimal cold hardiness characteristics.

y Acceptable quality canes consisted of 5 or more live nodes but failed one of the optimal cold hardiness characteristics.

z Poor quality canes consisted of less than 5 live nodes or failed at least two of the optimal cold hardiness characteristics.

F values significant at the 5% (*), 1% (**), or not significant (ns).

Mean separation within rows using Duncan's New Multiple Range Test.

TABLE 9. Influence of pruning treatments on occurance of shootless nodes to Seyval grapevines measured just past bud burst from 1991-1993 at Fenn Valley vineyards. Expressed as percent blind nodes.

	1991		1992		1993		Average Over Years	
	#/Vine	%	#/Vine	%	#/Vine	%	#/Vine	%
Control x	2 b	26	1 b	5 b	4 b	20 b	2 b	17 b
Full Trellis y	7 b	16	6 b	13 b	5 b	11 b	6 b	13 b
Hedge z	20 a	26	71 a	50 a	59 a	46 a	48 a	42 a
Sig. F	**	ns	**	**	**	**	**	**

x Control vines were pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

y Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

z Hedge treatment was accomplished using hand shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node.

F values significant at the 5% (*), 1% (**), or not significant (ns).

Mean separation within rows using Duncan's New Multiple Range Test.

Fig. 1. Effect of canopy configuration on seasonal canopy development averaged from 1991-1993 of Seyval grapevines at Fenn Valley vineyards, expressed as leaf layer number.

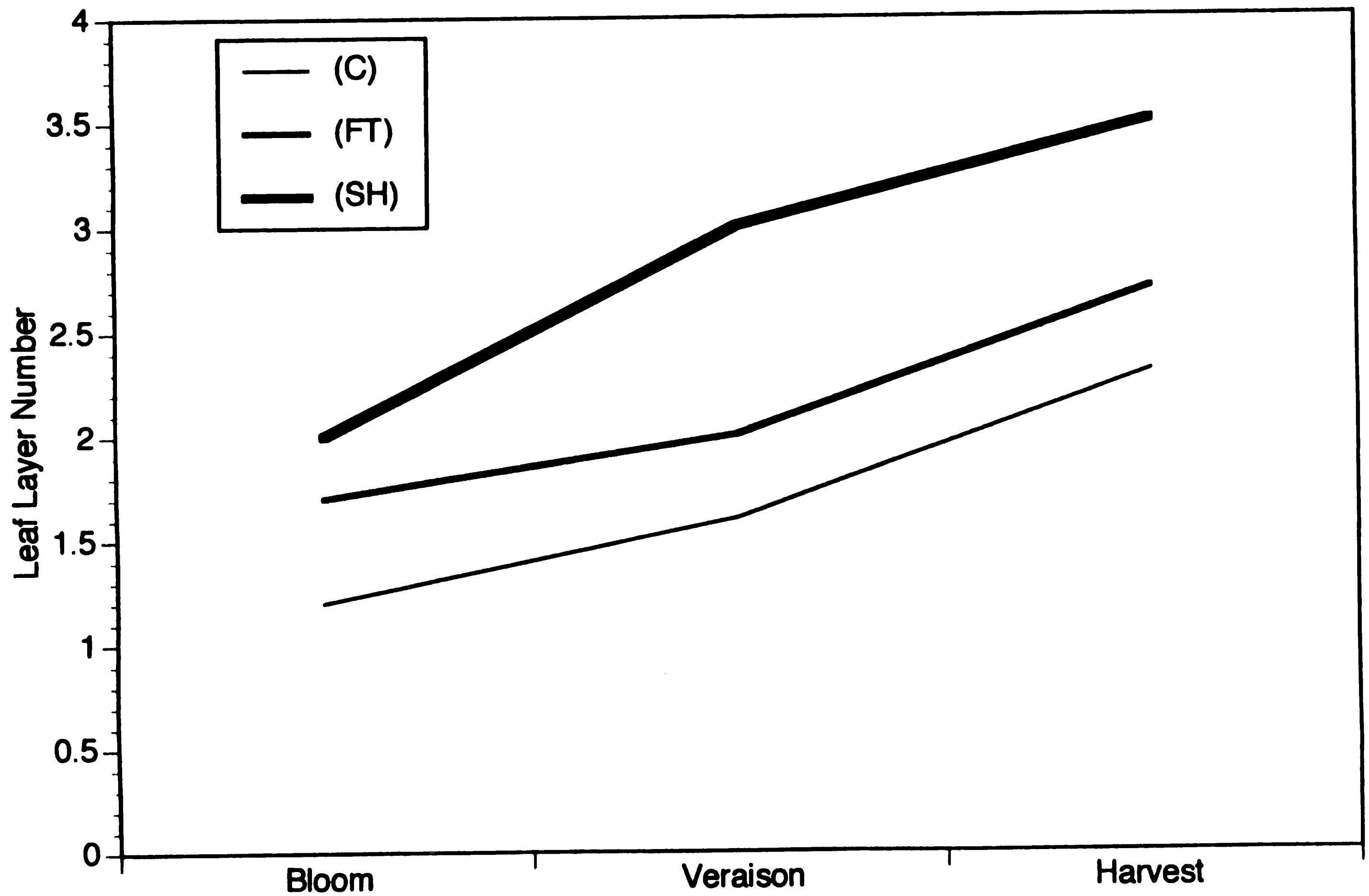


Fig. 2. Frequency distribution averaged from 1991-1993 of the number of contacts (leaves and fruit) measured at bloom by point quadrat for Seyval grapevines pruned to three canopy configurations. Zero contacts represents a gap in the canopy.

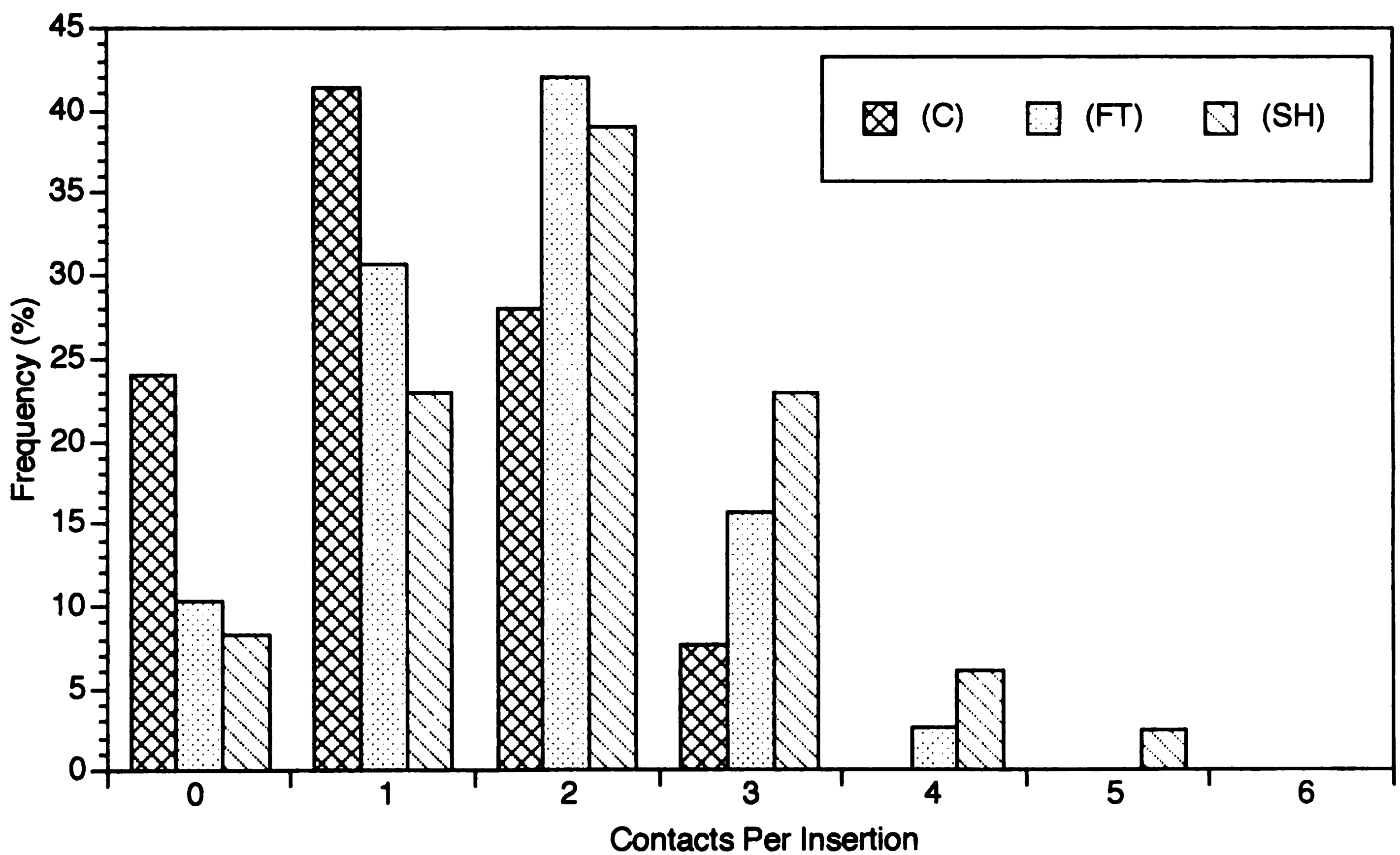


Fig. 3. Frequency distribution averaged for 1991-1993 of the number of contacts (leaves and fruit) measured at veraison by point quadrat for Seyval grapevines pruned to three canopy configurations. Zero contacts represents a gap in the canopy.

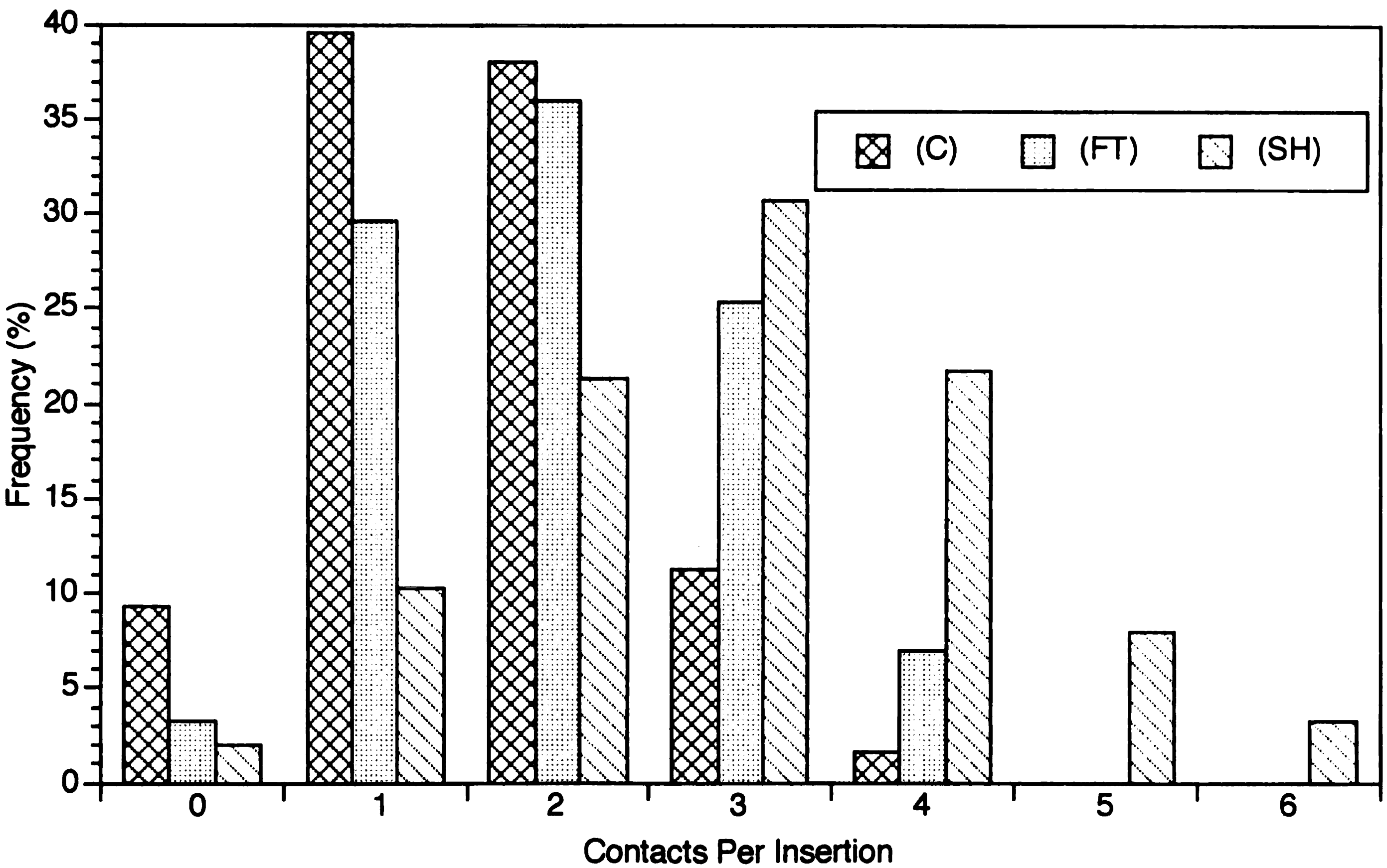
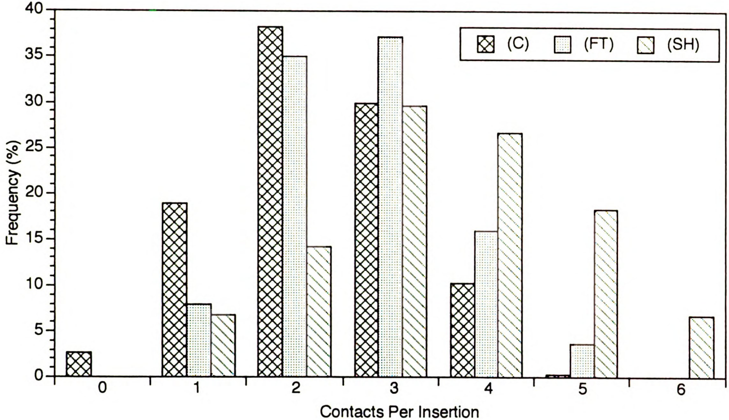


Fig. 4. Frequency distribution averaged for 1991-1993 of the number of contacts (leaves and fruit)measured at harvest by point quadrat for Seyval grapevines pruned to three canopy configurations. Zero contacts represents a gap in the canopy.



CHAPTER II

INFLUENCE OF CANOPY CONFIGURATION ON SHOOT GROWTH, LEAF DEVELOPMENT, AND LEAF AREA OF SEYVAL GRAPEVINES

Abstract

Seyval grapevines were trained to three canopy configurations in 1988. One treatment filled the trellis early (Full Trellis) by spacing 45 buds along the cordon. Another simulated a hedge (Hedge) by hand pruning four inches around the cordon. A control was used where vines were balanced pruned to 8 nodes per 454 g. cane prunings. All vines were flower cluster thinned to 15 clusters per 454 g. cane prunings. Shoot measurements were taken throughout the 1993 growing season, including a leaf area measurement at harvest. The full trellis and hedge treatments had a larger number of nodes retained and increased shoot and leaf development early in the growing season. The full trellis vines provided higher yields by producing heavier clusters with larger berries. Full trellis and hedged vines also produced a greater leaf area through verasion. But, by harvest, severely pruned vines obtained a leaf area equal to the other treatments. This resulted from new leaf production from laterals. The full trellis vines also produced many new leaves during fruit ripening, however, hedging showed little leaf production after veraison. Severe pruning caused an increase in *Botrytis* bunch rot in 1993, but, no other significant differences in fruit quality or vine size were observed. A canopy structure that exhibits early shoot and leaf development with properly spaced shoots and yet allows for new leaf production during fruit ripening, appears to be the best canopy configuration for Seyval grapevines.

Introduction

Seyval is an important white wine grape cultivar across the Eastern United States. It has numerous desirable characteristics. It is cold hardy, disease resistant, and phylloxera resistant. It does, however, form large, compact clusters susceptible to cluster rot under

Michigan conditions and the large clusters can lead to overcropping. Crop levels are usually maintained by severe balance pruning and flower-cluster thinning. Reynolds et al. (19) suggested an optimal cropping level of 17 clusters per 500 grams of cane prunings in New York state. Severe pruning reduces the thinning expense incurred by the grower, but results in a later filling of the canopy and thus potential loss of photosynthesis. The current suggested balanced pruning formula is 15+10 (15 nodes retained for the first 454 gm of dormant one year cane prunings, and 10 nodes retained for each additional 454 gm). This results in a canopy that does not fill the trellis area until after fruit set.

The photosynthate produced during the vegetative season must drive the processes of vegetative growth, fruiting, and flower bud development for next years crop. Reserves must also be stored over the winter for cold hardiness, and initiation of growth and development until a new canopy is producing photosynthate the following spring. Equally as significant is the mobilization and transport of assimilate between different organs of the vine in order to carry out these processes.

Grapevine shoot development has been an area of recent interest and research. Spring shoot growth is dependant on the remobilization of carbohydrates stored in roots, trunks, cordons, and canes from the previous year (38,39), and cluster development is slow until leaf area is established (37). Shoots become net exporters of carbohydrates during anthesis (18). Cell division before anthesis and cell expansion after anthesis are the major determinants of the increase in weight of grape berries (4). Thus, it seems important to fill the trellis area with vegetative growth and leaf surface as early as possible to facilitate vine growth and fruit development.

Leaf development is important for fruit and shoot maturity. A leaf number greater than 10 per shoot is necessary for optimal fruit ripening and shoot weight (34,36). Leaf photosynthesis is greatest when the leaf is fully expanded, and then gradually declines shortly after (17). The amount of photosynthate produced by each leaf is important for the development of the subtending bud (6,27). Over eighty percent of the assimilate a cluster collects is produced by the leaves on the same side of the shoot (14,15). Buttrose (2) found that as leaf number was reduced, root dry weight decreased most severely, followed by reductions in berry development, and then trunk and shoot carbohydrate reserves. Increasing the number of leaves per shoot increases berry sugar, weight, and coloration at harvest (34). However, the production of each new leaf adds to the vine leaf area and the formation of leaf layers within the canopy.

The leaf area of the vine is critical because it produces the assimilate necessary for crop ripening and wood maturity. A minimum leaf area of 7-14 cm^2 per gram of fruit is needed for adequate fruit ripening (10,31). Smart showed that a dense canopy can reduce light levels to 1% of the solar radiation in the fruiting and renewal zone (28), and an optimal canopy has no more than three leaf layers (29). Light penetration into the canopy is important for photosynthesis (11,26), fruitfulness (8,25), flower bud formation (25,28), fruit set (3,23), fruit quality (20,22,30), yields (25), and wood hardiness (7,25,32). Thus, it is evident that a maximum leaf area exists where light penetration into the canopy is restricted to the point that vine productivity begins to diminish. The maintenance of this leaf area is important to maximize the amount of assimilate produced in the vegetative season for vine growth and development. When this maximum leaf area to facilitate vine growth is established is of great interest.

Mechanical hedging, selective hand pruning, or no pruning at all, increase the number of buds retained for potential shoot production from the previous years vegetative growth. These minimally pruning management techniques change vine morphology. They increase the leaf area before bloom and decrease leaf production after (5). Minimally pruned vines partition fixed carbon differently than conventional pruned vines (5). They store more carbohydrates in old wood and less in their canes and roots (24). Increasing shoot number increases canopy density (7) and the labor expense incurred by cluster thinning fruitful varieties.

Mechanical hedging has received increasing attention in the United States, since the pioneering efforts of the Australian researchers. This is suggested to be a cost effective alternative to hand pruning. Hedging leaves more buds in the canopy area, increasing the amount of vegetation per foot of row and per square foot of canopy space (12,13,16). With no further crop control, increasing shoot number yields more clusters per vine, and thus increased sink competition and higher crop levels. This in turn results in morphological characteristics such as reduced shoot length, leaf size, cluster size, cluster weight, and berry weight (1,9,35). Whole canopy microclimate improves (20,21) and photosynthetic efficiency increases through reduced shading (31). However, hedging alone has shown only to be useful for a few years before yields, fruitfulness, and fruit quality diminish (12,13,16). Given the differences in climate and limitations of sunlight and carbon assimilation between the North Eastern United States and Australia, an objective evaluation of the limitations of this technology deserves effort and Seyval would seem to be a good candidate for this effort. Since thinning is required to control overcropping in Seyval, the crop level can be managed so that the influence of canopy configuration and decreasing pruning severity on shoot and leaf development, can be further investigated. Reducing labor expenses by mechanical hedging would greatly decrease the cost of producing this variety.

Experimental Objectives:

1. To determine the results of increasing bud numbers and balanced cropping (based on the previous years vine size) on vegetative growth, yield, and fruit composition and quality in Seyval.

2. To evaluate balanced cropping with a set pruning number of buds retained, designed to space shoots at optimal distances from each other along the cordon in Seyval.

3. To analyze the impacts of hedging in conjunction with balanced cropping by cluster thinning in Seyval.

4. To measure the impact of these pruning/cropping strategies on shoot, lateral, and leaf development in Seyval.

5. To measure the impact of these pruning/cropping strategies on leaf area formation in Seyval.

Materials and Methods

Plant Material

The experiment was performed during the 1993 growing season, 4.5 miles East of Lake Michigan (42-15' latitude) at Fenn Valley vineyards in Fennville Mi. Mature, bearing Seyval grapevines planted in 1975 on an Oshtemo sandy-loam soil were used in the experiment. Three unique canopy configurations were initiated in 1988. Rows were spaced 3.0 meters apart with vines 2.4 meters apart within rows. The vines were trained to a bilateral cordon on the top wire, 1.8 meters high (Hudson River Umbrella training system).

Pruning Treatments

The three canopy configurations consisted of: 1) a full trellis treatment (FT) spacing 45 buds along the cordon with five-node canes and two-node spurs; 2) a mechanically pruned hedge (SH) was simulated by hand pruning four inches around the cordon; and 3) a control (C) (the current standard cultural method) was employed to ensure a typical rate of canopy development. In all cases an 8+8 balance pruning formula (8 buds retained for every 454 grams of dormant one year cane prunings) was used.

The control and full trellis vines were pruned to 45-nodes and the live one-year cane prunings weighed to estimate the previous year's vine size. The node number for the control vines was then set for the duration of the growing season following the procedures stated above. Because hedged vines retained a larger number of nodes, a method was devised to estimate the weight of retained wood. After pruning the hedge treatment, the live canes were weighed and nodes counted. The remaining live nodes of canes on the vine were counted. A weight was assigned to the number of nodes over 45 retained on the vine, based on a node weight of 113 gm per 50 nodes. This weight and the weight of cane prunings were added producing the vine size estimate for each (SH) vine.

Since pruning is not sufficient for optimal crop control in Seyval, cluster thinning was also required. The weight of live one-year-old canes at pruning (vine size) was used to determine cluster number after thinning. The treatments were flower-cluster thinned just prior to or during bloom to 15-clusters per 454 grams of dormant cane prunings. At bud burst, nodes that did not produce a shoot (shootless nodes) were counted. Percent blind nodes, vegetativeness (vine size (gm) per shoot), count shoots (nodes retained at pruning minus blind nodes), and non-count shoots (total shoots minus count shoots) were calculated for each vine.

Harvest Procedures and Fruit Quality Assessments

Treatment vines were harvested October 1. Each sample vine was hand harvested, the cluster number recorded and the fruit placed into an individual bin. Each bin was then weighed in the field and a cluster weight calculated. Apical berries were taken from clusters of all sample vines within a treatment replication to create a 100 berry sample. From these samples pH, titratable acidity, soluble solids, and a berry weight were measured and the number of berries per cluster calculated. Using the harvest and pruning data, shoots per cluster (total shoots/ harvest cluster number) was calculated.

Shoot and Leaf Measurements

During the 1993 growing season, detailed shoot and leaf measurements were taken on one vine from each treatment block. The vines were selected to conform to an average vine size range (0.57-0.91 kg). Within each sample vine, six shoots were randomly flagged along the cordon for vegetative measurements during the growing season. These included: 1) primary shoot length (PSL); 2) primary shoot leaf number (PSLF); 3) lateral number; 4) lateral length (LL); and 5) lateral leaf number (LLF); measured on May 26 (WK3 weeks after bud burst), June 2 (WK4), June 9 (WK5), June 16 (WK6), June 30 (WK8), July 29 (WK12), and September 23 (WK21) one week prior to harvest. Additional calculated data included total leaves per shoot (TSLF=PSLF+LLF) and total vegetative shoot length (PSL+LL). Treatment comparisons were made at appropriate dates and over dates on those variables measured or calculated.

At thinning, three of the sample shoots were defruited while one cluster was retained on the other three. Shoot development with and without a fruiting sink, was compared for the remainder of the growing season. A standard curve was developed to allow rapid determination of flower number per cluster based on cluster length. Thirty clusters were randomly sampled from guard vines just prior to bloom. Rachis length was calculated using the length of rachis from the lowest basal arm to the tip added to the length of the lowest basal arm. Flowers of each sample cluster were counted and a strong correlation was found (Fig. 1). The rachis length of clusters on sample shoots was measured and an estimated flower number calculated. At harvest, berry pedicles of sample shoot clusters were counted and the percentage of berries set analyzed.

A count of shoots longer than 10 cm and bearing three or more leaves was taken two weeks prior to harvest. Primary leaves per vine (PSLF*SC), lateral leaves per vine (LLF*SC), and total leaves per vine (TSLF*SC) were then calculated and compared between treatments. A leaf area standard curve was developed for primary shoot and lateral leaves at WK21 by sampling 100 primary shoot leaves and 50 lateral leaves randomly from guard vines. The mid-rib length and area was measured for each leaf. A strong curvilinear relationship was found between mid-rib length and leaf area for primary shoot (Fig. 2) and lateral leaves (Fig. 3). Mid-rib lengths of leaves from sample shoots were measured WK21 and leaf area calculated using the standards. Leaf area was calculated on a per leaf, per shoot, per vine, per cluster, and per yield basis for comparison. Leaf area accumulation per vine over the 1993 growing season was calculated using the average leaf area and number of both primary and lateral leaves in each treatment.

Experimental Design and Analysis

A randomized complete block design was used with four blocks. Two rows, containing two blocks each, of own rooted Seyval grapevines were utilized. Within each block, the treatments consisted of five sample vines. A guard row was situated outside and between the two treatment rows, and a guard vine separated each treatment. Comparisons between treatments were done using the MSTAT-C statistical computer package. Analysis was by ANOVA, with mean separations calculated using Duncan's Multiple Range Test (33). Leaf area regressions were calculated using the Delta Graph computer package.

Results and Discussion

Vine Yield and Fruit Quality

Vine yield was favored by a decrease in pruning severity (Table 1). The (FT) and (SH) vines produced 35-40 percent more fruit than (C). Normally, these differences in yield might be the result of increased cluster number or cluster weight. Although large differences in nodes retained provided conditions favorable for large variations in cluster number, this variable was eliminated by the process of cluster thinning based on vine size. As a result, no significant differences were observed in cluster number at harvest (Table 1). The yield differences are, therefore, due to cluster weight, and must be a result of variations in berry weight and/or the number of berries per cluster (Table 1). The (FT) system improved the components of yield compared to the other two treatments. Its average weight per cluster was 17-27 percent heavier. Since there were no significant differences in the percent berry set or number of berries per cluster among treatments, the major response was berry weight in 1993. The (FT) treatment produced berries nearly 10 percent greater than the other treatments.

The minimal differences in cluster weight of (C) and (SH) vines contrast with previous work (1,9,35). Since the vines were flower cluster thinned near bloom each year, many more shoots per cluster existed in the (SH) canopy than the (C) at that stage. The greater leaf area at bloom may explain this response. The fruitfulness data suggest a reduced yield per node, but that was expected based on the thinned treatment response.

Fruit composition data provided little basis for discriminating among treatments (Table 1). There were no differences among soluble solids , pH, and titratable acidity. *Botrytis cinerea* infection of the clusters was the most noticeable fruit quality variant among canopies. Subjective ratings performed the day of harvest showed that the amount of *Botrytis* rot was severe across all treatments. The average loss of crop was nearly 25 percent. No significant differences were observed in rot incidence within clusters, however, the higher amount of rot incidence in (C) clusters expressing rot (vine rot), influenced yield (Table 1). The (FT) vines showed less incidence of vine rot in 1993. The full trellis canopy was the least conducive to *Botrytis* rot infection.

Vine Vegetative Growth Response

No significant differences were found in vine size; however, increasing the number of nodes retained reduced vegetative vine growth measured by kilograms of cane prunings per node (Table 2). This result was likely due to two factors: 1) the stimulation of non-count shoot production in (C) vines, which resulted in three-quarters of the total shoot number per vine from non-count positions; and 2) the competition for stored reserves, nutrients and water among the large number of primary shoots arising from count positions in the (SH) canopies resulted in shootless nodes.

Adventitious shoots comprised much of the (C) canopy. These non-count shoots formed along the cordon, or from secondary and tertiary buds when a primary shoot was present. Since nearly all of the count shoots were needed to carry the crop load, non-count shoots served as additional sources of photosynthate. Some of these adventitious shoots produced flower clusters. Because they developed as quickly as on non-count shoots, they were thinned during bloom as well. The competition among shoots was most evident in the hedged vines, as many buds failed to produce any growth. Less than ten non-count shoots were produced by the (FT) vines and very few produced by (SH). Whatever was gained by adventitious shoots on (SH) vines, was negated by the loss of count shoots during the growing season. The (SH) vines also produced two to four times as many shootless nodes as the other treatments. Even taking into account the non-count shoot contribution and shootless nodes, total shoot number was highly significant among treatments (Table 2). The (C) vines produced the least amount of shoots and (SH) the most. The large number of non-count shoots exemplifies the severe pruning practice of the (C) treatment; while the shootless nodes in hedged vines indicate vine capacity is attained.

Shoot Assessments

Because shoots begin exporting carbohydrates during anthesis, shoot development early

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early in the spring is important for overall vine production. Seyval clusters are very large and become strong carbohydrate sinks at fruit set. Berry growth and most of the vegetative growth in a season occurs between bloom and verasion (4). Laterals form just prior to bloom and grow for the remainder of the season. Shoots thinned of fruit are sources of photosynthate for various sinks within the vine. During the 1993 growing season, detailed shoot measurements were taken on six sample shoots from one vine in each treatment block. Shoots of (FT) vines were more developed before bloom. Between WK3 and WK6, (FT) vines had a greater primary shoot length than (C) or (SH) (Fig. 4). This suggests the (FT) shoots were able to utilize reserves better than the other treatments and become self sufficient earlier. The earlier shoot and leaf development of the (FT) vines coincides with early cell division in the berry (4), and may be the cause for their superior berry weights. The (C) shoots caught up in length to (FT) shoots by WK12, and they both averaged more than 40 cm longer than (SH) shoots at harvest. Shoot growth rate for each treatment increased after WK6 and decreased again after WK12. Little primary shoot growth was achieved by (SH) after veraison, while (C) and (FT) shoots continued to grow.

Since internode length remained consistent between treatments at every date, leaf production was closely related to primary shoot length. The (FT) shoots averaged one more leaf on WK4 (Fig. 5). At veraison, (C) and (FT) primary shoots averaged 5 more leaves than (SH). This response continued through harvest, but as (FT) and (SH) primary shoots stopped producing leaves, (C) primary shoots increased leaf number. New leaf growth rate for each treatment increased after WK6 and decreased again after WK12.

Lateral growth began to appear during WK6. By WK12, (C) and (FT) shoots produced over twice as many laterals than (SH) (Fig. 6). None of the canopies produced new lateral shoots after verasion. The laterals of (C) and (FT) shoots produced more leaves than (SH) shoots by verasion, and continued to produce more till harvest (Fig. 7).

They also had a greater rate of elongation between WK6 and WK8, and length at harvest (Fig. 8). Rate of elongation after anthesis was inversely related to bud number. Shoots of (SH) vines were considerably smaller with less leaves and lateral growth.

No differences were found in the total vegetative shoot length until WK21 when (SH) shoots were inferior to the other two treatments (Fig. 9). Shoots of (SH) also had fewer leaves per shoot than the (C) shoots on WK12 and WK21 (Fig. 10). Over dates measured, (SH) shoots were inferior to (C) and (FT) shoots in length and leaf number, while control and (FT) shoots were never significantly different from each other. This agrees with previous work with hedging systems (1,9,35). Shoots with and without a cluster were compared in each treatment and no significant differences or interactions were found at any date. However, shoot and leaf measurements on defruited shoots were significantly greater than shoots bearing fruit over the year.

Canopy type influenced the rate of growth between veraison and harvest (Table 4). At veraison the (SH) vines averaged 2800 leaves, 600-800 more than (C) or (FT). Only 12 percent (389 leaves) of the total (SH) leaf production was grown between veraison and harvest. The (C) and (FT) vines produced 900 (31%) and 700 (24%) of their leaves during this time respectively. Lateral shoots were responsible for the additional leaf production after veraison. Laterals provided young, productive leaves during fruit ripening. The (C) and (FT) canopies produced laterals that continued to produce leaves after veraison, while (SH) shoots had little lateral leaf production. The lack of new leaf production after veraison in (SH) vines suggests older, less photosynthetically efficient (17) leaves were responsible for photosynthate production during fruit and wood ripening. Although, fruit quality was not affected, wood maturity was a concern. The vegetativeness per shoot was significantly lower in (SH) vines (Table 2).

Leaf Area Measurements

The mid-ribs of leaves from sample vines were measured at harvest. The (SH) primary shoot leaves were significantly smaller than those of the other two treatments (Table 3). However, no differences among treatments were seen in lateral leaf area or the whole shoot average area per leaf. Shoot leaf area was directly related to leaves per shoot and inversely related to shoot number (Table 3.). The (SH) vines produced the fewest leaves per shoot and the least leaf area per shoot. They produced a primary shoot leaf area over 750 square centimeters smaller than the other two treatments and a 70 percent decrease in lateral shoot leaf area from the control; leaf area per whole shoot was over 45 percent smaller than (C) and (FT). The (FT) and (C) vines never varied significantly in leaf number or leaf area per shoot. Obviously, there exists a limit in the number of vegetative sinks a vine can support and grow to full potential. Shoots with and without a cluster were compared in each treatment and no significant differences or interactions were found. Thus, the crop level influence was over the entire vine and not limited to the shoot.

Leaf area per vine at harvest was calculated using the average area per leaf, total leaves per shoot, and number of shoots per sample vine (Table 4). Although (SH) shoots were less developed and possessed less leaf area, no significant differences among treatments in the total number of leaves or leaf area per vine at harvest were observed (Table 4). (SH) shoots averaged over 3000 leaves per vine with an area more than 16 meters square. However, it is interesting to note how the treatments achieved this leaf area. Using the average leaf area for primary shoot and lateral leaves and the leaf number of each of these at the dates counted, a seasonal history of leaf area development was constructed (Fig. 11). Increasing the number of shoots within the canopy increased the leaf area from pre-bloom until after veraison, supporting Downton and Grant's results (5) on minimal pruned vines. Lateral shoots produced the additional leaf area in the (C) and (FT) vines from veraison to harvest. Leaf area per cluster was not significantly different among treatments, although (FT) and (SH) had 1000 and 1500 square centimeters less per cluster than (C) respectively. Significant differences among treatments did surface when leaf area was expressed per gram of yield. The (FT) and (SH) vines produced over 10 cm^2 less leaf area per gm yield than (C) vines (Table 4). However, all the treatments produced over 20 cm^2 of leaf area per gram of fruit, sufficient to adequately ripen fruit (10,31). A greater leaf area, necessary to ripen fruit and wood in Michigan's climate, was expected. Canopy configuration and increased bud numbers increased the amount of leaf area through veraison, though the leaf area response to increasing node number was limited. The (SH) vines never achieved greater amounts of leaf area compared to the (FT) vines.

Conclusions

The treatments established three unique canopy architectures. Severe pruning and hedging were compared with a constant pruning level created to optimally space shoots along the cordon. Increasing node number at pruning increased yield with no affect on pH, titratable acidity, or soluble solids. Cluster number was consistent between treatments because of balanced cropping based on vine size. Yield responses were due to an increase in berry weight.

The greatest cause for a decrease in fruit quality or crop loss was *Botrytis* rot infection. An average of 25 percent of the crop was lost between all of the treatments. The adventitious shoots forming from secondary and tertiary buds, as well as vigorous laterals from basil nodes, formed a dense leaf area immediately around the control clusters. A dense canopy inhibits air flow and chemical penetration to the clusters. Crop loss was most severe in control vines, while the full trellis canopy was the most consistent in avoiding rot infection due to optimally spaced shoots creating a low leaf density around the clusters.

It is evident that early shoot development is important for fruit development. Severe pruning inhibited shoot and leaf area development and promoted adventitious shoot growth early in the growing season. Because of greater shoot numbers, the hedged and full trellis canopies developed earlier. However, the full trellis canopy configuration was superior because of optimal vegetative sink competition and leaf area development allowing for better shoot development. This resulted in the full trellis vines yielding the heaviest clusters with the largest berries. Full trellis vines seldom producing shoots from non-count positions. In the hedging system, vines achieved their full capacity, since all of their vegetative growth arose from count positions and shoot abortion occurred throughout the growing season. Dead wood accumulated in the canopy and optimal shoot spacing declined each year.

Because sufficient source levels were available, the control and full trellis canopies produced large primary shoot leaves and lateral shoots. The lateral leaves were an important component of total leaf area. However, much of the leaf and leaf area production by control canopies was produced after verasion. Small primary shoot leaves comprised most of the leaf area of hedged canopies. Full trellis and hedged vines produced a greater leaf area through verasion; however, new leaf production in hedged vines decreased because of the lack of laterals. Laterals provided young, productive leaves during fruit ripening. The full trellis canopy was superior because it increased shoot development early in the growing season and allowed for further leaf area development during fruit and wood ripening. This was not an advantage in 1993, since each treatment produced more than enough leaf area to sufficiently ripen fruit. However, if crop levels were to be increased, mid to late season leaf production could be crucial. Increasing node number per vine by hedging showed no advantage over the full trellis system in production of leaf area or fruit. Hand pruning to a set number of buds spaced along the cordon produced the best canopy configuration in this experiment.

Literature Cited

1. Bravdo, B., Y. Hepner, C. Loinger, S. Cohen, and H. Tabacman. 1984. Effect of crop level in a high yielding Carignane vineyard on growth, yield, and wine quality. Am. J. Enol. Vitic. 35:247-252.

2. Buttrose, M.S. 1968. The effect of varying berry number on Gordo grapevines with constant leaf area. Vitis 7:299-302.

3. Coombe, B.G. 1962. The effect of removing leaves, flowers and shoot tips on fruit set of *Vitis vinifera* L. J. Hort. Sci. 37:1-15.

4. Coombe, B.G. 1976. The development of fleshy fruits. Ann. Rev. Plant Physiol. 27(2):507-528.

5. Downton, W.J.S. and W.J.R. Grant. 1992. Photosynthetic physiology of spur pruned and minimal pruned grapevines. Aust. J. Plant Physiol. 19:309-316.

6. Hale, C.R., and P.J. Weaver. 1962. The effect of developmental stage on direction of translocation of photosynthate in *Vitis vinifera* . Hilgardia 33:89-131.

7. Howell, G.S., B.S. Stergios and S.S. Stackhouse. 1978. Interrelation of productivity and cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 29:187-191.

8. Howell, G.S., D.P. Miller, C.E. Edson and R.K. Streigler. 1991. Influence of training system and pruning severity on yield, vine size, and fruit maturity of Vignoles grapevines. Amer. J. Enol. Vitic. 42(3):191-198.

9. Kaps, M.L. and G.A. Cahoon. 1989. Berry thinning and cluster thinning influence on vegetative growth, yield, fruit composition, and net photosynthesis of Seyval blanc grapevines. J. Amer. Soc. Hort. Sci. 114(1):20-24.

10. Kliewer, W.M. and R.J. Weaver. 1971. Effect of crop level and leaf area on growth, composition and correlation of 'Tokay' grapes. Am. J. Enol. Vitic. 23:172-177.

11. Kriedemann, P.E., B.R. Loveys, and W.J.S. Downton. 1975. Internal control of stomatal physiology and photosynthesis. 2. Photosynthetic responses to phaseic acid. Aust. J. Plant Physiol. 2:553-567.

12. Morris, J.R., D.L. Cawthon, and J.W. Flemming. 1975. Effect of mechanical pruning on yield and quality of Concord grapevines. Ark. Farm Res. pub. 24(3):1-

13. Morris, J.R. and D.L. Cawthon. 1981. Yield and quality response of Concord grapes to mechanized pruning. Am. J. Enol. Vitic. 32(4):280-282.

14. M

15. M

16. P

17. P

18. Q

19. R

20. R

21. R

22. R

23. R

24. R

25. S

26. S

14. Motomura, Y. 1990. Distrbution of 14C-assimilates from individual leaves on clusters in grape shoots. Am. J. Enol. Vitic. 41:306-312.

15. Motomura, Y. 1993. 14C-assimilate partitioning in grapevine shoots: Effects of shoot pinching, girdling of shoot, and leaf-halving on assimilate partitioning from leaves into clusters. Am. J. Enol. Vitic. 44:1-7.

16. Pollock, J.G., E.S. Shepardson, N.J. Shaulis, and D.E. Crowe. 1977. Mechanical pruning of American hybrid grapevines. Trans. ASAE 20(5):817-821.

17. Poni, S., C. Intrieri, and O. Silvestroni. 1994. Interactions of leaf age, fruiting and exogenous cytokinins in Sangiovese grapevines under non-irrigated conditions. 1. Gas exchange. Am. J. Enol. Vitic. 45(1):71-78.

18. Quinlan, J.D. and R.J. Weaver. 1970. Modification of pattern of the photosynthate movement within and between shoots of *Vitis vinifera* L. Plant Physiol. 46:527-530.

19. Reynolds, A.G., R.M. Pool and L.R. Mattick. 1986a. Effect of shoot density and crop control on growth, yield, fruit composition and wine quality of 'Seyval blanc' grapevines. J. Amer. Soc. Hort. Sci. 111(1):55-63.

20. Reynolds, A.G., and D.A. Wardle. 1989a. Impact of various canopy management techniques on growth, yield, fruit composition and wine quality of Gewurtztraminer. Am. J. Enol. Vitic. 40:121-129.

21. Reynolds, A.G. and D.A. Wardle. 1989b. Effects of timing and severity of summer hedging on growth, yield, fruit composition, and canopy characteristics of 'De Chaunac' 1. Canopy characteristics and growth parameters. Amer. J. Enol. Vitic. 40:109-120.

22. Reynolds, A.G. and D.A. Wardle. 1989c. Effects of timing and severity of summer hedging on growth, yield,fruit composition, and canopy characteristics of 'De Chaunac' 2. Yield and fruit composition. Am. J. Enol. Vitic. 40:299-308.

23. Roublelakis, K.A. and W.M. Kliewer. 1976. Influence of light intensity and growth regulators on fruit set and ovule fertilization in grape cultivars under low temprature conditions. Am. J. Enol. Vitic. 27(4):163-167.

24. Ruhl,E.H. and P.R. Clingeleffer. 1993. Effect of minimal pruning and virus inoculation on the carbohydrate and nitrogen accumulation in Cabernet franc vines. Am. J. Enol. Vitic. 44(1):81-85.

25. Shaulis, N., and R. Smart. 1974. Grapevine canopies: management microclimate and yield responses. In: Proc. XIXth International Hort. Congress. pp. 255-265. 11-18 Sept., Warsaw.

26. Smart, R.E. 1974a. Photosynthesis by grapevine canopies. J. Applied Ecology 11:997-1006.

27. Smart, R.E., N.J. Shaulis, and E.R. Lemon. 1982b. The effect of Concord vineyard microclimate on yield. 2. The interrelations between microclimate and yield expression. Am. J. Enol. Vitic. 33:109-116.

28. Smart, R.E. 1984. Some aspects of climate canopy microclimate, vine physiology and wine quality. In: Proc. First Intl. Symp. Cool Climate Vitic. Enol. D.A. Heatherbell, P.B. Lombard, F,W. Bodyfelt, and S.F. Price (eds.). pp 1-18. June 1984, Eugene, Oregon. Oregon State Univ.

29. Smart, R.E. 1985. Principles of grapevine canopy microclimate manipulation with implications for yield and quality. A review. Am. J. Enol. Vitic. 36(3):230-239.

30. Smart, R.E. 1987. Influences of light on composition and quality of grapes. Acta Horticulture. 206:37-47.

31. Smart, R.E., J.K. Dick, I.M. Gravett and B.M. Fisher. 1990. Canopy management to improve grape yield and wine quality - principle and practices. S. Afric. J. Enol. Vitic. 11:3-17.

32. Stergios, B.G. and G.S. Howell. 1977. Effects of defoliation, trellis height, and cropping stress on the cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 28(1):34-42.

33. Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometric Approach. McGraw-Hill Book Company, New York, NY.

34. Weaver, R.J. 1958. Effect of leaf to shoot ratio on fruit quality and shoot develepment in Carignane and Zinfandel wine grapes. Am. Soc. Enol. Vitic. 14:1-12.

35. Weaver, R.J. and R.M. Pool. 1968. Effect of various levels of cropping on *Vitis vinifera* grapevines. Am. J. Enol. Vitic. 19:185-193.

36. Winkler, A.J. 1930. The relation of number of leaves to size and quality of table grapes. Proc. Am. Soc. Hrt. Sci. 27:158-160.

37. Winkler, A.J., J.A. Cook, W.M. Kliewer and L.A. Lider. 1981. General Viticulture. University of California Press, Berkeley.

38. Yang, Y.S. and Y. Hori. 1979. Studies on retranslocation of accumulated assimilates in 'Delaware' grapevines. I. Retranslocation of 14C-assimilates in the following spring after 14C feeding in summer and autumn. Tohoku J. of Agr. Res. 30(2):43-56.

39. Yang, Y.S., Y. Hori, and R. Ogata. 1980. Studies on retranslocation of accumulated assimilates in 'Delaware' grapevines. II. Retranslocation of assimilates accumulated during the previous growing season. Tohoku J. of Agr. Res. 31(2):109-119.

TABLE 1. **Influence of pruning system in 1993 on the yield components and the fruit quality indices of Seyval grapevines at Fenn Valley vineyards. Harvested Oct. 1, 1993.**

Treatment (pruning formula)	Yield (Kg/vine)	Cluster Number	Cluster Wt. (gm)	% Berry Set	Berries/ Cluster	Berry Wt. (gm)	pH	Titratable Acidity	Soluble Solids	Cluster Rot v	Vine Rot w
Control (8+8) x	4.52 b	24	187.7 b	49.0	96	1.96 b	3.21	0.59	18.5	2.6	3.2 a
Full Trellis (45) y	8.12 a	33	256.3 a	46.0	114	2.25 a	3.27	0.61	18.4	2.2	1.9 c
Hedge (4" radius) z	6.97 a	33	211.9 ab	47.0	108	1.97 b	3.21	0.62	17.8	2.6	2.6 b
	*	ns	**	ns	ns	*	ns	ns	ns	ns	**

v Within cluster rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of berries within the clusters were rotten.

w Vine rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of clusters on the vine were rotten.

x Control vines pruned to 8+8 and flower cluster thhined to 1.5 clusters/node retained.

y Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

z Hedge treatment was accomplished using hand hedging shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of ckusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

F values significant at 5% (*); 1% (**); or not significant (ns).

Means separation within columns using Duncan's New Multiple Range Test.

TABLE 2. Influence of pruning treatments in 1993 on the vine size indices of Seyval grapevines at Fenn Valley vineyards. Harvested Oct. 1, 1993.

Treatment (pruning formula)	1993 Vine Size (Kg/vine)	Nodes Retained	Vegetativeness (vine size (g)/ node)	Vegetativeness (vine size (g)/ shoot)	% shootless Nodes/ Vine	Shoot Number (9/16/93)	Count Shoots	Non-count Shoots
Control (8+8) x	0.53	11 c	51 a	18 a	20 b	34 b	9 c	25 a
Full Trellis (45) y	0.49	45 b	11 ab	10 ab	11 b	49 b	40 b	9 b
Hedge (4" radius) z	0.47	129 a	4 b	7 b	46 a	72 a	72 a	0 c
	ns	**	*	*	**	**	**	**

x Control vines pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

y Full Trellis vines were pruned to retain 45 nodes/vine. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

z Hedge treatment was accomplished using hand hedging shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according tothe number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

F values significant at 5% (*); 1% (**); or not significant (ns).

Means separation within columns using Duncan's New Multiple Range Test.

TABLE 3. Influence of pruning system in 1993 on shoot leaf area at harvest of Seyval grapevines at Fenn Valley vineyards. Harvested Oct. 1, 1993.

Treatment (pruning formula)	Leaf Area / Primary Shoot Leaf (cm^2)	Leaf Area/ Lateral Shoot Leaf (cm^2)	Total Leaf Area/ Leaf (cm^2)	Leaves/ Primary Shoot	Leaves/ Lateral Shoot	Total Leaves/ Shoot	Leaf Area/ Primary Shoot (cm^2)	Leaf Area/ Lateral Shoot (cm^2)	Total Leaf Area/ Shoot (cm^2)
Control (8+8) x	87 a	37	52	23 a	51 a	74 a	1943 a	2090 a	4033 a
Full Trellis (45) y	94 a	27	57	20 ab	40 ab	60 ab	1866 a	1304 ab	3170 ab
Hedge (4' radius) z	69 b	24	50	15 b	19 b	34 b	1106 b	662 b	1768 b
	*	ns	ns	**	**	**	*	*	*

x Control vines pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

y Full Trellis vines pruned to retain 45 nodes/vine. crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

z Hedge treatment was accomplished using hand hedging shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

F values significant at 5% (*); 1% (**); or not significant (ns).

Means separation within columns using Duncans New Multiple Range Test.

TABLE 4. Influence of pruning system in 1993 on vine leaf area at harvest of Seyval grapevines at Fenn Valley vineyards. Harvested Oct. 1, 1993.

Treatment (pruning formula)	Total Leaf Area/ Leaf (cm^2)	Total Leaves/ Shoot	Total Leaf Area/ Shoot (cm^2)	Samp. Vine Shoot Number (9/16/93)	Total Leaves/Vine at Verasion	Total Leaves/Vine at Harvest	Leaf Growth from Verasion to Harvest	Leaf Area (m^2)/ Vine	Leaf Area (cm^2)/ Cluster	Leaf Area (cm^2)/ Yield (gm)
Control (8+8) x	52	74 a	4033 a	40 c	2052 b	2977	925 a	16.07	6563	35.6 a
Full Trellis (45) y	57	60 ab	3170 ab	54 b	2236 b	2946	710 a	16.83	5497	21.9 b
Hedge (4' radius) z	50	34 b	1768 b	97 a	2873 a	3262	389 b	16.43	4992	24.0 b
	ns	**	*	**	*	ns	**	ns	ns	*

x Control vines pruned to 8+8 and flower cluster thinned to 1.5 clusters/node retained.

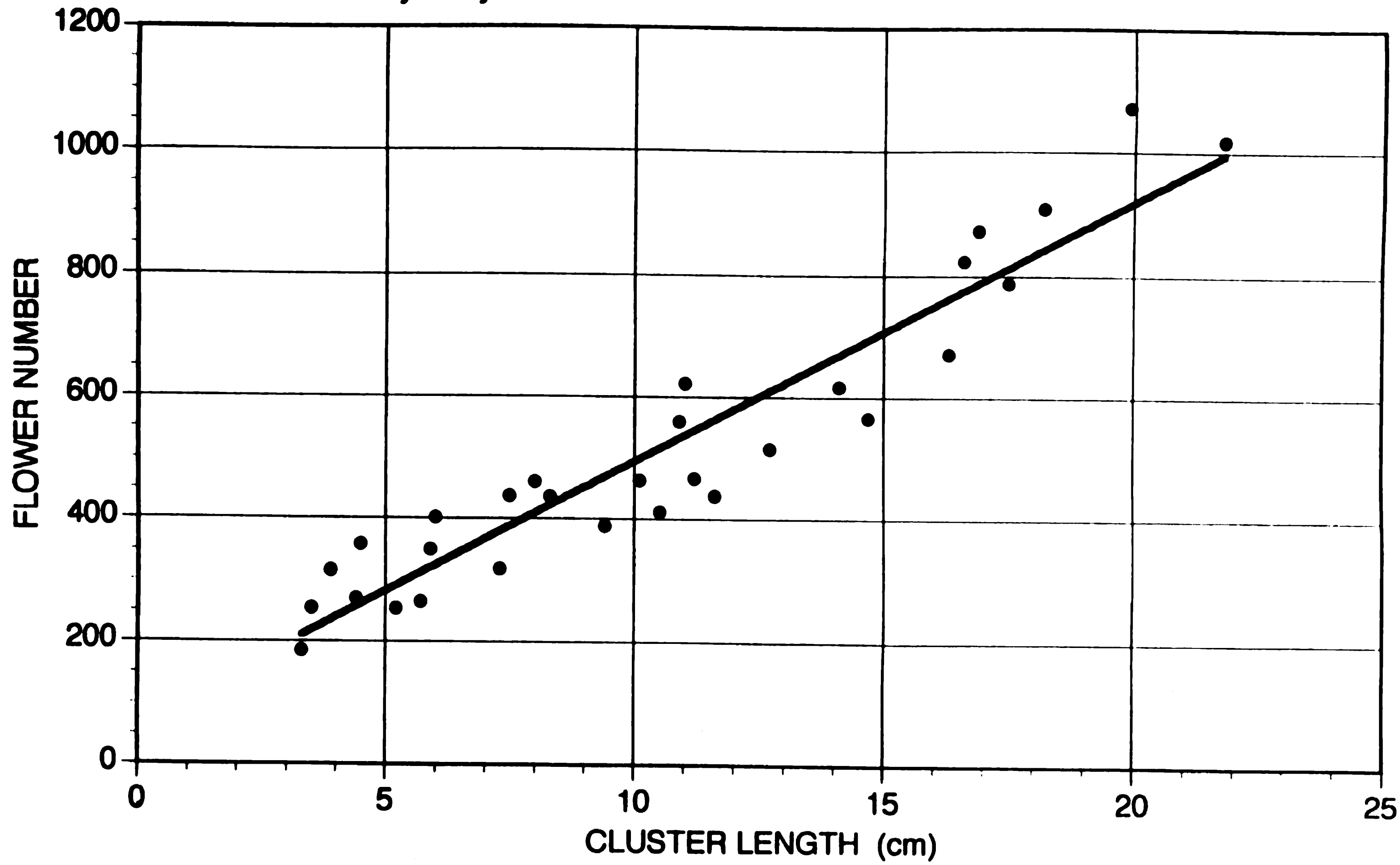
y Full Trellis vines pruned to retain 45 nodes/vine. crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

z Hedge treatment was accomplished using hand hedging shears which removed canes outside a 4 inch radius from the cordon. Crop level was set according to the number of clusters for an 8+8 pruned vine retaining 1.5 clusters/node retained.

F values significant at 5% (*); 1% (**); or not significant (ns).

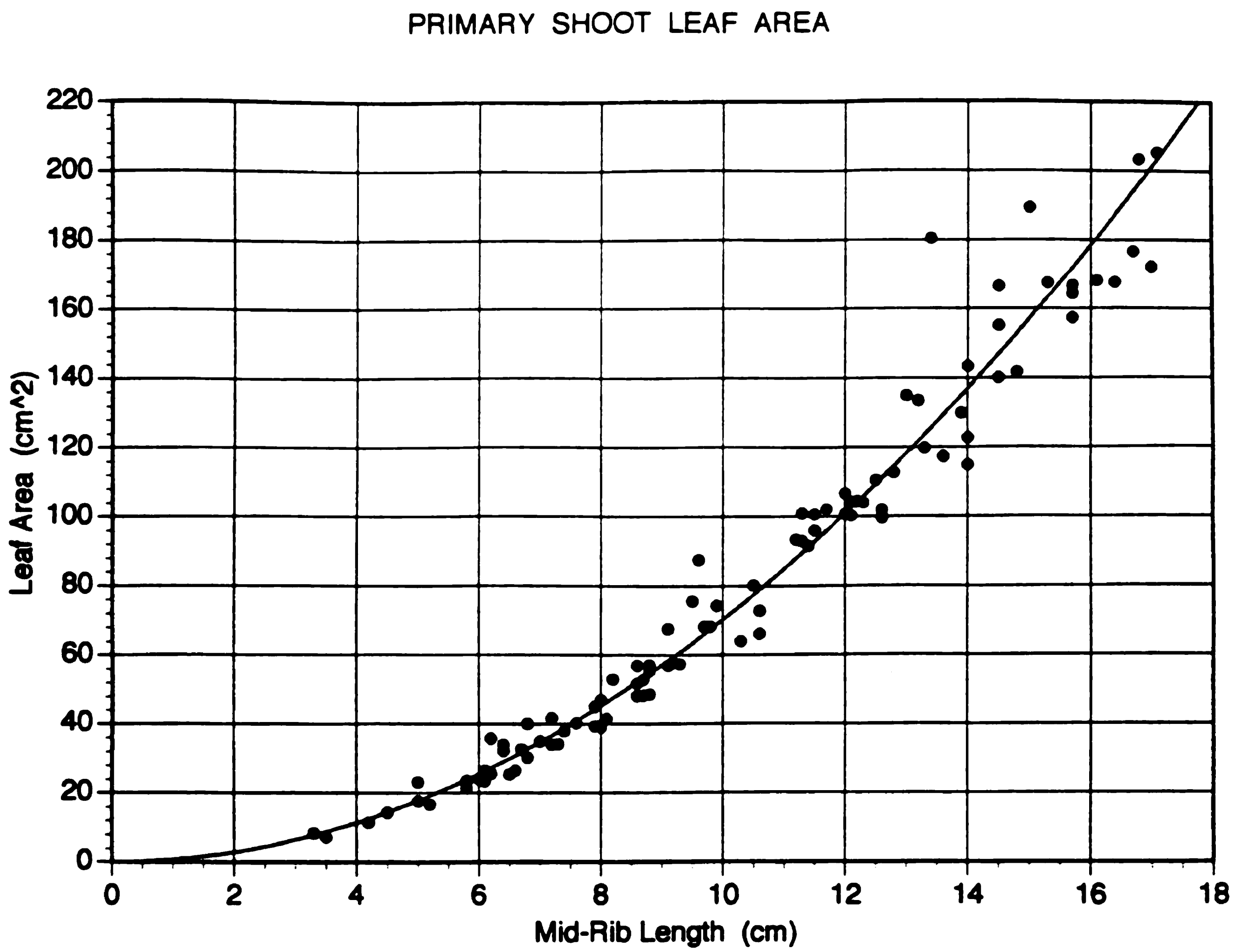
Means separation within columns using Duncans New Multiple Range Test.

Fig. 1. 1993 Standard for flowers per cluster measurements in Seyval grapevines at Fenn Valley vineyards.



R^2 = 0.9008
R**

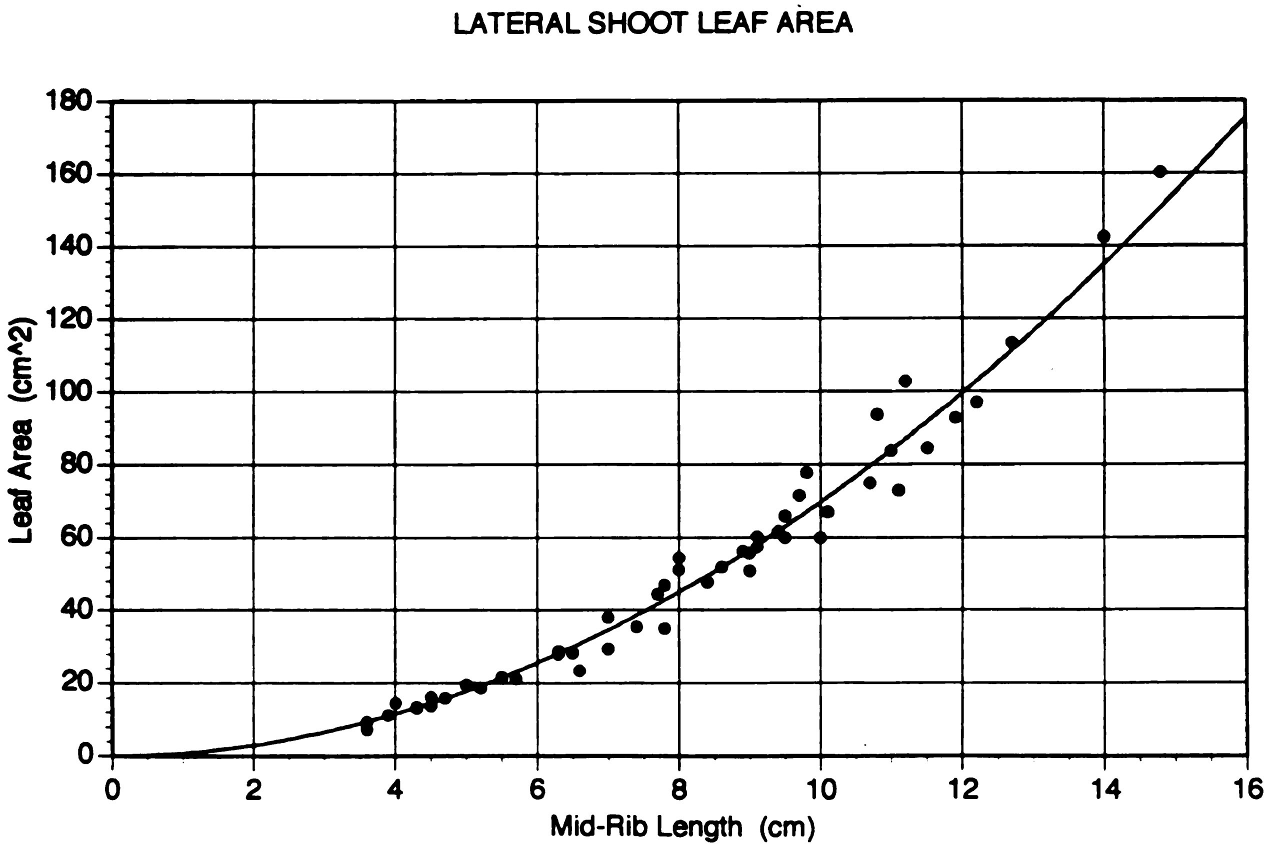
f(x)= 42.451(x)+70.874



R^2=0.9798

f(x)=(0.7377) * (x^1.9793)

Fig. 2. Standard for primary shoot leaf area measurements in Seyval grapevines at Fenn Valley vineyards in 1993.



R^2=0.9804

f(x)=(0.7591) * (x^1.9629)

Fig. 3. Standard for lateral shoot leaf area measurements in Seyval grapevines at Fenn Valley vineyards.

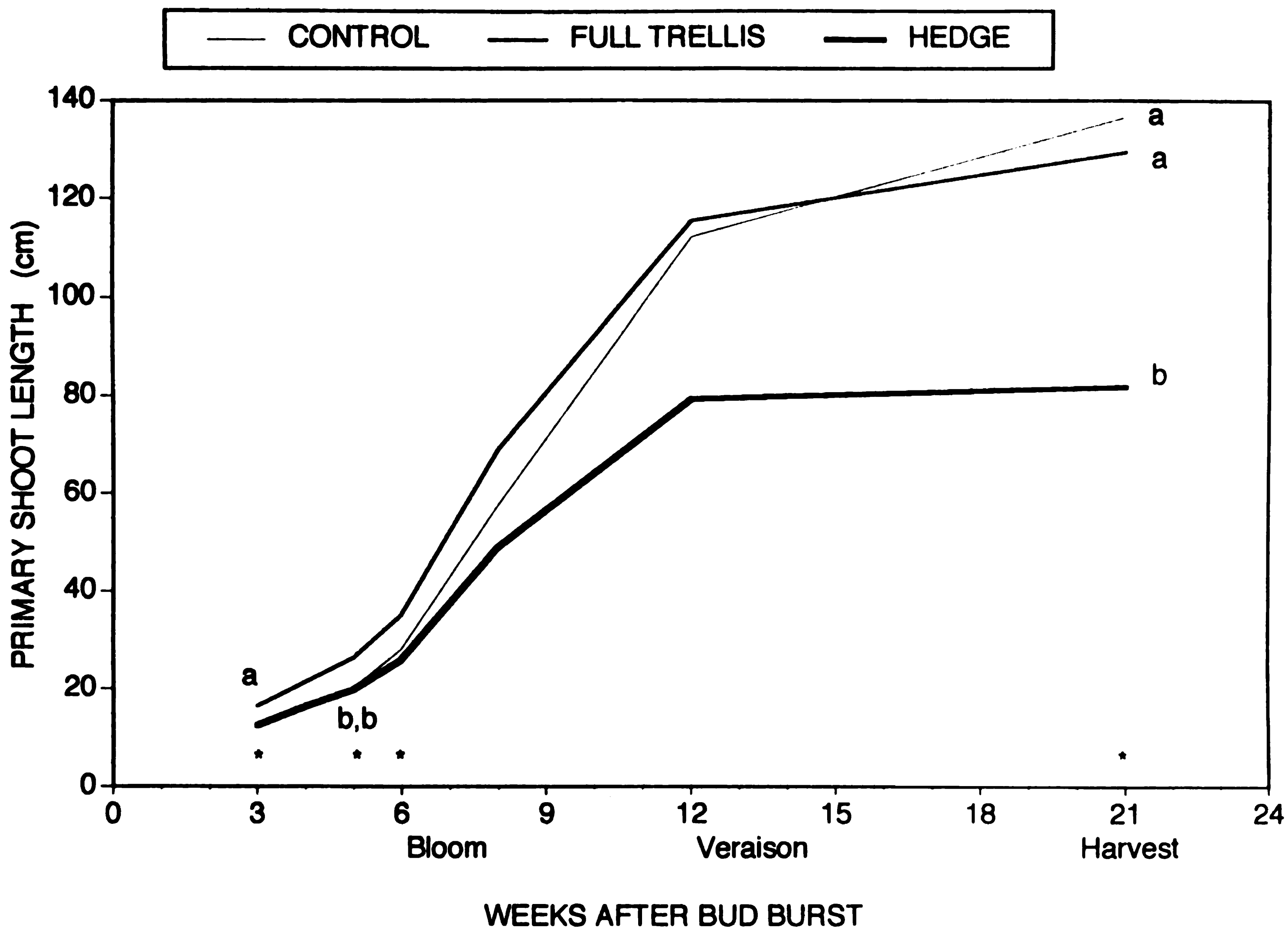


Fig. 4. Influence of canopy configuration on primary shoot length (cm) in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

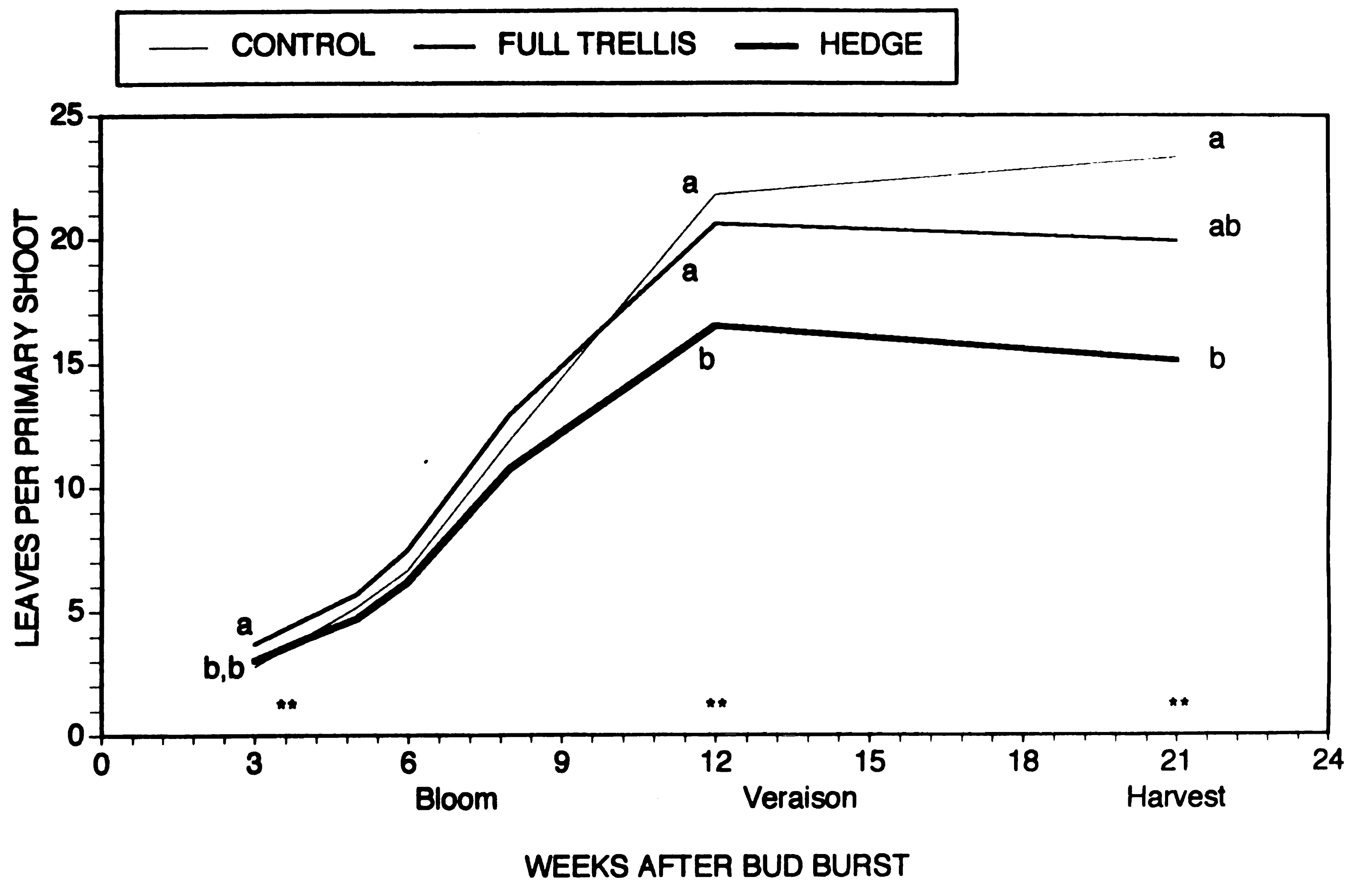


Fig. 5. Influence of canopy configuration on primary shoot leaf production in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

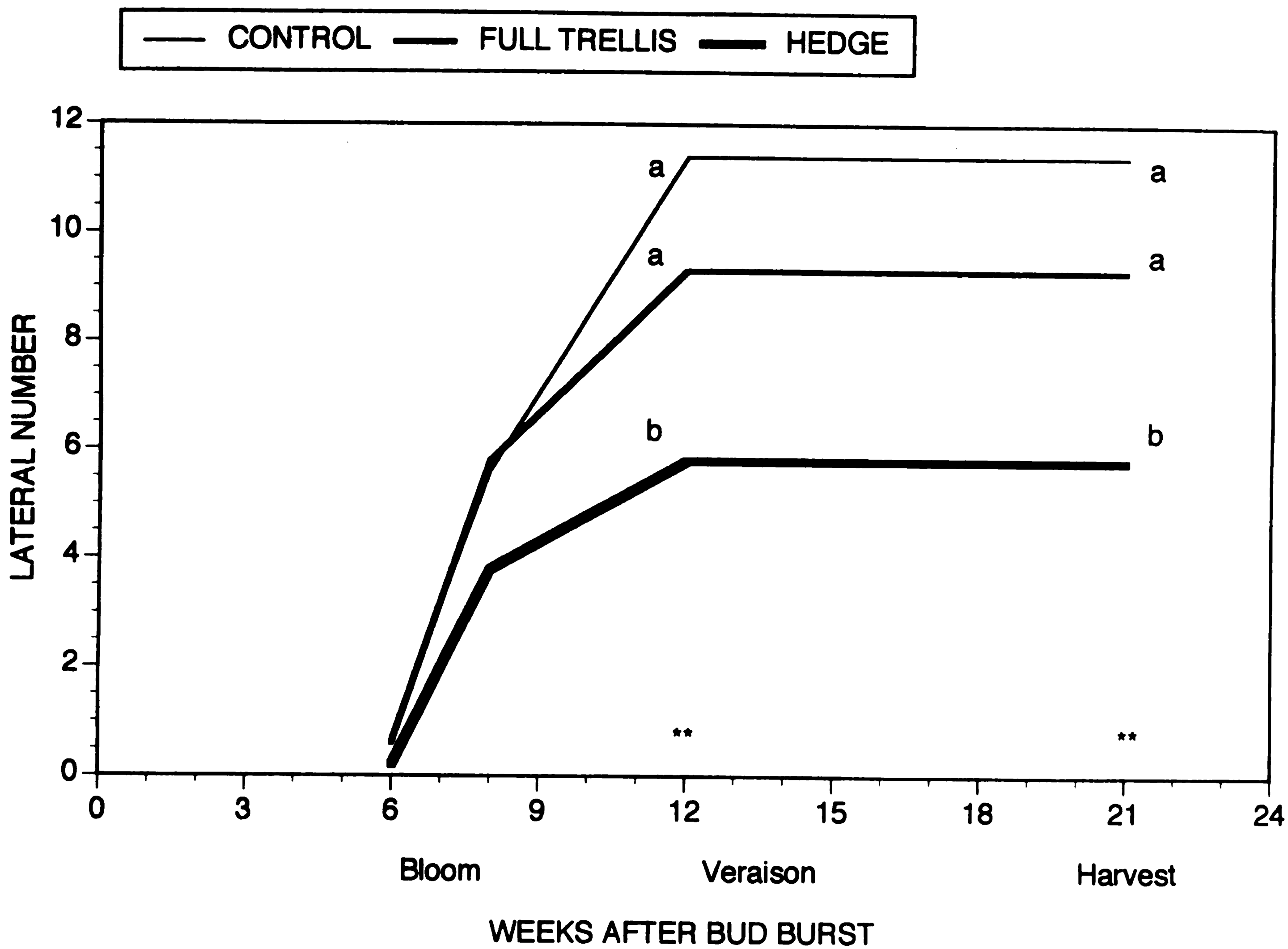


Fig. 6. Influence of canopy configuration on lateral shoot production in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

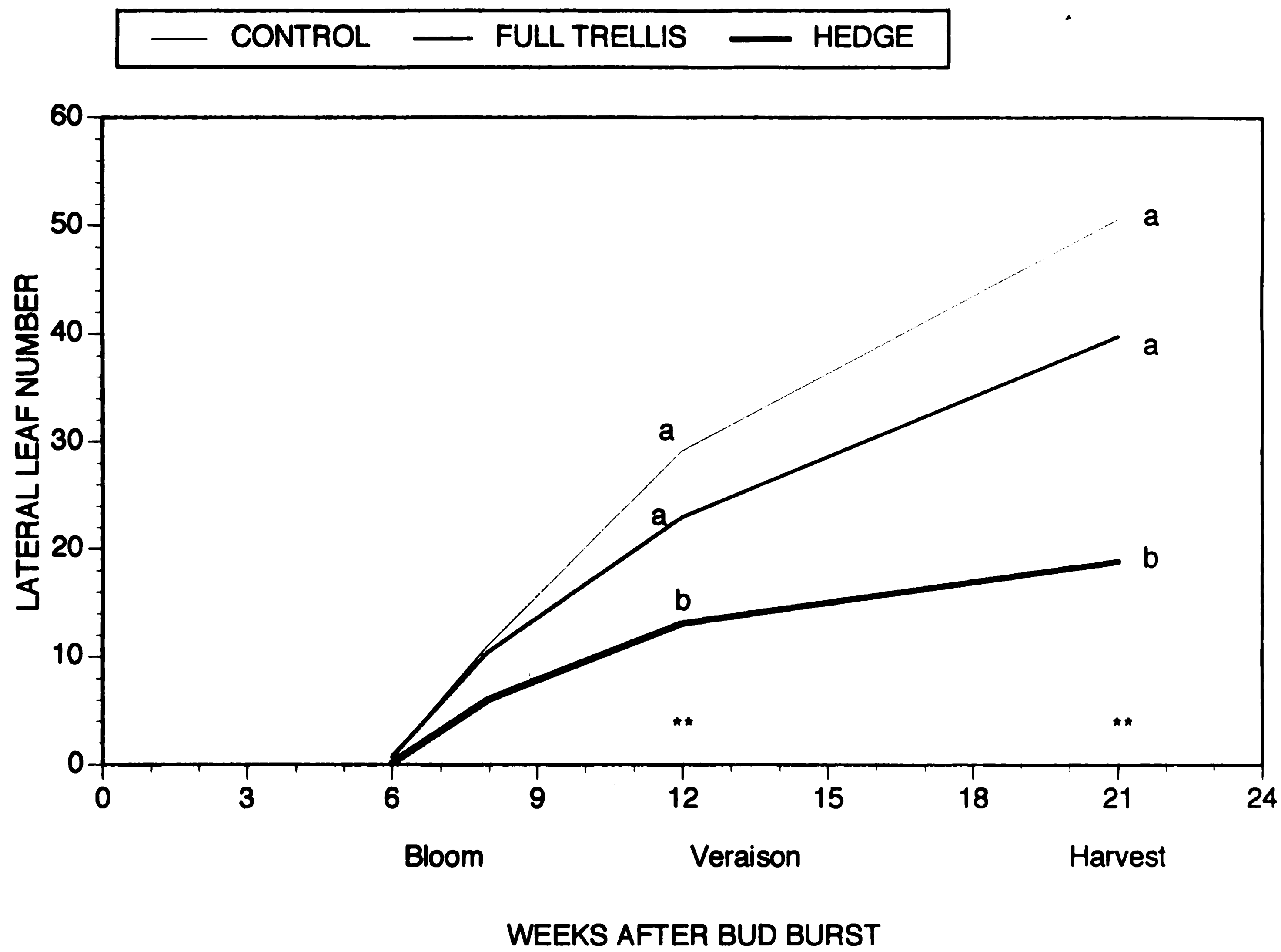


Fig. 7. Influence of canopy configuration on lateral shoot leaf production in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

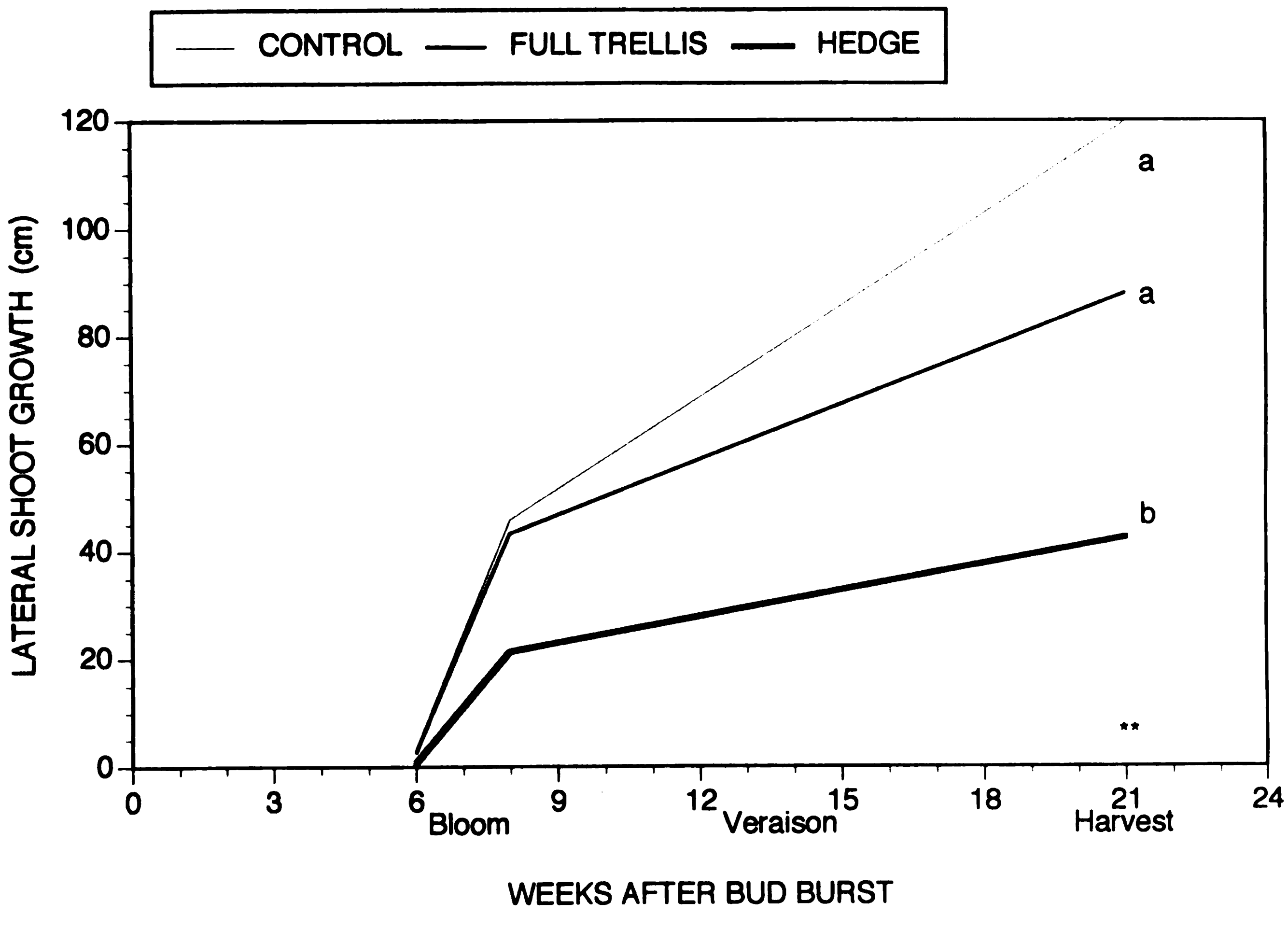


Fig. 8. Influence of canopy configuration on lateral shoot growth (cm) in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

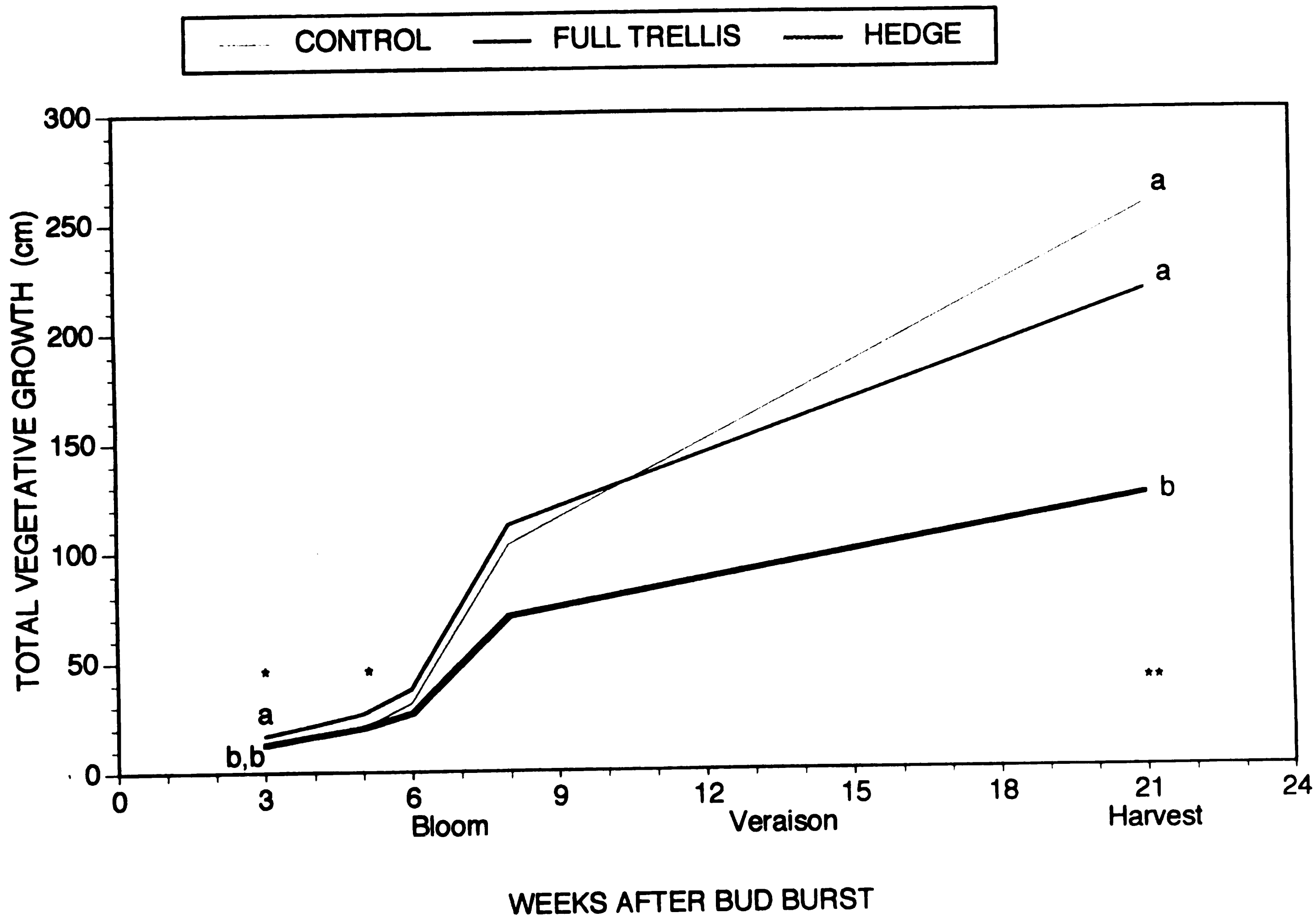


Fig. 9. Influence of canopy configuration on the total shoot vegetative growth (cm) in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

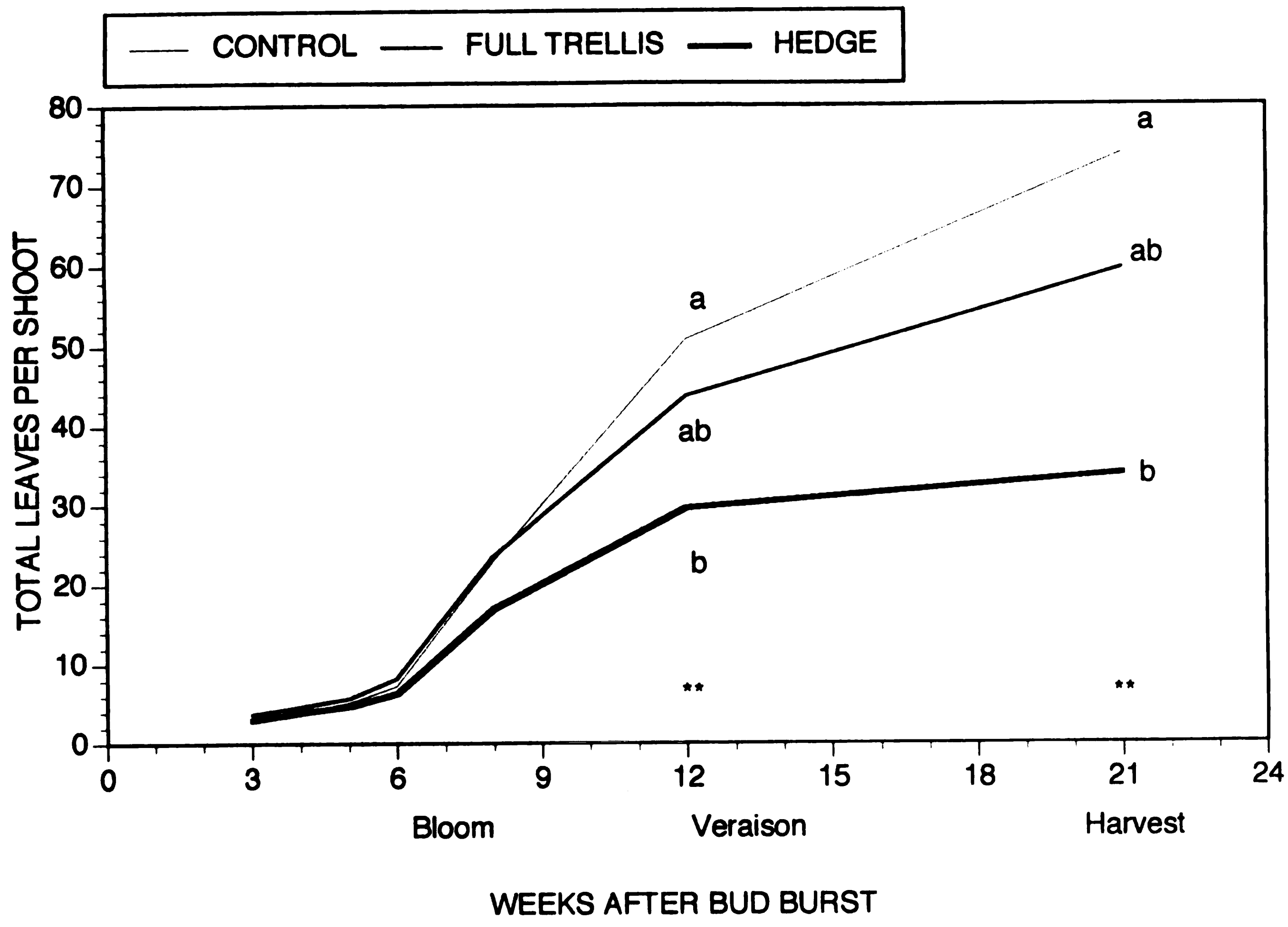


Fig. 10. Influence of canopy configuration on the total leaves per shoot in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

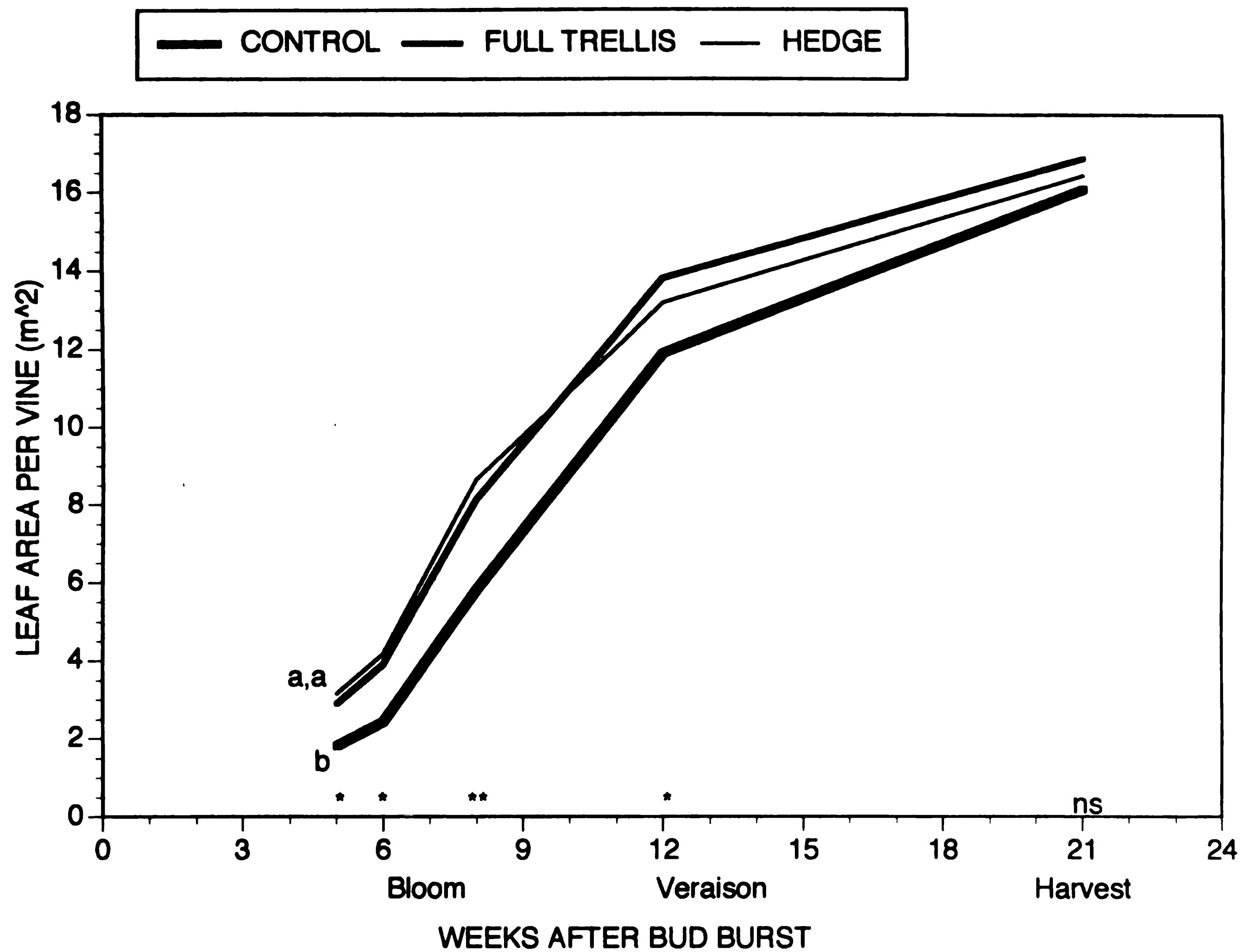


Fig. 11. Influence of canopy configuration on leaf area production per vine in Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

CHAPTER III

THE USE OF CARBOHYDRATE SINK COMPETITION TO REDUCE FRUIT SET AND *BOTRYTIS* ROT IN SEYVAL GRAPEVINES

Abstract

Three pruning severities and two times of thinning were applied to Seyval grapevines to vary the amount of fruiting and vegetative sinks at fruit set. Vines were balanced pruned to either 10, 30, or 60 nodes per 454 g. of cane prunings. Half were flower cluster thinned and half post-set thinned to 15 clusters per 454 g. of cane prunings. In 1993, a third factor of cropping level was imposed across each treatment. Post-set thinning decreased fruit set, yield, and *Botrytis* bunch rot while increasing berry weight and soluble solids. Losses in yield could be overcome by decreasing thinning severity. Increased sink competition created by greater numbers of apical meristems, had no effect on fruit set or *Botrytis* infection, and decreased cane cold hardiness. Post-set thinning to increase sink competition and reduce fruit set appears to be a viable cultural practice to reduce *Botrytis* cluster rot.

Introduction

Botrytis bunch rot is a severe disease in Michigan's cool, wet climate. Its control to prevent the loss of yield and fruit quality can be a costly endeavor for the vineyard manager. Chemical control and sanitation are successful approaches to minimizing *Botrytis* infection. However, chemical control is expensive in Michigan's climate and control products are becoming more limited. *Botrytis cinerea* lives most of its life as a saprophyte, getting nutrients from dead or dying plant parts (12). Sanitation practices reduce the amount of inoculum in the vineyard before each growing season by removing old clusters, dead wood, and debris from the vineyard. This can be costly and does not completely relieve the problem.

Selecting for cultivar resistance and canopy management are also methods to control bunch rot infection. Unfortunately, some cultivars used in wine production are susceptible to infection. The cultivar Seyval (S.V. 5276) was chosen for this study because of its importance in Michigan's wine industry and serious cluster rot problems. Seyval vines are susceptible to *Botrytis* infection because they form large, compact clusters. It is for this reason that they are also easily overcropped. Seyval is managed using severe balanced pruning and flower cluster thinning. It is recommended that a 15+10 balance pruning formula with thinning to 17 clusters per 500 grams of cane prunings be employed to control crop level (17). The potential for yield increase is great if canopy management practices are developed to control overcropping and help inhibit the infection of *Botrytis* bunch rot of Seyval in Michigan.

Botrytis cinerea may infect grape flowers and it can remain latent in these tissues until the clusters begin to mature (13). The spores require prolonged periods of free water and nutrients on the berry surface for germination (12,14). The fungus produces enzymes that can destroy the integrity of the berry in less than 24 hours (12). The main protection for the grape berry to infection is its skin. The cuticle membrane and the epicuticular wax provide the primary physical barriers to pathogen invasion (1). For berry infection to occur, the pathogen must find a weakness on the berry surface where it can bypass the cuticle membrane, or directly penetrate the surface (3). The epicuticular wax layer influences the retention of pesticides, the water retention of the berry surface, and the adhesive ability of plant pathogens (1). Percival et al. (15) found that exposed clusters and those having little berry contact, produced more epicuticular wax and cuticle. Clusters with less berry contact may be achieved by reducing the number of berries set per cluster.

The competition for carbohydrates and growth hormones between sources and sinks to influence fruit set has been well documented. Intra-vine competition for carbohydrates and growth hormones by vegetative (22) and fruiting sinks (7) influences fruit set. Decreasing the competition between sinks by shoot tipping at bloom (5,6,18), girdling (2,5), or flower-cluster thinning (23,24,25) increase fruit set. Heavy pruning (23), leaf removal during bloom (4), and within-cluster competition decrease fruit set (11). Flower clusters compete for carbohydrates during bloom (16) and after anthesis when the shoot apex and the developing clusters become the strongest sinks (6,9,16). Flower-cluster thinning increases pollen germinability (25) and shoot growth (8,11). Post-set thinning can decrease fruit set by increasing the fruiting and vegetative sink competition for assimilate and growth hormone (7,22), thus loosening cluster compactness. Post-set thinning reduces berries per cluster in Seyval, and a compensatory increase in berry size and fruit quality results (10). Vegetative vigor and the development of laterals decreased when thinning was delayed until after fruit set (10). Potentially the number of berries per cluster can be reduced, resulting in less berry contact and thus less *Botrytis* infection.

Experimental Objectives

1. To explore the effect of reducing pruning severity and/or post-set cluster thinning to increase competition between sinks through anthesis in Seyval.
2. To determine if increasing the amount of fruiting sinks at fruit set will decrease the number of berries set per cluster in Seyval.
3. To determine if increasing the amount of vegetative sinks at fruit set will decrease the number of berries set per cluster in Seyval.
4. To investigate if decreasing the number of berries set per cluster by post-set cluster thinning will decreases the amount of *Botrytis* rot in Seyval.
5. To determine if the loss in yield in Seyval due to the decrease in fruit set can be overcome by retaining more clusters per vine during thinning.

Materials and Methods

Plant Material

The experiment was established in March of 1991, 4.5 miles East of Lake Michigan (42-15' latitude) at Fenn Valley vineyards in Fennville Mich. Mature, bearing Seyval grapevines planted in 1975 on an Oshtemo sandy-loam soil were used in the experiment. Rows were spaced 3.0 meters apart with vines 2.4 meters apart within rows. The vines were trained to a bilateral cordon on the top wire, 1.8 meters high (Hudson River Umbrella training system).

Experimental Treatments

By leaving three levels of nodes retained, three levels of sinks (vegetative and fruitful) were established for each vine during the dormant season pruning in an effort to increase competition among sinks during bloom. This was accomplished by retaining 10, 30, or 60 nodes (N, 3N, 6N) for every 454 grams of dormant one year cane prunings respectively. The most severely pruned treatment (N), retained nodes on short spurs along the cordon. The (3N) treatment kept five node canes; and the lightly pruned (6N) treatment retained canes of ten to fifteen nodes in length along the cordon.

The (N) vines were pruned to 45-nodes and the live one-year cane prunings weighed to estimate the previous year's vine size. The node number for the (N) vines was then set for the duration of the growing season following the procedures stated above. Because of the number of nodes needed to obtain the (3N) and (6N) levels were much greater than 45 nodes, a method was devised to estimate the weight of retained wood. After pruning the (3N) and (6N) treatments to 90 and 180 nodes per vine respectively, the live canes were weighed. The remaining live nodes of canes on the vine were counted. A weight was assigned to the number of nodes over 45 retained on the vine, based on a node weight calculated in 1992 (113 gm per 52 nodes) and 1993 (113 gm per 50 nodes). This weight and the weight of cane prunings were added, producing the vine size for each (3N) and (6N) vine.

Crop thinning is also required in Seyval for optimal crop control. Flower-cluster thinning (FCT) and post-set thinning (PST) were imposed to compare the influence of increased cluster numbers per vine during fruit-set. Cluster thinning was conducted just prior to bloom in the (FCT) vines, and when the berries were 3-5 mm in diameter (2-3 weeks post-bloom) in the (PST) vines. The number of clusters per vine were proportioned by using the weight of live one-year-old canes at pruning (vine size). Thus, crop level was balanced among vines based on their vegetative production of the previous year.

In 1992, the treatment vines were cluster thinned to 15 clusters per 454 grams of dormant one-year cane prunings. In 1993, three cropping levels were employed in an attempt to offset any loss in yield due to a decrease in fruit set. The (C15) treatment maintained the cropping level imposed the previous year (15 clusters per 454 grams of dormant one-year cane prunings). Higher crop levels, (C18) and (C21), increased the number of clusters per vine after thinning to 18 and 21 per 454 grams of dormant one-year cane prunings respectively.

Vegetative Measurements

The effect of increased sink competition during bloom on vegetative growth was examined. A consistent determination of vine size was measured as described above. At bud burst, nodes that did not produce a shoot (shootless nodes) were counted. Percent shootless nodes, vegetativeness (vine size (gm) per shoot), count shoots (nodes retained at pruning minus blind nodes), and non-count shoots (total shoots minus count shoots) were calculated for each vine. Treatment comparisons and interactions of pruning data were analyzed each year and over both years.

Point Quadrat Analysis

Point quadrat assessments were taken at three times during the growing season each year. A thin metal rod was inserted into the canopy to determine the number of leaves above the fruiting zone (19). Five insertions along the cordon were made on each treatment vine at bloom, veraison, and harvest. Insertions were always made from the West side of the canopy. A frequency distribution of the number of contacts and a seasonal history of leaf layer formation were developed.

Shoot and Leaf Measurements

During the 1993 growing season, detailed shoot and leaf measurements were taken on every (C15) vine of the sub-sub-plots in each replication. Within each sample vine, five shoots were randomly flagged along the cordon for vegetative measurements during the growing season. These included: 1) primary shoot length (PSL); 2) primary shoot leaf number (PSLF); 3) lateral number (L); 4) lateral length (LL); and 5) lateral leaf number (LLF); measured on May 26 (WK3 weeks after bud burst), June 2 (WK4), June 9 (WK5), June 16 (WK6), June 30 (WK8), July 29 (WK12), and September 23 (WK21) one week prior to harvest. Additional calculated data included total leaves per shoot (TSLF= PSLF+LLF) and total vegetative shoot length (PSL+LL). Treatment comparisons were made at appropriate dates and over dates on those variables measured or calculated.

At thinning, none of the sample shoots were defruited so that shoot development with a fruiting sink could be studied for the remainder of the growing season. A count of shoots (CS) longer than 10 cm and bearing three or more leaves was taken two weeks prior to harvest. Primary leaves per vine (PSLF*SC), lateral leaves per vine (LLF*SC), and total leaves per vine (TSLF*SC) were then calculated and compared between treatments.

Cold Hardiness Evaluations

Prior to pruning in 1993-1994, a cold hardiness evaluation was taken of the previous season's vegetative growth. Previous work with Seyval (21) and a re-evaluation of that work (Appendix 1) has led to a definition of Seyval cane characteristics closely associated with cold hardiness. Classifications were created from hardiness analyses done on Dec 19, 1991 and Jan 22, 1992 on Seyval canes (Appendix 1). Periderm and primary bud T50's were determined for variations within four cane characteristics, and over node positions along the cane. Canes having a medium diameter (7-10 mm), medium internode length (6-8 cm), and dark brown periderm were found to have superior cane and primary bud cold hardiness. Persistent laterals and node position (2-9) did not have any influence on cold hardiness. Total one-year-old canes were counted on each treatment vine and each cane given a excellent, acceptable, or poor classification. Excellent canes consisted of ten or more live nodes with the optimal characteristics stated above. Acceptable canes had five or more living nodes but failed in one of the optimal characteristics. Canes with less than five live nodes or failing at least two optimal characteristics were placed in the poor cold hardiness category. Samples of Seyval canes within the three classifications were collected in December, January, and March. Periderm and primary bud cold hardiness were significantly different among the treatments at the 0.01 level over the three dates. Excellent canes were superior while poor canes were inferior to acceptable canes. Using the three classifications was a rapid and effective way to evaluate the relative cold hardiness of each treatment vine.

Fruit-Set and *Botrytis* Rot Evaluations

A standard curve was developed to allow rapid determination of flower number per cluster based on rachis length for both years. Thirty clusters were randomly sampled from guard vines just prior to bloom. Cluster length was calculated by adding the length of rachis from the lowest basal arm to the tip and the length of the lowest basal arm. Flowers of each sample cluster were counted and a strong correlation was found each year (Figs. 1 and 2). The rachis length of clusters on sample shoots of (C15) vines were measured and their estimated flower number calculated. At harvest, berry pedicles of sample shoot clusters were counted and the percentage of berries set analyzed. The number of whole berries showing no incidence of *Botrytis* rot infection were counted for rot calculations. Subtracting these quality berries from the number of pedicles per cluster provides a number of the berries infected with rot. Fruit-set and *Botrytis* rot comparisons were made each year and over both years.

Harvest Procedures and Fruit Quality Assessments

Treatment vines were harvested each year within ten days of October 1. Each vine was hand harvested with the cluster number noted and the fruit placed into an individual bin. Each bin was then weighed in the field and a cluster weight calculated. Clusters from sample shoots of (C15) vines were harvested separately, weighed, and placed into individual bags for berry counts and fruit quality determination. Berries were randomly taken from these sample clusters to create a 100 berry sample for every (C15) treatment in each replication. From these samples pH, titratable acidity, soluble solids, and berry weight were determined and the number of berries per cluster calculated. The number of non-count clusters per vine was calculated from the number of clusters harvested minus the number retained after cluster thinning. Treatment comparisons of harvest data were analyzed for each year and over both years. Using the harvest and pruning data, shoots per cluster (total shoots/ harvest cluster number), productivity (yield per previous year's vine size), fruitfulness (yield (gm) per shoot), and crop load (yield per current season's vine size) were calculated for every sample vine and analyzed for each year and over both years.

Experimental Design and Analysis

A split-plot design was used with the main-plot consisting of three treatments (N, 3N, 6N) of six vines each, replicated six times. Three rows, containing two blocks each were utilized. A guard vine separated each main-plot treatment. Each main-plot was divided into two sub-plots, (FCT) and (PST), consisting of three vines. The three vines of the sub-plots were further divided into single vine treatments (C15, C18, C21) as sub-sub-plots in 1993. Comparisons and interactions between treatments were made each year and over both years using the MSTAT-C statistical computer package. Analysis was by ANOVA, with mean separations calculated using Duncan's Multiple Range Test (20). The fruit-set standards and fruit-set vs. rot regressions were calculated using the Delta Graph computer package. Point quadrat frequency distributions were calculated using the MSTAT-C computer package. The experiment was terminated after pruning in March of 1994.

Results and Discussion

Vegetative Growth

Decreasing pruning severity while maintaining a balanced crop influenced canopy development, morphology, and maturity with little effect on total vegetative growth. Increasing the number of clusters per vine through anthesis showed no influence on vegetative growth. Vine size was never significantly different among treatments of either the main-plots or sub-plots, averaging 0.55 kg of cane prunings per vine (Table 1). Reduced pruning severity accelerated filling of the trellis area with foliage, but caused more shading within the canopy by verasion (Figs. 3 and 4). Increasing the number of nodes per vine three fold (3N) from the standard pruning severity (N), redistributed shoot growth from non-count to count positions (Table 1). Over 65 percent of (N) canopies were comprised of non-count shoots, while count shoots made up 75 percent of (3N) canopies. Shoot numbers were similar; and thus, the number of vegetative apices remained consistent. Increasing the number of nodes per vine six-fold (6N) from the standard pruning severity (N), produced 70 percent more shoots per vine and no growth from non-count positions. As node number per vine was increased, vegetativeness decreased (Table 1) along with total shoot length, total leaf number, and lateral number per shoot (Figs. 5, 6, and 7). Post-set thinning appeared to reduce the rate of growth of every vegetative parameter measured per shoot between bloom and verasion, although no significant differences were observed. The (FCT) and (PST) shoots had nearly identical rates of growth from verasion to harvest. The (N) and (3N) treatments produced 70 percent of their total leaf number before veraison, while (6N) vines produced 80 percent by veraison and half as many leaves as the other two treatments between then and harvest (Fig. 6). The lack of new leaf production after veraison in (6N) vines suggests older leaves were responsible for photosynthate production during fruit and wood ripening in (6N) vines. Shading, caused by dense canopies, also contributed to poor wood maturity of (6N) vines. The (6N) canopies produced significantly less excellent, and more poor cold hardy canes (Table 1). No differences in cane cold hardiness were observed between thinning times. Varying the number of nodes retained at pruning influences vegetative growth more than greater numbers of clusters per vine during fruit-set.

Influence of Nodes Retained and Thinning Treatment on Yield, Components of yield, and Fruit Composition

Increasing the number of clusters during fruit-set by post-set thinning reduced fruit-set, concurring with work previously done (7,21). Post-set thinning increased the level of competition between fruitful sinks, resulting in fewer berries set within the cluster (Table 2). As the level of fruitful sinks retained through anthesis was augmented across pruning severities, the level of competition increased and berry-set further declined. This additional loss of berries reduced yield and vine productivity (Table 3). The (6NFCT) treatment was superior to the other treatments yielding 4.4 tons per acre. However, raising the number of clusters per vine 20 and 40 percent at post-set thinning made yields at each pruning severity comparable to that of flower cluster thinning to 15 clusters per pound of cane prunings (Table 4). Post-set thinning controlled unwanted crop (non-count clusters) better than (FCT) (Table 5).

Post-set thinning increased berry weight, soluble solids, and pH with no variance in titratable acidity (Table 5). The greatest variance was observed in the (6N) treatments where the competition was the highest between sinks during fruit-set. Post-set thinning increased the percent soluble solids two brix greater than (FCT). Larger berry weights and improved percent soluble solids agrees with Hunter et al. (10) findings on post-set thinning. Post-set cluster thinning reduced berry-set within the cluster and improved fruit composition.

Botrytis Rot Evaluations

Decreasing the number of berries set per cluster influenced the incidence of *Botrytis* bunch rot infection in Seyval. A count of infected berries was performed on clusters from sample shoots of (C15) vines at every level of pruning severity and time of thinning. Over 40 percent of the berries from (FCT) clusters showed signs of rot infection at each pruning severity over years, while post-set thinning averaged 16 percent (Table 2). As the number of clusters increased during fruit-set between the (N), (3N), and (6N) treatments, the percent of berry rot infection decreased. The (NPST), (3NPST), and (6NPST) treatments exhibited an average of 29, 13, and 7 percent berry infection respectively over years. Each year, the percentage of berry rot decreased linearly with decreasing berries per cluster (Figs. 8 and 9). Thus, as the competition between fruitful sinks became greater and fruit-set decreased, the percentage of berries infected declined. As the number of berries set per cluster ranged from 100 to over 300 among treatments, *Botrytis* berry rot increased linearly from 5 to 50 percent. Thus, the number of quality berries per cluster decreased only 25 percent in the (PST) treatments, although the reductions in the number of berries set per cluster were much more severe (Table 3). The reduction of berries within the cluster provided a loose cluster architecture non-conducive to *Botrytis* cluster rot infection. This agrees with Percival et al. (15) findings with clusters having little berry contact producing more epicuticular wax and cuticle, the main protection against rot infection (1). Post-set cluster thinning reduced *Botrytis* bunch rot in Seyval grapevines.

Conclusions

The relationship between sources and sinks competing for photoassimilate played a major role in Seyval grapevine development throughout the growing season. Increasing the number of vegetative apices created greater distribution of vegetative growth within the canopy, resulting in earlier filling of the trellis area with foliage and optimal potential light absorption. However, shading and reductions in leaf production after veraison become a concern for fruit and wood ripening. Increasing the number of vegetative sinks during anthesis had no affect on fruit-set. The increase in competition caused by additional fruitful sinks reduced berry-set and, thus, *Botrytis* bunch rot. It appears that competition among fruitful sinks is the determining factor in fruit-set and that this competition has little affect on vegetative growth or maturity when maintained only through anthesis. Reductions in yield caused by decreased fruit-set were overcome by decreasing the number of clusters thinned after anthesis. Once the crop level was established, fruitful sinks gained superiority in competing for carbohydrates and/or growth hormones. This occurred at the expense of vegetative growth if insufficient supplies were available. Post-set cluster thinning appears to be a viable cultural method for reducing *Botrytis* bunch rot, and the level of sink competition during bloom can be manipulated by pruning severity.

The 30+30 pruning severity adequately spaced shoots within the canopy to fill the trellis area with vegetative growth earlier than the 10+10 severity. The occurrence of some non-count shoots suggests that the pruning severity could even be lower to better distribute vegetative growth. The 30+30 pruning severity provided adequate photoassimilate competition between fruitful sinks to reduce fruit-set sufficiently to deter *Botrytis* bunch rot infection. It also afforded superior cane and flower bud maturity for growth the following year. A pruning severity slightly greater than 30+30 with post-set cluster thinning to a level of crop that maximizes yield and allows for adequate vine maturity, would be recommended for management of Seyval grapevines.

Literature Cited

1. Baker, E.L. 1982. Chemistry and morphology of plant epicuticular waxes. In: Cutler, D.F., Alvin K.L., Price, C.E. (Eds.): The Plant Cuticle, 139-161. Academic Press, Toronto.

2. Brown, K., D.I. Jackson, and G.F. Steans. 1988. Effects of Chlormequat, girdling, and tipping on berry set in *Vitis vineifera* L. Am. J. Enol. Vitic. 39(1):91-94.

3. Bulit, J., and D. Dubos. 1988. *Botrytis* bunch rot and blight. In: Pearson, R.C., Goheen, A.C. (Eds.): Compendium of grape diseases, 13-15. APS Press, St. Paul.

4. Candolfi-Vasconcelos, M.C. and W. Koblet. 1990. Yield, fruit quality, bud fertility and starch reserves of the wood as a function of leaf removal in Vitis vinifera - Evidence of compensation and stress recovering. Vitis. 29:199-221.

5. Coombe, B.G. 1959. Fruit set and development in seeded grape varieties as affected by defoliation, topping, girdling, and other treatments. Am. J. Enol. Vitic. 10:85-100.

6. Coombe, B.G. 1962. The effect of removing leaves, flowers and shoot tips on fruit set of Vitis vinifera L. J. Hort. Sci. 37:1-15.

7. Coombe, B.G. 1973. Regulation of set and the development of the grape berry. Acta. Horticulture 34:261-273.

8. Fisher, K.H., O.A. Bradt, J. Wiebe and V.A. Dirks. 1977. Cluster thinning 'de Chaunac' French hybrid grapes improves vine vigor and fruit quality in Ontario. J. Amer. Soc. Hort. Sci. 102(2):162-165.

9. Hale, C.R., and P.J. Weaver. 1962. The effect of developmental stage on direction of translocation of photosynthate in *Vitis vinifera* . Hilgardia 33:89-131.

10. Hunter, D.M. and J.T.A. Proctor. 1985. Effects of timing of thinning influence on Seyval blanc fruit yields and quality. Presented at 10th Annual meeting of the American Society for Enology and Viticulture/Eastern section, Mississauga, Ont. (August 1985).

11. Looney, N.E. 1981. Some growth regulator and cluster thinning effects on berry set and size, berry quality, and annual productivity of 'De Chaunac' grapes. Vitis 20:22-35.

12. Marios, J.J. 1987. *Botrytis* bunch rot of grapes. Oregon Dpt. of Agr.: The Wine Advisory Board Research Report. June (5):1-6.

13. McClellan, W.D. and W.B. Hewitt. 1973. Early *Botrytis* rot of grapes: Time of infection and latency of *Botrytis cinerea* Pers. in *Vitis vinifera* L. Phytopathology. 63:1151-1157.

14. Nelson, K.E. 1951. Factors influencing the infection of table grapes by *Botrytis cinerea* (Pers). Phytopathology. 41:319-326.

15. Percival, D.C., J.A. Sullivan, and K.H. Fisher. 1993. Effect of cluster exposure, berry contact and cultivar on cuticle membrane formation and occurrence of bunch rot (*Botrytis cinerea* Pers.:Fr.) with 3 *Vitis vinifera* L. cultivars. Vitis 32:87-97.

16. Quinlan, J.D. and R.J. Weaver. 1970. Modification of pattern of the photosynthate movement within and between shoots of *Vitis vinifera* L. Plant Physiol. 46:527-530.

17. Reynolds, A.G., R.M. Pool and L.R. Mattick. 1986a. Effect of shoot density and crop control on growth, yield, fruit composition and wine quality of 'Seyval blanc' grapevines. J. Amer. Soc. Hort. Sci. 111(1):55-63.

18. Skene, K.G.M. 1969. A comparison of the effects of "Cycocel" and tipping on fruit set in *Vitis vinifera*. Austr. J. Biol. Sci. 22:1305-1311.

19. Smart, R.E., C.M. Seaver. 1988. Handbook for Canopy Management Workshop. Pesented at 2nd International Cool climate Viticulture and Oenology Symposium, Matua Valley Vineyard Kumeu, New Zealand. (Jan. 1988). pg. 1-20.

20. Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometric Approach. McGraw-Hill Book Company, New York, NY.

21. Striegler, R.K., and G.S. Howell. 1991. The influence of rootstock on the cold hardiness of Seyval grapevines: 1. Primary and secondary effects on growth, canopy development, yield, fruit quality and cold hardiness. Vitis. 30:1-10.

22. Weaver, R.J. and R.M. Pool. 1968. Effect of various levels of cropping on *Vitis vinifera* grapevines. Am. J. Enol. Vitic. 19:185-193.

23. Weaver, R.J. and R.M. Pool. 1971b. Chemical thinning of grape clusters (*Vitis vinifera* L.). Vitis. 10:201-209.

24. Winkler, A.J. 1929. The effect of dormant pruning on the carbohydrate metabolism of the vine. Hilgardia. 4:153-173.

25. Winkler, A.J. 1958. The relation of leaf area and climate to vine performance and grape quality. Amer. J. Enol. 9:10-23.

TABLE 1. *Influence of pruning severity and time of cluster thinning on the vine size indices averaged from 1992-1993 of Seyval grapevines at Fenn Valley vineyards.*

Treatment	Vine Size (kg/vine)	Nodes Retained	Vegetatineness (vine size gm /Shoot)	% Blind Nodes	Count Shoots	Non-Count Shoots	Excellent Quality Canes x	Acceptable Quality Canes x	Poor Quality Canes x	Total Canes
Nodes Retained by Pruning Formula (N=10+10)										
N	0.55	14 c	15.3 a	16 a	11 c	28 a	9 a	16	15 b	40 b
3N	0.54	39 b	13.3 ab	10 b	34 b	11 b	9 a	17	18 b	44 b
6N	0.58	80 a	11.2 b	14 ab	68 a	0 c	6 b	17	38 a	62 a
	ns	**	**	**	**	**	*	ns	**	**
Time of Cluster X Thinning										
Bloom y	0.53	43	12.8	13	37	11	8	15	24	48
Post Set z	0.59	45	13.7	13	39	11	8	18	23	50
	ns	ns	ns	ns	ns	ns	ns	**	ns	ns
Nodes Retained X Thinning Time										
N Bloom	0.51	14	14.2	16	11	28	8	15	15	39
Post Set	0.59	14	16.4	15	12	29	10	17	14	41
3N Bloom	0.50	38	12.9	11	33	10	8	15	19	43
Post Set	0.59	40	13.7	10	35	11	10	19	18	46
6N Bloom	0.57	78	11.4	13	67	0	7	15	39	62
Post Set	0.59	81	10.9	15	69	0	6	18	38	62
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

x The number of canes per vine within the catagory (Excellent, Acceptable, or Poor) exhibiting those cold hardiness characteristics.

y Crop load was set in the Bloom treatments to 15 clusters/lb. cane prunings.

z Crop load was set in the Post-Set treatments to 15 clusters/lb. cane prunings.

F values significant at 5% (*); 1% (**); or not significant (ns).

Means separation within columns using Duncan's New Multiple Range Test.

TABLE 2. *Influence of pruning severity and time of cluster thinning on fruit set averaged from 1992-1993 of Seyval grapevines at Fenn Valley vineyards.*

Treatment	Cluster Length (cm)	Est. Flower Number x	Total Berries Set/ Cluster	Percent Berry Set	Quality Berries/ Cluster y	Percent Berry Rot/ Cluster z	Berry wt. (gm)
Nodes Retained by Pruning Formula (N=10+10)							
N	10.4	575 b	237	41 a	137	35 a	2.13 b
3N	11.3	625 a	236	37 b	147	27 b	2.27 a
6N	10.3	576 b	216	37 b	135	25 b	2.36 a
	ns	*	ns	**	ns	**	**
Time of Cluster Thinning							
Bloom	11.0	605	302	50	158	42	2.09
Post Set	10.3	579	157	27	121	16	2.41
	ns	ns	**	**	**	**	**
Nodes Retained X Thinning Time							
N Bloom	10.6	575	281 a	49 ab	149 ab	41 a	1.99
Post Set	10.2	575	192 b	34 c	126 bc	29 b	2.27
3N Bloom	11.7	640	306 a	47 b	159 ab	41 a	2.06
Post Set	11.0	609	166 b	27 d	135 abc	13 c	2.48
6n Bloom	10.8	598	318 a	53 a	167 a	42 a	2.22
Post Set	9.9	554	114 c	21 e	103 c	7 d	2.50
	ns	ns	**	**	*	**	ns

x Estimated Flower numbers based on a standard made from counts and measurements of 30 Seyval clusters taken just prior to bloom.
y The number of berries per cluster exhibiting no rot infection.
z The percentage of berries per cluster exhibiting rot infection.
F values significant at 5% (*); 1% (**); or not significant (ns).
Means separation within columns using Duncan's New Multiple Range Test.

TABLE 3. *Influence of pruning severity and time of cluster thinning on the vine size and yield indices averaged from 1992-1993 of Seyval grapevines at Fenn Valley vineyards.*

Treatment	Vine Size (kg/vine)	Nodes Retained	Yield (Kg/vine)	Yield (T/A)	Productivity (yield/prev. yr vine size)	Fruitfulness (yield (gm)/ Shoot)	Crop Load (yield/current yr vine size)
Nodes Retained by Pruning Formula (N=10+10)							
N	0.55	14 c	5.53	3.15	13.15	150.3 a	13.90
3N	0.54	39 b	5.83	3.32	16.31	139.7 a	13.35
6N	0.58	80 a	6.05	3.45	13.56	108.3 b	13.45
	ns	**	ns	ns	ns	**	ns
Time of Cluster Thinning							
Bloom y	0.53	43	6.71	3.82	16.73	156.0	16.07
Post Set z	0.59	45	4.90	2.79	11.95	109.5	11.06
	ns	ns	**	**	**	**	**
Nodes Retained X Thinning Time							
N Bloom	0.51	14	5.86 bc	3.34 bc	14.02 b	167.4	14.70
Post Set	0.59	14	5.21 bc	2.97 bc	12.27 bc	133.1	13.10
3N Bloom	0.50	38	6.57 ab	3.74 ab	18.52 a	160.5	16.84
Post Set	0.59	40	5.09 bc	2.90 bc	14.10 b	118.9	10.05
6n Bloom	0.57	78	7.70 a	4.39 a	17.65 a	140.1	16.67
Post Set	0.59	81	4.40 c	2.51 c	9.47 c	76.5	10.23
	ns	ns	*	*	**	ns	ns

y Crop load was set in the Bloom treatments to15 clusters/lb. cane prunings.
z Crop load was set in the Post Set treatments to 15 clusters/lb. cane prunings.
F values significant at 5% (*); 1% (**); or not significant (ns).
Means separation within columns using Duncan's New Multiple Range Test.

Table 4. **Influence on increasing crop levels retained at thinning on yield (kg) [illegible] Fenn Valley vineyards.**

Table 4. **Influence on increasing crop levels retained at thinning on yield (kg) in 1993 of Seyval grapevines at Fenn Valley vineyards.**

Pruning severity by Cropping Level x	FCT y	PST z
N 15	4.46	3.28
18	4.20	5.12
21	5.58	6.86
3N 15	5.14	4.23
18	6.46	4.91
21	6.46	5.54
6N 15	5.61	2.84
18	6.56	5.05
21	7.39	5.44

x Crop level determined at either bloom (FCT) or post-set (PST) to 15, 18, or 21 clusters per 453.6 grams of cane prunings.

y The (FCT) vines were cluster thinned on June 23, 1993.

z The (PST) vines were cluster thinned on July 8, 1993.

TABLE 5 *Influence of pruning severity and time of cluster thinning on the yield components and fruit quality indices averaged from 1992-1993 of Seyval grapevines at Fenn Valley vineyards*

TABLE 5. Influence of pruning severity and time of cluster thinning on the yield components and fruit quality indices averaged from 1992-1993 of Seyval grapevines at Fenn Valley vineyards.

Treatment	Yield (Kg/vine)	Cluster Number	Cluster wt. (gm)	Berry wt. (gm)	Non-Count Clusters	pH	Titratable Acidity	Soluble Solids	Shoots/ Cluster
Nodes Retained by Pruning Formula (N=10+10)									
N	5.53	24	235.7 b	2.13 b	2	3.23	0.74	18.2	1.8 b
3N	5.83	23	266.6 a	2.27 a	2	3.19	0.78	17.8	2.1 b
6N	6.05	25	256.4 ab	2.36 a	3	3.23	0.76	18.1	2.8 a
	ns	ns	*	**	ns	ns	ns	ns	**
Time of Cluster Thinning									
Bloom y	6.71	25	281.5	2.09	4	3.19	0.77	17.5	2.1
Post Set z	4.90	23	224.3	2.41	1	3.25	0.75	18.6	2.4
	**	ns	**	**	**	**	ns	**	*
Nodes Retained X Thinning Time									
N Bloom	5.86 bc	24	248.6 b	1.99	3	3.21	0.75	18.0 b	1.8
Post Set	5.21 bc	24	222.9 b	2.27	2	3.26	0.72	18.4 b	1.8
3N Bloom	6.57 ab	23	295.9 a	2.06	2	3.17	0.77	17.5 bc	2.0
Post Set	5.09 bc	23	237.3 b	2.48	1	3.21	0.79	18.0 b	2.2
6N Bloom	7.70 a	28	300.0 a	2.22	7	3.20	0.79	17.0 c	2.4
Post Set	4.40 c	23	212.7 b	2.50	0	3.26	0.73	19.3 a	3.2
	*	ns	*	ns	ns	ns	ns	**	ns

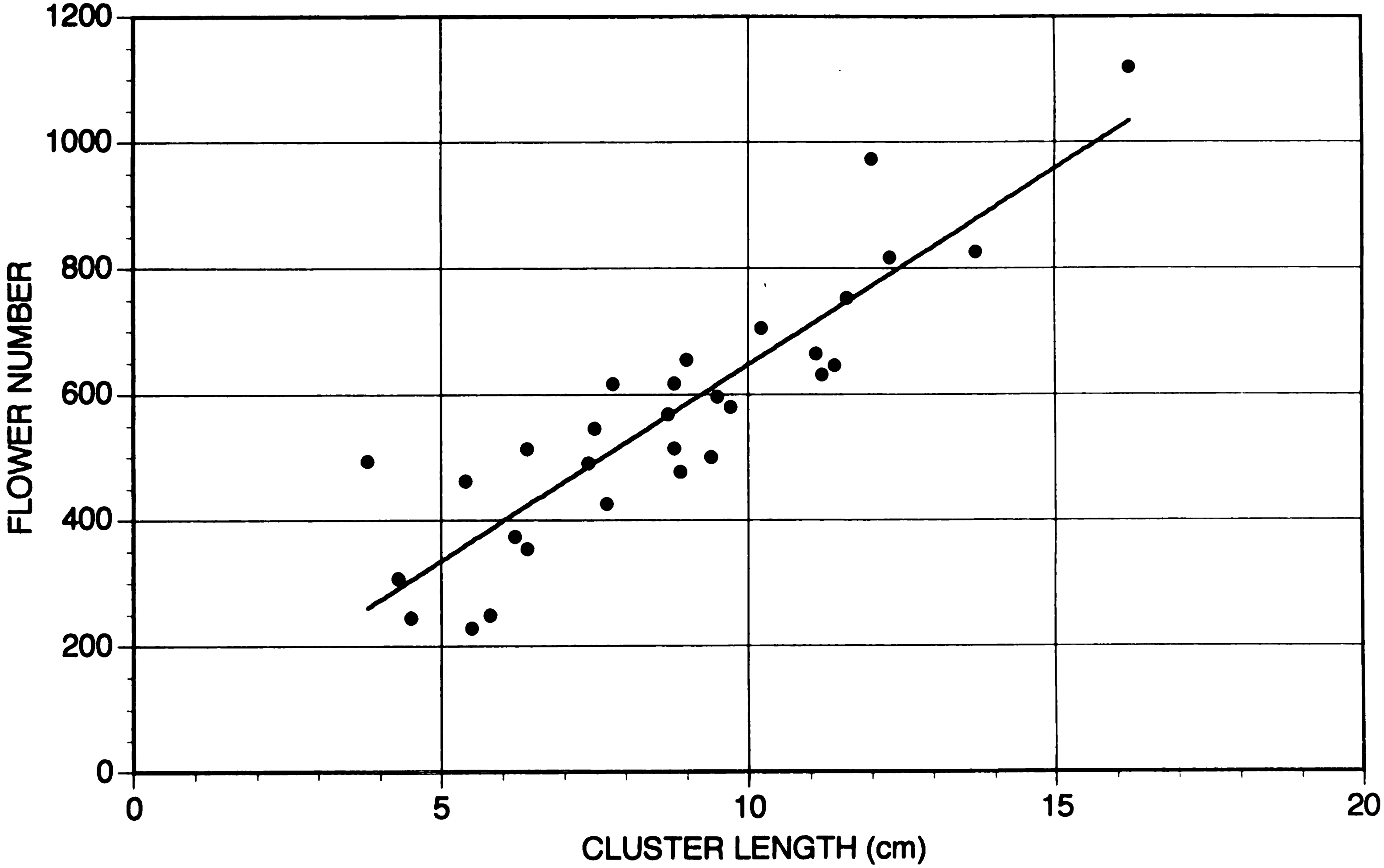
y Crop load was set in the Bloom treatments to 15 clusters/lb. cane prunings.

z Crop load was set in the Post Set treatments to 15 clusters/lb. cane prunings.

F values significant at 5% (*); 1% (**); or not significant (ns).

Means separation within columns using Duncan's New Multiple Range Test.

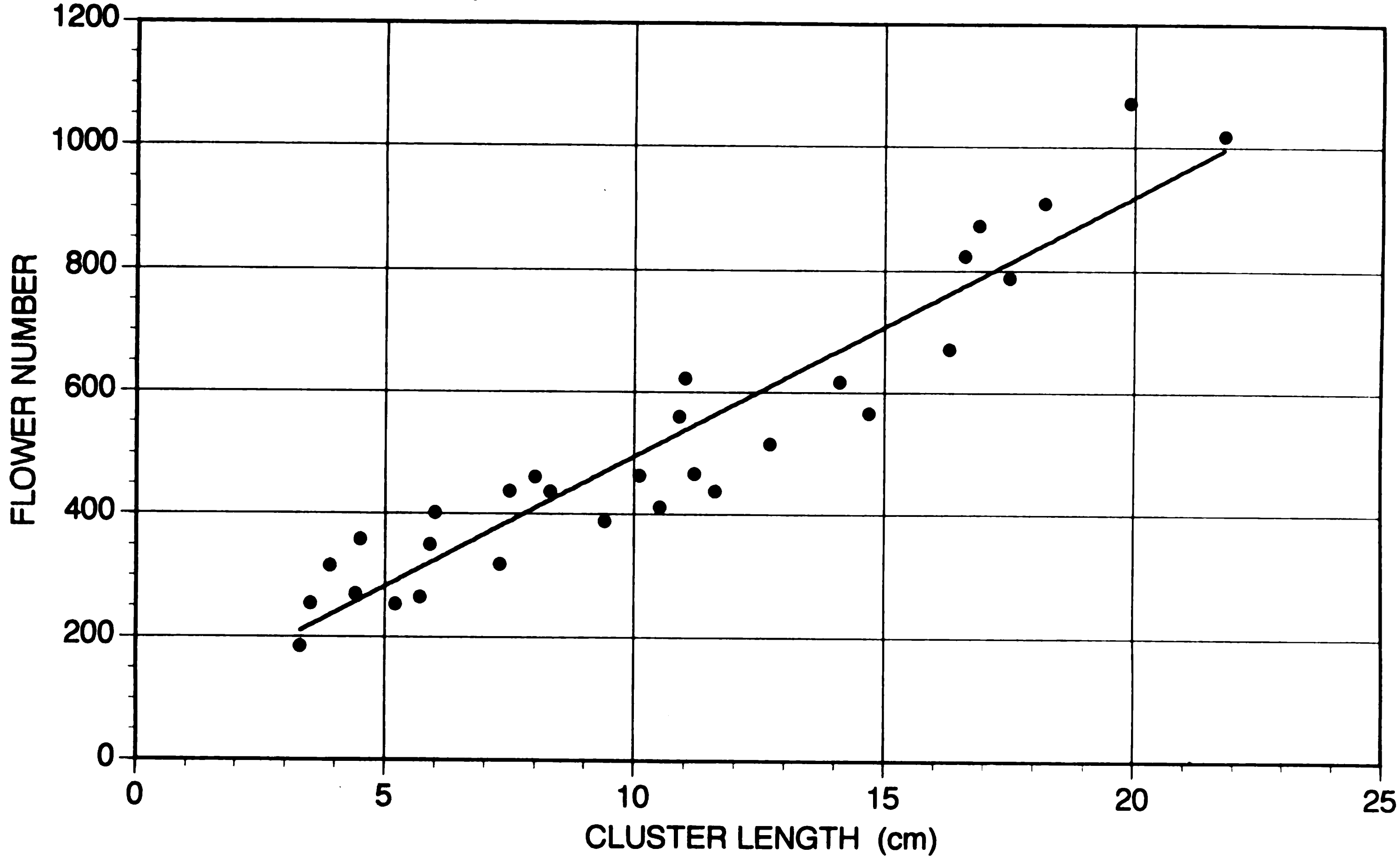
Fig. 1. 1992 standard for flowers per cluster measurements in Seyval grapevines at Fenn Valley vineyards.



R^2 = 0.7965
R**

f(x) = 62.323 (x) + 24.102

Fig. 2. 1993 Standard for flowers per cluster measurements in Seyval grapevines at Fenn Valley vineyards.



R^2 = 0.9008
R**

f(x)= 42.451(x)+70.874

Fig. 3. Effect of pruning severity on the 1992 season canopy development of Seyval grapevines at Fenn Valley vineyards, expressed as leaf layer number.

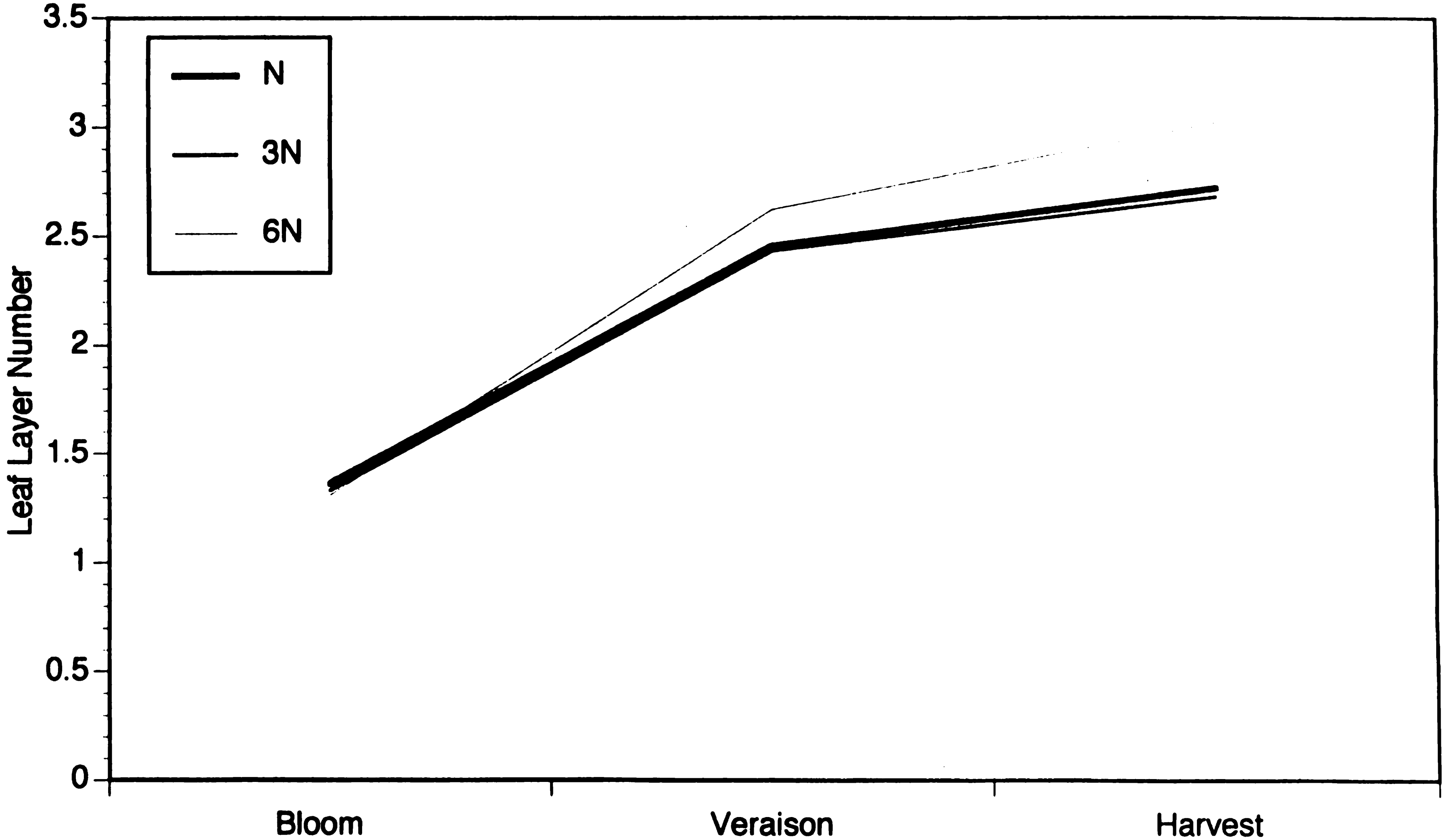
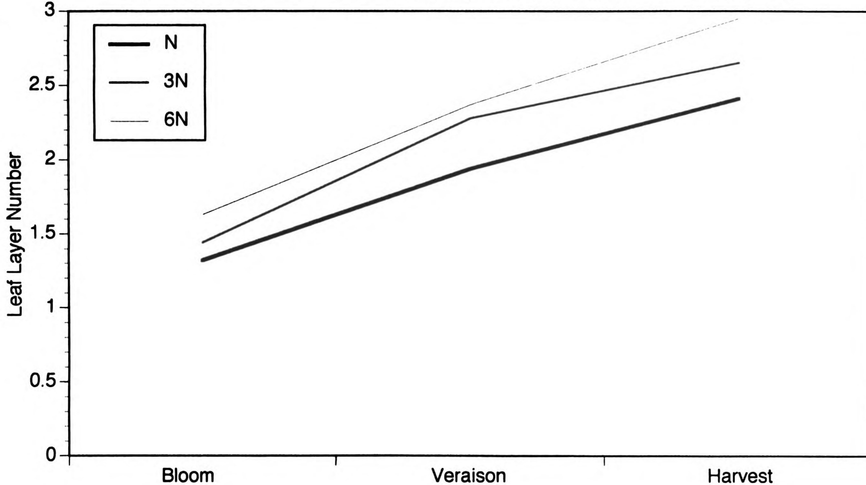


Fig. 4. Effect of pruning severity on the 1993 season canopy development of Seyval grapevines at Fenn Valley vineyards, expressed as leaf layer number of Seyval.



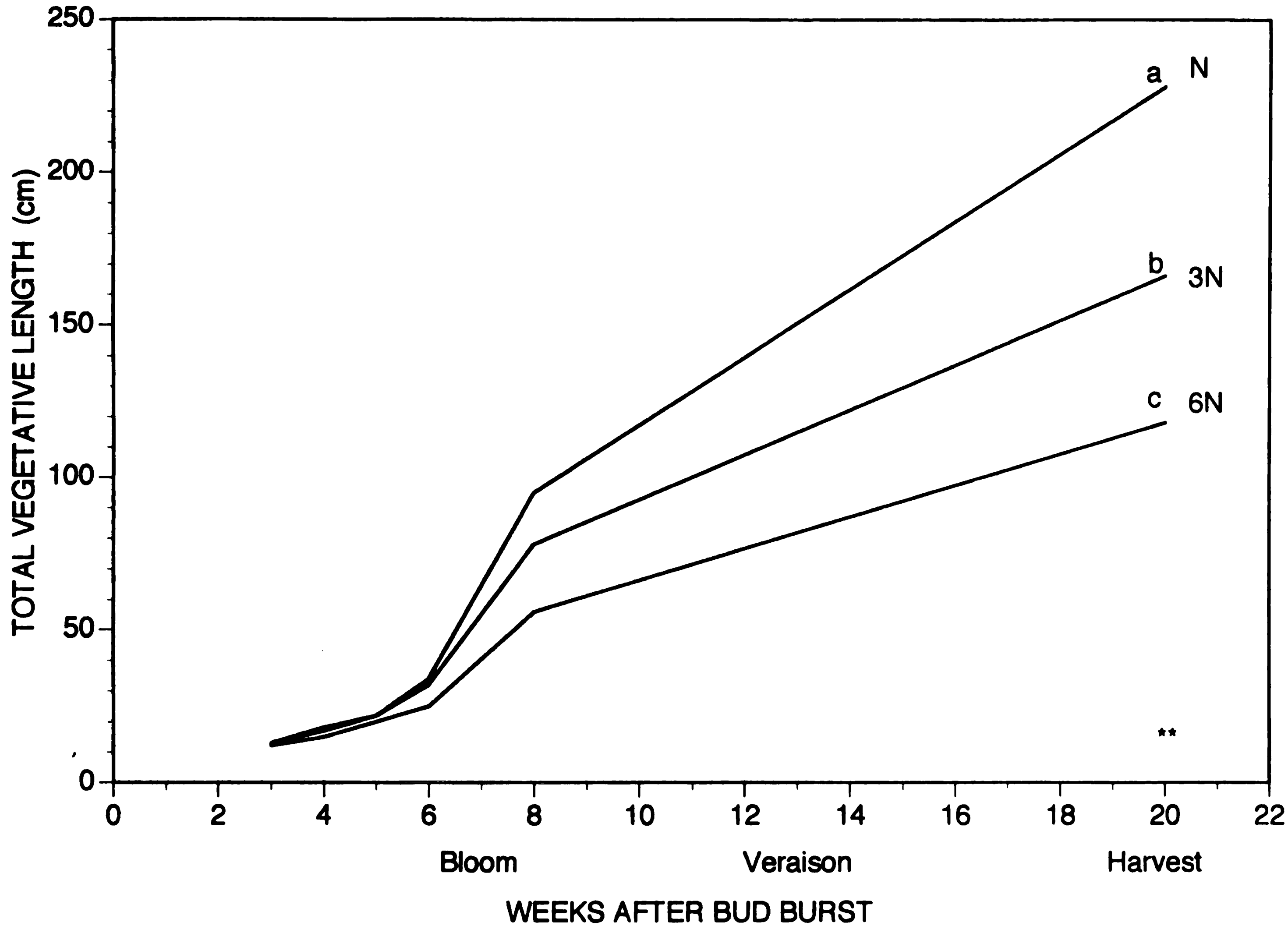


Fig. 5. Influence of pruning severity on the total vegetative length per shoot (primary + lateral) of Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

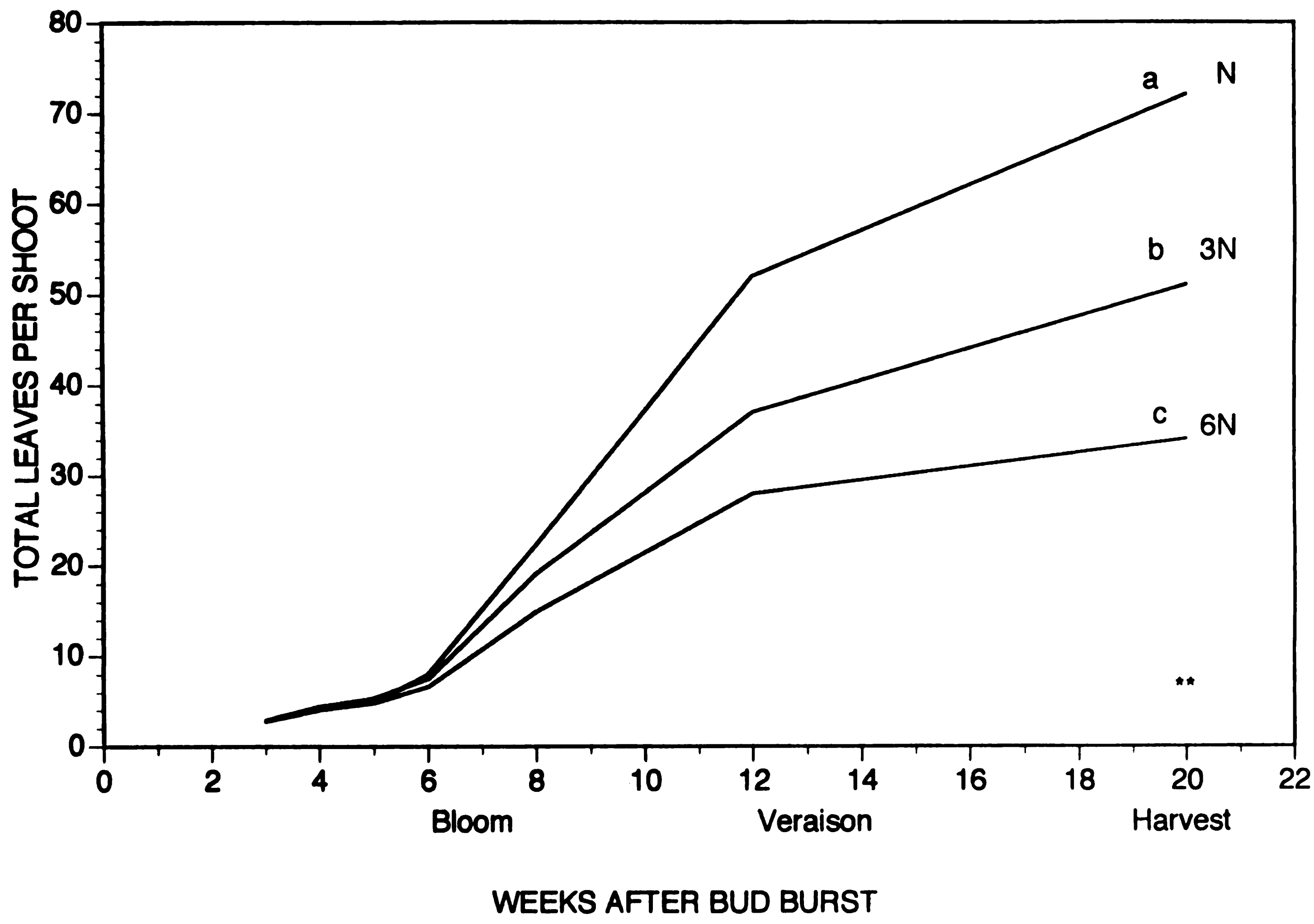


Fig. 6. Influence of pruning severity on the total leaves per shoot (primary + lateral) of Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

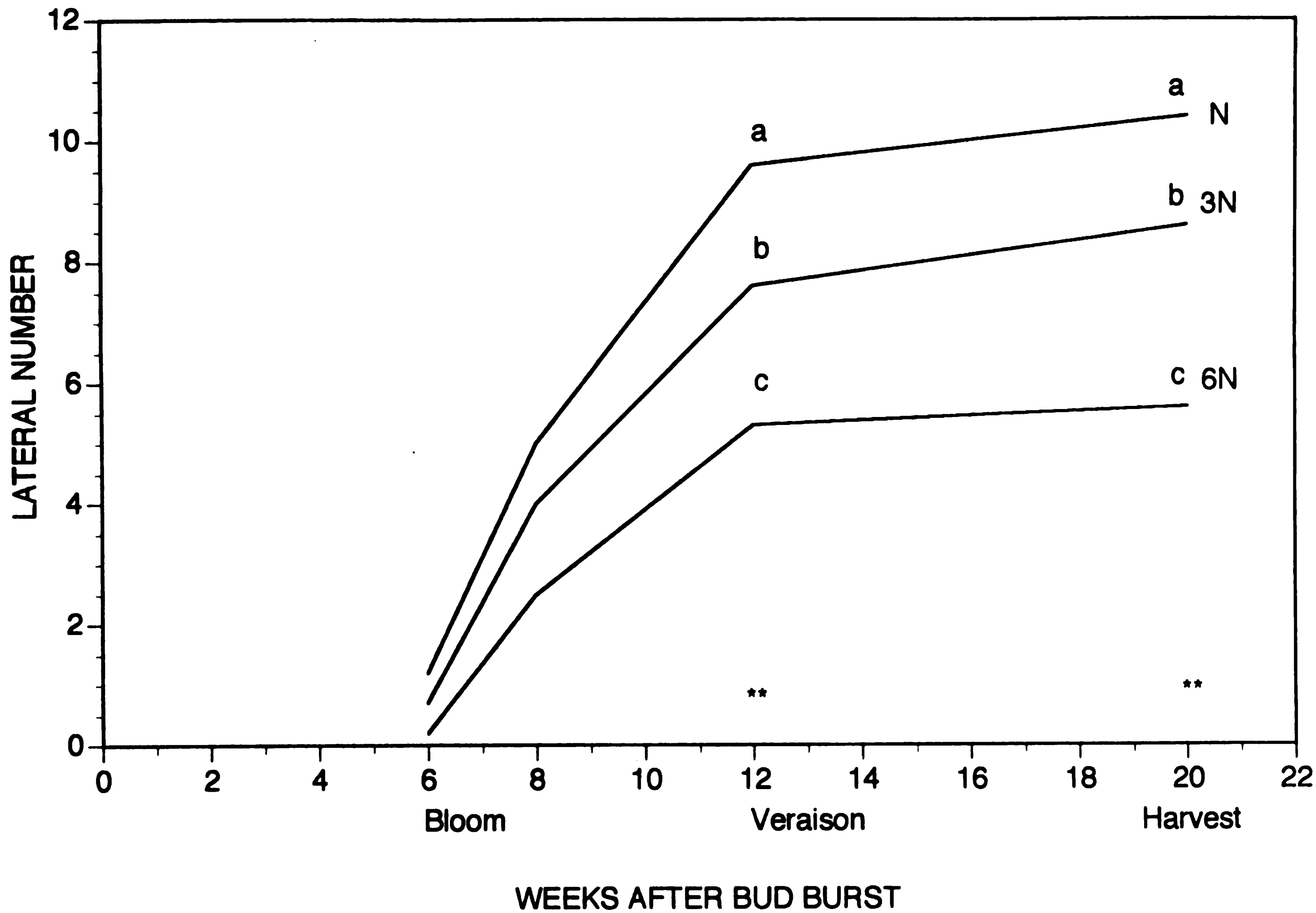
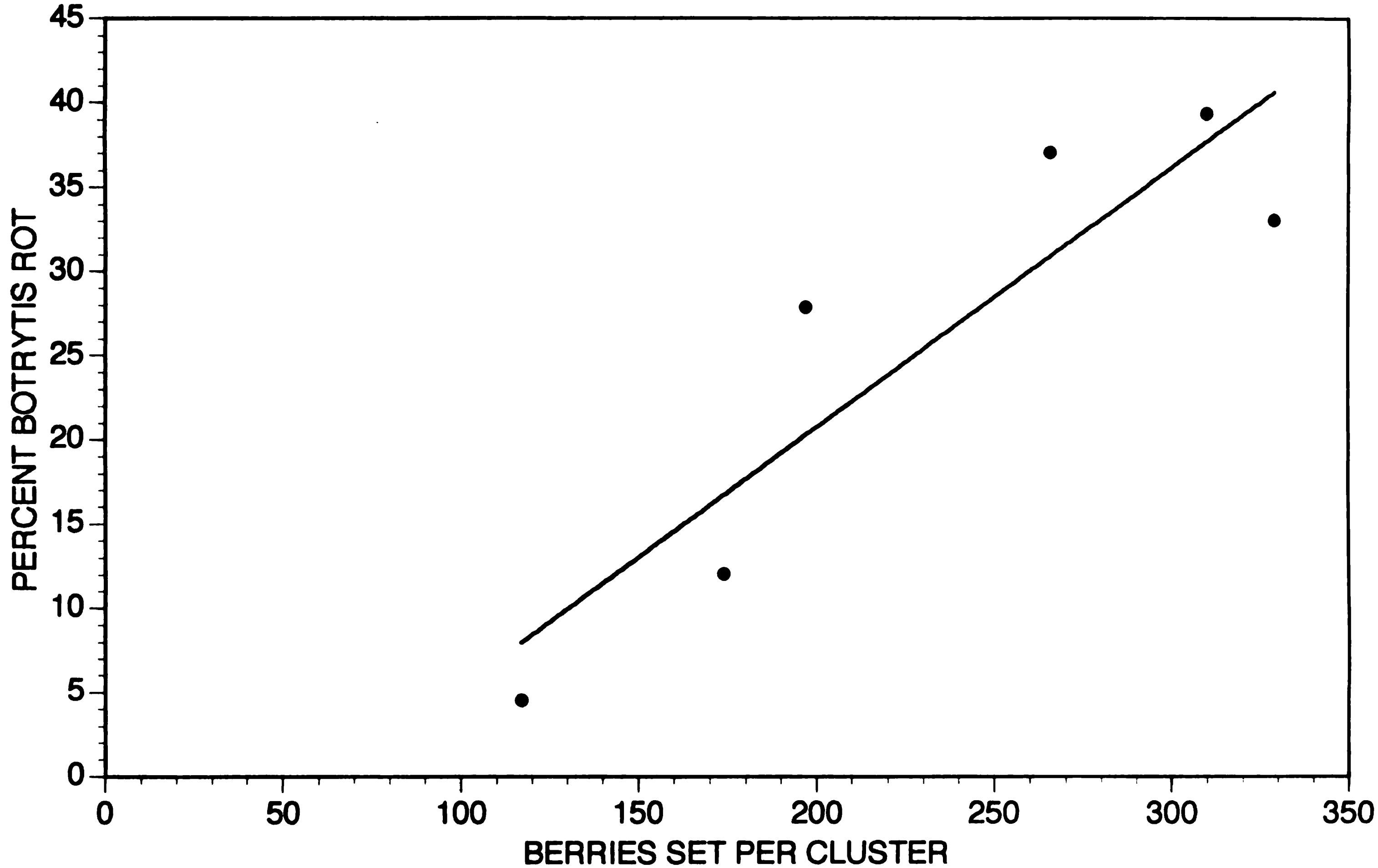


Fig. 7. Influence of pruning severity on lateral number per shoot of Seyval grapevines at Fenn Valley vineyards during the 1993 growing season.

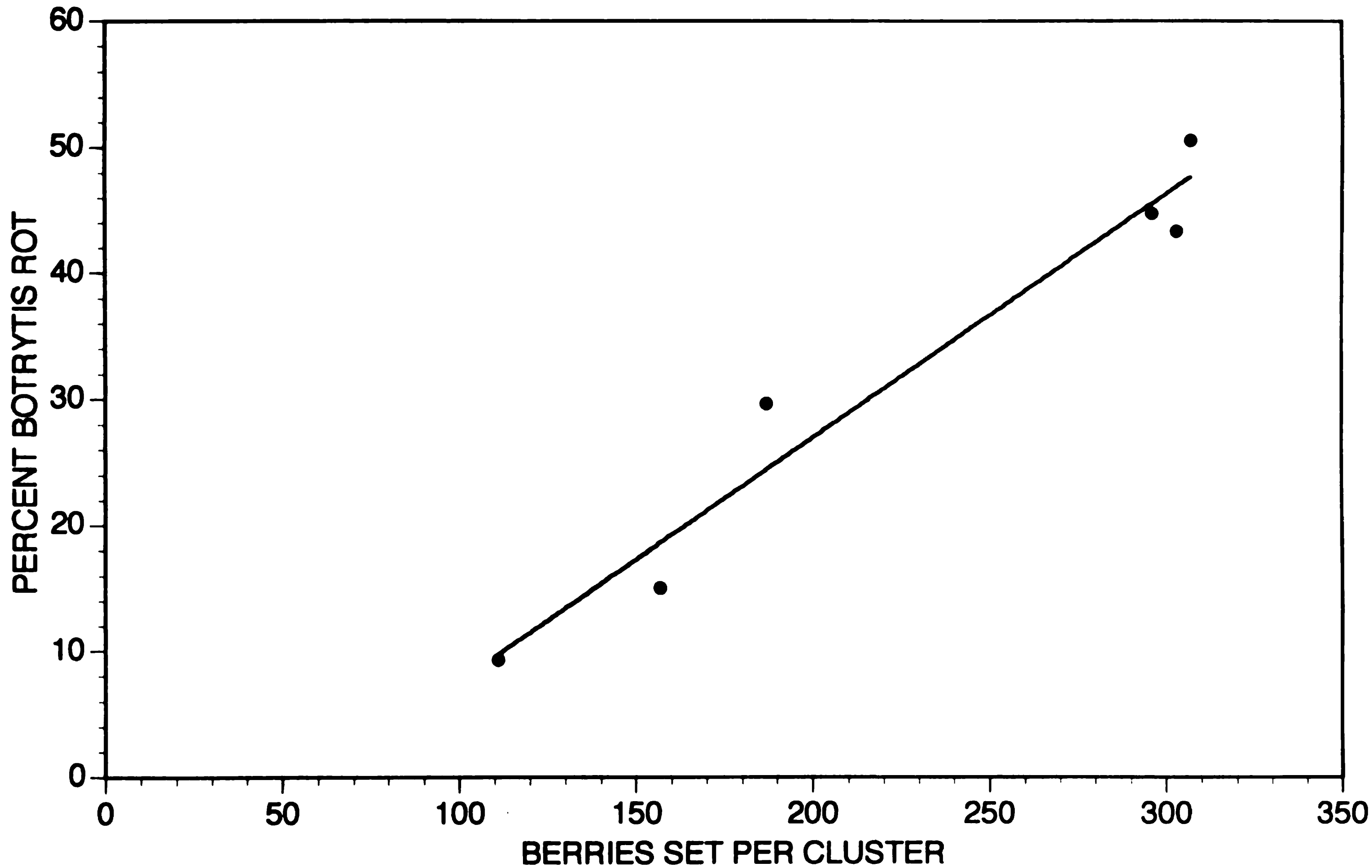
Fig. 8. 1992 Percentage Botrytis rot as a function of the number of berries set per cluster in Seyval grapevines.



R^2= 0.81283
R*

f(x)= 0.154 (x) - 10.088

Fig. 9. 1993 Percentage Botrytis rot as a function of the number of berries set per cluster in Seyval grapevines.



R2= 0.9573

R**

f(x)= 0.193 (x) - 11.699

CHAPTER IV

THE USE OF CARBOHYDRATE SINK COMPETITION TO REDUCE FRUIT SET AND BOTRYTIS ROT IN VIGNOLES GRAPEVINES

Abstract

Three dormant season pruning severities and an unpruned (UP) treatment were imposed on Vignoles grapevines to vary fruiting and vegetative sinks during fruit set. Vines were balanced pruned to either 15, 30, or 60 nodes per 454 g. of cane prunings. The treatments leaving additional nodes per vine during the dormant season, were balanced pruned after anthesis. Five and ten node canes were compared at each pruning severity. Increasing the competition for carbohydrates between fruitful and vegetative sinks during anthesis by decreasing pruning severity during the dormant season had little affect on fruit-set. The (UP) treatment decreased yield, due to reduced cluster formation per shoot. The clusters that did develop had fewer flowers each year and thus, fewer berries set. Reductions in *Botrytis* infection were observed only in 1993 in the (UP) treatment. Cane length had no affect on fruit-set or *Botrytis* infection. Competition induced by fruitful sinks was limited because of the small size of Vignoles clusters. However, increasing carbohydrate competition between fruitful and vegetative sinks through anthesis was detrimental to fruit and vine maturity. Post-set pruning does not appear to be a viable cultural practice for management of Vignoles grapevines in Michigan's climate.

Introduction

Vignoles is an important cultivar in Michigan's wine industry. It bears small, compact clusters that are susceptible to harvest season *Botrytis* bunch rot infection. Because of the smaller clusters, balance pruning alone is sufficient for crop control. A 15+15 pruning formula on a High Cordon training system is recommended (11). *Botrytis* bunch rot is a severe disease in Michigan's cool, wet climate. Its prevention or control can be expensive, and if not sufficient, produce losses of yield and fruit quality. Chemical control, sanitation, and canopy management are all successful approaches to minimizing *Botrytis* infection (14). However, chemical control is extensive in Michigan's climate and control products are becoming more limited. *Botrytis cinerea* lives most of its life as a saprophyte, getting nutrients from dead or dying plant parts (14). Sanitation practices reduce the amount of inoculum in the vineyard before each growing season by removing old clusters, dead wood, and debris from the vineyard (14). This can be costly and will not completely relieve the problem. Canopy management practices for Vignoles grapevines need to be developed to help inhibit the infection of *Botrytis* bunch rot in Michigan.

Botrytis cinerea may infect grape flowers and remain latent in these tissues until the clusters begin to mature (15). The spores require prolonged periods of free water and nutrients on the berry surface for germination (14,16). The fungus produces enzymes that can destroy the integrity of the berry in less than 24 hours (14). The main protection for the grape berry to infection is its skin. The cuticle membrane and the epicuticular wax provide the primary physical barriers to pathogen invasion (1). For berry infection to occur, the pathogen must find a weakness on the berry surface where it can bypass the cuticle membrane, or directly penetrate the surface (4). The epicuticular wax layer influences the retention of pesticides, the water retention of the berry surface, and the adhesive ability of plant pathogens (1). Percival et al. (17) found that exposed clusters and those having little berry contact, produced more epicuticular wax and cuticle. Clusters with less berry contact may be achieved by reducing the number of berries set per cluster.

The competition for carbohydrates and growth hormones between sources and sinks to influence fruit set has been well documented. Intra-vine competition for carbohydrates and growth hormones by vegetative (25) and fruiting sinks (8) influences fruit set. Decreasing the competition between sinks by shoot tipping at bloom (6,7,22), girdling (3,6), or flower-cluster thinning (26,27) increases fruit set. Within-cluster competition decreases fruit set (13), while severe pruning (26), or leaf removal during bloom decreases fruit set (5). Flower clusters compete for carbohydrates during bloom (18) and after anthesis when the shoot apex and the developing clusters become the strongest sinks (7,9,18). By increasing the competition for carbohydrates during bloom, potentially the number of berries per cluster can be reduced, resulting in less berry contact and thus less *Botrytis* infection. The following experiment was designed to test this hypothesis and to answer several other questions:

Experimental Objectives

1. Does reduced pruning severity and post-set pruning increase competition among sinks through anthesis in Vignoles?
2. Do the number of vegetative and fruiting sinks at fruit set reduce the number of berries set per cluster in Vignoles?
3. Does reduction in number of berries set per cluster also reduce *Botrytis* rot in Vignoles?
4. Do these pruning strategies influence shoot development or bud and cane cold hardiness of Vignoles?

Materials and Methods

Plant Material

The experiment was established in March of 1991, 4.5 miles East of Lake Michigan (42-15' latitude) at Fenn Valley vineyards in Fennville Mi. Mature, bearing Vignoles grapevines planted in 1976 on an Oshtemo sandy-loam soil were used in the experiment. Rows were spaced 3.0 meters apart with vines 3.7 meters apart within rows. The vines were trained to a bilateral cordon on the top wire, 1.8 meters high (Hudson River Umbrella training system).

<u>Experimental Treatments</u>

The experimental treatments compared four levels of pruning severity in an effort to increase competition between sinks (vegetative and fruitful) during bloom. This was accomplished by retaining 15, 30, or 60 nodes retained (N, 2N, 4N) for every 454 grams of dormant one year cane prunings respectively, and an unpruned treatment (UP). The (2N), (4N), and (UP) treatments were pruned to the (N) level of nodes when the berries were 3-5 cm in diameter (2-3 weeks post-bloom). Two cane lengths (5 or 10 nodes) were compared to study the influence of node position within the canopy. One treatment retained short (5 nodes), while the other retained long (10 nodes) canes, after dormant season and post-set prunings. The unpruned treatments were pruned to either short or long canes after fruit-set. The treatments provided increasing levels of vegetative and fruitful sinks during anthesis.

The (N) vines were pruned to 65-nodes and the live one-year cane prunings weighed to estimate the previous year's vine size. The node number for the (N) vines was then set for the duration of the growing season following the procedures stated above. Because of the number of nodes needed to obtain the (2N) and (4N) levels were much greater than 65-nodes, a method was devised to estimate the weight of retained wood. After pruning the (2N) and (4N) treatments to 90 and 180 nodes per vine respectively, the live canes were weighed. The remaining live nodes of canes on the vine were counted. A weight was assigned to the number of nodes over 65 retained on the vine, based on a node weight calculated in 1992 (113 gm per 41 nodes) and 1993 (113 gm per 43 nodes). This weight and the weight of cane prunings were added producing the vine size estimate for each (2N) and (4N) vine. The total number of live nodes above 65 were counted on each (UP) vine, and a vine size calculated using the average node weight of that year.

Vegetative Measurements

The effect of increased sink competition during bloom on vegetative growth was examined. A consistent determination of vine size was measured as described above. Vegetativeness (vine size (gm) per shoot and node) was calculated for each vine and a shoot number taken at verasion in 1993. Treatment comparisons and interactions of pruning data were analyzed each year. During the 1993 growing season, detailed shoot and leaf measurements were taken on one vine in each treatment replication. Within these sample vines, five shoots were randomly flagged along the cordon for vegetative measurements during the growing season. These include: 1) primary shoot length (PSL); 2) primary shoot leaf number (PSLF); 3) lateral number (L); 4) lateral length (LL); and 5) lateral leaf number (LLF); measured on May 26 (WK3 weeks after bud burst), June 2 (WK4), June 9 (WK5), June 16 (WK6), June 30 (WK8), July 29 (WK12), and September 23 (WK21) one week prior to harvest. Additional calculated data included total leaves per shoot (TSLF=PSLF+LLF) and total vegetative shoot length (PSL+LL). A count of shoots (CS) longer than 10 cm and bearing three or more leaves was taken on WK19. Treatment comparisons were made at appropriate dates and over dates on those variables measured or calculated.

Cold Hardiness Evaluations

Prior to pruning in 1993-1994, a cold hardiness evaluation was taken of the previous season's vegetative growth. Total one year old canes were counted and each cane given an excellent, acceptable, or poor classification. This approach has been used previously by Streigler and Howell (24). Excellent canes consisted of ten or more live nodes with the optimal characteristics of medium diameter (7-10 mm), medium internode length (6-8 cm), and dark periderm. Acceptable canes had five or more living nodes but failed in one of the optimal characteristics. Canes with less than five live nodes or failing at least two optimal characteristics were placed in the poor cold hardiness category. Samples of Vignoles canes within the three classifications were collected in December, January, and March after the 1991 and 1992 growing seasons. Using the three classifications was a rapid and effective way to evaluate the relative cold hardiness of each treatment vine.

Fruit-Set and *Botrytis* Rot Evaluations

A standard curve was developed to allow rapid determination of flower number per cluster based on rachis length for both years. Thirty clusters were randomly sampled from guard vines just prior to bloom. Cluster length was calculated by adding the length of rachis from the lowest basal arm to the tip and the length of the lowest basal arm. Flowers of each sample cluster were counted and a strong correlation was found each year (Figs. 1 and 2). The rachis length of clusters on sample shoots within the sub-plots were measured and their estimated flower number calculated. At harvest, berry pedicles of sample shoot clusters were counted and the percentage of berries set analyzed. The number of whole berries showing no incidence of *Botrytis* rot infection were counted for rot calculations. Subtracting these quality berries from the number of pedicles per cluster provided a number of the berries infected with rot. Fruit-set and *Botrytis* rot comparisons were made each year.

Harvest Procedures and Fruit Quality Assessments

Treatment vines were harvested each year within ten days of October 1. Each vine was hand harvested with the cluster number noted and the fruit placed into an individual bin. Each bin was then weighed in the field and a cluster weight calculated. Clusters from sample shoots of sub-plot vines were harvested separately, weighed, and placed into individual bags for berry counts and fruit quality determination. Berries were randomly taken from these sample clusters to create a 100 berry sample for every sub-plot treatment in each replication. From these samples pH, titratable acidity, soluble solids, and berry weights were determined and the number of berries per cluster calculated. Treatment comparisons of harvest data were analyzed for each year. Using the harvest and pruning data, shoots per cluster (total shoots/ harvest cluster number), productivity (yield per previous year's vine size), fruitfulness (yield (gm) per shoot), and crop load (yield per current season's vine size) were calculated for every treatment vine and analyzed for each year.

Experimental Design and Analysis

The plots were established in March of 1991 at Fenn Valley vineyards in Fennville Mi. A split-plot design was used with the main-plot consisting of four treatments (N, 2N, 4N, and UP) of four vines each, replicated five times. One guard vine separated each main-plot treatment. Each main-plot was divided into two sub-plots (Short and Long canes) consisting of two vines. Comparisons and interactions between treatments were made each year using the MSTAT-C statistical computer package. Analysis was by ANOVA, with mean separations calculated using Duncan's Multiple Range Test (23). The fruit-set standards were calculated using the Delta Graph computer package. The experiment was terminated after pruning in March of 1994.

Results and Discussion

Vine Size Response

Decreasing pruning severity increased the number of nodes retained, and increased the amount of vegetation removed at post-set pruning. No significant differences were found in vine size from 1991 among the treatments (Table 1). In 1992, vine size in the (UP) treatment decreased dramatically to 180 grams per vine compared to the other treatments of 760 grams or more (Table 1). The (UP) vines averaged over 400 nodes retained through anthesis. The (4N), (2N), and (N) treatments were significantly lower at 130, 56, 32 nodes retained, respectively. Thus, increasing amounts of vegetation (vine size) was pruned away at post-set as pruning severity decreased. Nearly all of shoot production arose from count positions in each of the treatments. Shoot numbers per vine were similar to the number of nodes retained at post-set pruning (Table 1). In 1993, the (4N) and (UP) vine sizes were significantly different from (N) (Table 2). The (UP) vines improved their vine size to nearly equal that of (2N) and (4N), due to many of the shoots being non-fruitful. The (4N) and (UP) vines had the same number of nodes retained (103), 2-3 times more than (N) and (2N) (31 and 59 nodes retained respectively). Shoot numbers decreased with the reduced pruning severity, and each treatment averaged 12-14 adventitious (arising from non-count positions) shoots (Table 2). Vine size decreased in all of the treatments from 1991, however, decreasing pruning severity through anthesis increased the rate of vine size reduction.

Cane Maturity

Cane maturity was examined by calculating vegetativeness per node and shoot, and by cold hardiness evaluations. Since nodes retained after post-set pruning and shoot numbers among treatments in 1992, the vegetative response per node and shoot followed the vine size response (Table 1). Because of the low vine size of the (UP) vines in 1992, less nodes were retained during the post-set pruning in 1993. As a result, vegetativeness per node was significantly greater (Table 2). However, no variance was observed in vegetativeness per shoot although, shoot number decreased with decreasing pruning severity (Table 2).

Samples of Vignoles canes within the three classifications (excellent, acceptable, and poor) were collected in December, January, and March after the 1991 and 1992 growing seasons. Periderm and primary bud cold hardiness were significantly different among treatments at the 0.01 level (Figs. 3 and 4). Excellent canes were superior while poor canes were inferior to acceptable canes over years and at each date evaluated. Using these classifications, each treatment vine cane was evaluated. In 1992, decreasing pruning severity reduced the number of excellent quality canes, while increasing poor quality canes per vine (Table 1). Decreasing pruning severity to the (4N) or (UP) level, reduced the number of excellent quality cold hardy canes by 50 percent in 1993, but was found not to be significant (Table 2). However, (4N) and (UP) vines matured significantly less acceptable quality canes, and (4N) vines produced more poor quality canes than the other treatments. No significant differences were found in any of the vegetative indices measured for either year between cane lengths. Reducing the severity of dormant season pruning and increasing the amount of post-set pruning, decreased the amount of vegetation the vine was able to utilize and mature after anthesis.

Shoot Assessments

Detailed shoot measurements were taken during the 1993 growing season from five sample shoots on one vine of each treatment replication. Treatments did not vary in primary shoot length or leaf number until after bloom, when (N) shoots were significantly longer and had more leaves than (UP) shoots (Figs. 5 and 6). At harvest (4N) and (UP) shoots were shorter than (N) shoots, and (UP) shoots still had fewer leaves. No differences were seen in lateral number, lateral leaf number, and lateral length until after bloom (Fig. 7, 8, and 9). Lateral growth decreased as pruning severity was reduced. The (N) shoots produced superior numbers of laterals with more leaves and length than any other treatment. The (2N) shoots produced greater numbers of laterals with more leaves and length than (4N) and (UP) shoots. Lateral growth contributed to the separation of treatments in total shoot length and leaf number. Again, (N) shoots were superior to the

other treatments and the (2N) shoots produced more than (4N) and (UP) shoots (Figs. 10 and 11). No differences in shoot growth were observed among cane lengths for any of the variables measured. Overall, decreasing pruning severity and increasing sink competition, reduced the vegetative production per shoot. This agrees with previous work on increased competition resulting from greater crop levels (2,23).

Yield Indices and Fruit Quality Assessments

Lower yields and fruit quality resulted from decreased pruning severities. In 1992, the (UP) vines yielded less than half the crop per vine (more than 1.5 tons per acre) than the other treatments (Table 3). This was the result of reduced berry and cluster weights. Titratable acidity and soluble solids were significantly lower and pH was higher in berries of (UP) vines. The (UP) vines produced 70 to 80 percent less crop than the other treatments in 1993 (Table 4). They managed a crop of only a third of a ton per acre, compared to yields of 1.25 to 1.90 tons per acre in the other treatments. This was a result of non-fruitful shoots, resulting in a four-fold increase in the number of shoots per cluster. The (4N) vines produced 80 percent less crop than (N) vines. All of the treatments subjected to post-set pruning had a decrease in berry weight each year, and the (UP) treatment had a reduction in berries per cluster in 1993 (Tables 3 and 4). However, only the cluster weight of the (UP) treatment was affected. This coincides with previous work with increasing sink competition (10,19). Berries in the (UP) treatment were significantly lower in titratable acidity with a higher pH than the other treatments in 1992 (Table 5). In 1993, the (4N) and (UP) vines produced berries with the highest pH and lowest titratable acidity (Table 6); again, the result of a decreased crop load. However, the (4N) and (UP) berries had the lowest soluble solids each year. This contradicts previous work (20,21) suggesting canopy reductions improve canopy microclimate. Post-set pruning reduced the leaf area available for fruit and wood ripening in the (4N) and (UP) vines. Increasing sink competition through anthesis caused reductions in yield, as a function of poor berry development, and fruit quality.

Due to the decrease in yield in 1992, productivity and fruitfulness declined in the (UP) vines, but a severe reduction in vines size caused crop load to be over twice as high as the other treatments (Table 3). Long canes increased fruitfulness and productivity in 1992. Fruitfulness was significantly lower again in the (UP) vines in 1993, and their crop load averaged 75 percent less than the other treatments (Table. 4). Long canes were more fruitful in 1993, due to a significant reduction in the number of shoots per cluster. Cane length had no other influence on the yield indices of Vignoles.

Fruit-Set and *Botrytis* Rot Evaluations

Delaying pruning until after anthesis, reduced the number of flowers produced per cluster in each year. The treatments did not influence berry-set or *Botrytis* infection in 1992 (Table 5), but fruit-set and bunch rot in (UP) vines was lower in 1993 (Table 6). Twenty to 30 fewer berries were set by the (UP) vines and half the rot of (N) was observed. The (UP) vines still ripened 30 percent less quality berries in 1993. Long canes produced more flowers per cluster in 1992 (Table 5), but no variance was seen between cane lengths in any other fruit-set or bunch rot measurement in that year or the next. Longer canes were more productive and fruitful because they were better exposed and produced more numbers of shoots per cluster. Only at the (UP) level of nodes retained through anthesis, did increasing carbohydrate competition influence fruit-set or *Botrytis* infection.

Conclusions

Increasing the competition for carbohydrates among fruitful and vegetative sinks during anthesis by decreasing pruning severity during the dormant season, had little effect on fruit-set in Vignoles. The (UP) treatment decreased yield, due to reduced cluster formation per shoot. The clusters that did develop had fewer flowers each year and thus, less berry set. This was caused by either poor bud maturity the previous year, or because of slower shoot development early in the growing season. Reductions in *Botrytis* infection were observed only in 1993 in the (UP) treatment. Cane length had no affect on fruit-set or*Botrytis* infection. Competition induced by fruitful sinks was limited because of the small size of Vignoles clusters. However, increasing sink competition among fruitful and vegetative sinks through anthesis was detrimental to vine maturity.

Reducing dormant season pruning severity resulted in more vegetation pruned from the vine after anthesis. This resulted in poor crop ripening and wood maturity as less canopy was available for a source of photoassimilate after anthesis. The number of shoots per vine of the (2N), (4N), and (UP) treatments were reduced to the (N) level based on vine size after anthesis. The canopies of differing treatments with the same vine size contained equal numbers of shoots from count positions after summer pruning. Individual shoot growth decreased as the pruning severity was reduced. Thus, with decreasing dormant season pruning severity and increased post-set pruning, the canopies contained smaller shoots with less leaf and lateral growth by verasion. The (UP) vines could not replace the deficiency in vegetation caused by post-set pruning. Yield, fruit quality, vine size at harvest, and cane cold hardiness, all decreased in the first year. The (4N) vines were affected in the second year showing the same characteristics as the (UP) vines. Cane length had no affect on shoot development or maturity. Longer canes were more productive and fruitful because they were better exposed and produced more numbers of shoots per cluster. Post-set pruning does not appear to be a viable cultural practice for management of Vignoles grapevines in Michigan's climate. A method to increase carbohydrate competition (through anthesis) to decrease fruit-set and *Botrytis* infection and yet, allow for adequate vegetation for fruit and wood maturity for the rest of the growing season, needs to be developed for Vignoles grapevines.

Literature Cited

1. Baker, E.L. 1982. Chemistry and morphology of plant epicuticular waxes. In: Cutler, D.F., Alvin K.L., Price, C.E. (Eds.): The Plant Cuticle, 139-161. Acedemic Press, Toronto.

2. Bravdo, B., Y. Hepner, C. Loinger, S. Cohen, and H. Tabacman. 1984. Effect of crop level in a high yielding Caragnane vineyard on growth, yield, and wine quality. Am. J. Enol. Vitic. 35:247-252.

3. Brown, K., D.I. Jackson, and G.F. Steans. 1988. Effects of Chlormequat, girdling, and tipping on berry set in *Vitis vineifera* L. Am. J. Enol. Vitic. 39(1):91-94.

4. Bulit, J., and D. Dubos. 1988. *Botrytis* bunch rot and blight. In: Pearson, R.C., Goheen, A.C. (Eds.): Compendium of grape diseases, 13-15. APS Press, St. Paul.

5. Candolfi-Vasconcelos, M.C. and W. Koblet. 1990. Yield, fruit quality, bud fertility and starch reserves of the wood as a function of leaf removal in Vitis vinifera - Evidence of compensation and stress recovering. Vitis. 29:199-221.

6. Coombe, B.G. 1959. Fruit set and development in seeded grape varieties as affected by defoliation, topping, girdling, and other treatments. Am. J. Enol. Vitic. 10:85-100.

7. Coombe, B.G. 1962. The effect of removing leaves, flowers and shoot tips on fruit set of *Vitis vinifera* L. J. Hort. Sci. 37:1-15.

8. Coombe, B.G. 1973. Regulation of set and the development of the grape berry. Acta. Horticulture 34:261-273.

9. Hale, C.R., and P.J. Weaver. 1962. The effect of developmental stage on direction of translocation of photosynthate in *Vitis vinifera* . Hilgardia 33:89-131.

10. Howell, G.S., T.K. Mansfield and J.A. Wolpert. 1987. Influence of training system, pruning severity, and thinning on yield, vine size and fruit quality of Vidal blanc grapevines. Am. J. Enol. Vitic. 38(2):105-112.

11. Howell, G.S. May 1992. Pruning and training Vignoles grapevines in Michigan. Vintner & Vineyard. Coop. Ext. Serv. Pub. 6(1):1-6.

12. Hunter, D.M. and J.T.A. Proctor. 1985. Effects of timing of thinning influence on Seyval blanc fruit yields and quality. Presented at 10th Annual meeting of the American Society for Enology and Viticulture/Eastern section, Mississauga, Ont. (August 1985).

13. Looney, N.E. 1981. Some growth regulator and cluster thinning effects on berry set and size, berry quality, and annual productivity of 'De Chaunac' grapes. Vitis 20:22-35.

14. Marios, J.J. 1987. *Botrytis* bunch rot of grapes. Oregon Dpt. of Agr.: The Wine Advisory Board Research Report. June (5):1-6.

15. McClellan, W.D. and W.B. Hewitt. 1973. Early Botrytis rot of grapes: Time of infection and latency of *Botrytis cinerea* Pers. in *Vitis vinifera* L. Phytopathology. 63:1151-1157.

16. Nelson, K.E. 1951. Factors influencing the infection of table grapes by *Botrytis cinerea* (Pers). Phytopathology. 41:319-326.

17. Percival, D.C., J.A. Sullivan, and K.H. Fisher. 1993. Effect of cluster exposure, berry contact and cultivar on cutical membrane formation and occurrence of bunch rot (*Botrytis cinerea* Pers.:Fr.) with 3 *Vitis vinifera* L. cultivars. Vitis 32:87-97.

18. Quinlan, J.D. and R.J. Weaver. 1970. Modification of pattern of the photosynthate movement within and between shoots of *Vitis vinifera* L. Plant Physiol. 46:527-530.

19. Reynolds, A.G., R.M. Pool and L.R. Mattick. 1986b. Influence of cluster exposure on fruit composition and wine quality of 'Seyval blanc' grapes. Vitis 25:85-95.

20. Reynolds, A.G., and D.A. Wardle. 1989a. Impact of various canopy management techniques on growth, yield, fruit composition and wine quality of Gewurztraminer. Am. J. Enol. Vitic. 40:121-129.

21. Reynolds, A.G. and D.A. Wardle. 1989b. Effects of timing and severity of summer hedging on growth, yield, fruit composition, and canopy characteristics of 'De Chaunac' 1. Canopy characteristics and growth parameters. Am. J. Enol. Vitic. 40:109-120.

22. Skene, K.G.M. 1969. A comparison of the effects of "Cycocel" and tipping on fruit set in *Vitis vinifera* . Austr. J. Biol. Sci. 22:1305-1311.

23. Steel,R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometric Approach. McGraw-Hill Book Company, New York, NY.

24. Striegler, R.K., and G.S. Howell. 1991. The influence of rootstock on the cold hardiness of Seyval grapevines: 1. Primary and secondary effects on growth, canopy development, yield, fruit quality and cold hardiness. Vitis. 30:1-10.

25. Weaver, R.J. and R.M. Pool. 1968. Effect of various levels of cropping on *Vitis vinifera* grapevines. Am. J. Enol. Vitic. 19:185-193.

26. Weaver, R.J. and R.M. Pool. 1971b. Chemical thinning of grape clusters (Vitis vinifera L.). Vitis. 10:201-209.

27. Winkler, A.J. 1929. The effect of dormant pruning on the carbohydrate metabolism of the vine. Hilgardia. 4:153-173.

TABLE 1. Influence of the number of nodes retained and cane length on the vine size and shoot and cane characteristics of Vignoles grapevines at Fenn Valley vineyards. Pruned March 19, 1992.

Treatment	1991 Vine Size (kg/vine)	1992 Vine Size (Kg/vine)	Nodes Retained at Pruning	Nodes Retained Post-Set x	Shoot Number	Vegetativeness 93 vine size (gm)/Node	Vegetativeness 93 vine size (gm)/shoot	Excellent Quality Canes	Acceptable Quality Canes	Poor Quality Canes
Nodes Retained y (N=15+15)										
N	0.94	0.89 a	32 c	32	30	31 ab	30 a	11 a	10	8 c
2N	0.86	0.87 a	56 c	29	31	35 a	28 a	7 b	11	14 b
4N	1.00	0.76 a	130 b	33	37	25 b	21 b	5 b	13	19 a
Unpruned	1.02	0.18 b	403 a	34	31	6 c	6 c	2 c	10	20 a
	ns	**	**	ns	ns	**	**	**	ns	**
Cane Length z										
Short	1.06	0.69	165	35	33	23	21	8	12	14
Long	0.85	0.66	145	29	32	26	21	8	11	14
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Nodes Retained X Cane Length										
N Short	1.22	0.99	39	39	32	28	31	11	12	9
Long	0.66	0.79	25	25	27	34	29	11	8	8
2N Short	0.84	0.86	53	30	31	37	28	7	10	13
Long	0.87	0.88	58	29	32	34	28	7	11	15
4N Short	1.09	0.74	136	36	37	21	20	5	13	19
Long	0.91	0.78	124	31	37	29	21	5	12	20
Unpruned Short	1.08	0.18	432	36	32	5	6	2	11	19
Unpruned Long	0.95	0.17	374	32	30	6	6	3	7	20
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

x Nodes retained after Post Set pruning on 7/15/92.
y Nodes retained (N) based on vine size at pruning on 3/19/92.
z Cane length set during pruning on 3/19/92: Short= 5 nodes; Long= 10 nodes
F values significant at 5% (*); 1% (**), or not significant (ns)
Means separation within columns using Duncan's New Multiple Range Test.

TABLE 2. Influence of the number of nodes retained and cane length on the vine size and shoot and cane characteristics of Vignoles grapevines at Fenn Valley vineyards. Pruned March 3, 1993.

Treatment	1992 Vine Size (kg/vine)	1993 Vine Size (Kg/vine)	Nodes Retained at Pruning	Nodes Retained Post-Set x	Shoot Number	Vegetativeness 93 vine size (gm)/node	Vegetativeness 93 vine size (gm)/shoot	Excellent Quality Canes	Acceptable Quality Canes	Poor Quality Canes
Nodes Retained y (N=15+15)										
N	0.89 a	0.64 a	31 b	31 a	44 a	21 b	15	12	22 a	11 b
2N	0.87 a	0.51 ab	59 b	29 a	41 a	18 b	13	13	17 ab	11 b
4N	0.76 a	0.46 b	104 a	26 a	39 ab	18 b	13	8	10 b	21 a
Unpruned	0.18 b	0.45 b	103 a	15 b	29 b	30 a	17	7	11 b	10 b
	**	*	**	**	**	*	ns	ns	**	**
Cane Length z										
Short	0.69	0.52	73	26	39	20	14	9	16	14
Long	0.66	0.52	75	25	38	21	15	11	14	12
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Nodes Retained X Cane Length										
N Short	0.99	0.67	33	33	47	20	14	11	25	12
Long	0.79	0.61	28	28	41	22	17	13	19	10
2N Short	0.86	0.51	58	29	40	18	14	9	20	11
Long	0.88	0.51	61	30	43	17	12	17	15	11
4N Short	0.74	0.41	102	25	40	16	12	8	9	23
Long	0.78	0.51	107	27	39	19	14	9	11	19
Unpruned Short	0.18	0.48	101	15	29	32	17	8	11	11
Unpruned Long	0.17	0.43	105	15	29	29	16	7	12	10
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

x Nodes retained after Post Set pruning on 7/21/93.
y Nodes retained (N) based on vine size at pruning on 3/3/93.
z Cane length set during pruning on 3/3/93: Short= 5 nodes; Long= 10 nodes
F values significant at 5% (*); 1% (**), or not significant (ns)
Means separation within columns using Duncan's New Multiple Range Test.

TABLE 3. Influence of the number of nodes retained and cane length on the Yield and the components of yield of Vignoles grapevines at Fenn Valley vineyards. Harvested Oct. 16,1992.

Treatment	Yield (Kg/vine)	Yield (T/A)	Cluster number	Cluster wt (gm)	Berries/ cluster	Berry wt. (gm)	Productivity (yield/1991 vine size)	Fruitfulness (yield (gm)/ shoot)	Crop Load (yield/1992 vine size)
Nodes Retained y (N=15+15)									
N	4.88 a	2.79 a	77 a	62.4 a	51	1.26 a	5.97 a	155 a	5.88 b
2N	4.29 a	2.46 a	65 ab	65.5 a	49	1.33 a	5.73 a	158 a	6.19 b
4N	4.75 a	2.73 a	74 a	63.8 a	49	1.30 a	4.95 a	144 a	6.99 b
Unpruned	2.04 b	1.17 b	49 b	42.0 b	41	1.02 b	2.11 b	54 b	14.24 a
	**	**	**	**	ns	**	**	**	**
Cane Length z									
Short	4.03	2.31	66	58.9	47	1.25	4.11	117	7.93
Long	3.94	2.26	67	57.9	48	1.20	5.26	143	8.73
	ns	ns	ns	ns	ns	ns	*	**	ns
Nodes Retained X Cane Length									
N Short	5.69	3.26	91 a	60.6	50	1.23	4.81	146	5.97
Long	4.06	2.33	63 bcd	64.1	52	1.29	7.12	164	5.81
2N Short	3.78	2.17	56 cd	65.9	48	1.37	5.41	134	4.68
Long	4.81	2.76	75 abc	65.1	51	1.28	6.05	182	7.69
4N Short	4.54	2.60	65 abcd	67.7	50	1.35	4.21	127	6.78
Long	4.96	2.84	83 ab	59.9	48	1.25	5.68	161	7.20
Unpruned Short	2.13	1.22	52 cd	41.6	40	1.04	2.01	61	14.27
Unpruned Long	1.95	1.12	47 d	42.5	43	0.99	2.20	66	14.22
	ns	ns	*	ns	ns	ns	ns	ns	ns

y Post-set nodes retained (N) based on vine size on 7/15/92.
z Cane length set during pruning on 3/19/92: Short= 5 nodes; Long= 10 nodes.
F values significant at 5% (*), 1% (**), or not significant (ns).
Mean separation within columns using Duncan's New Mutiple Range Test.

TABLE 4. Influence of the number of nodes retained and cane length on the Yield and components of yield of Vignoles grapevines at Fenn Valley vineyards. Harvested Oct. 1,1993.

Treatment	Yield (Kg/vine)	Yield (T/A)	Cluster number	Cluster Wt. (gm)	Berries/ Cluster	Berry Wt. (gm)	Productivity (yield/1992 vine size)	Fruitfulness yield (gm)/ shoot	Crop Load yield/ 93 vine size	Shoots/ Cluster
Nodes Retained y (N=15+15)										
N	3.34 a	1.91 a	42 a	80.4 a	56 a	1.32 a	4.85	77.1 a	6.73 a	1.3 b
2N	2.53 ab	1.45 ab	33 a	78.2 a	68 a	1.27 b	3.49	60.4 a	6.80 a	1.3 b
4N	2.17 b	1.24 b	30 a	75.1 a	57 a	1.25 b	3.11	56.2 a	5.06 ab	1.4 b
Unpruned	0.59 c	0.34 c	10 b	52.6 b	37 b	1.25 b	2.85	19.9 b	1.43 b	5.6 a
	**	**	**	**	**	**	ns	**	**	**
Cane Length z										
Short	2.01	1.15	27	69.1	55	1.32	3.31	47.2	4.52	3.1
Long	2.30	1.32	30	74.1	55	1.33	4.57	59.5	5.48	1.7
	ns	ns	ns	ns	ns	ns	ns	*	ns	*
Nodes Retained X Cane Length										
N Short	3.08	1.77	40	76.1	56	1.34	3.20	62.4	5.48	1.5
Long	3.59	2.06	44	84.8	61	1.30	6.50	91.7	7.97	1.1
2N Short	2.37	1.36	32	74.0	70	1.23	3.01	57.9	6.11	1.3
Long	2.7	1.55	34	82.5	65	1.31	3.96	62.9	7.48	1.4
4N Short	2.06	1.18	29	76.4	61	1.44	3.11	52.5	5.30	1.5
Long	2.28	1.31	31	73.7	53	1.45	3.10	59.8	4.83	1.4
Unpruned Short	0.54	0.31	8	49.7	32	1.26	3.93	16.1	1.23	8.1
Unpruned Long	0.64	0.37	11	55.4	43	1.25	4.70	23.7	1.63	3.1
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

y Post-set nodes retained (N) based on vine size on 7/21/93.

z Cane length set during pruning on 3/3/93: Short= 5 nodes; Long= 10 nodes.

F values significant at 5% (*), 1% (**), or not significant (ns).

Mean separation within columns using Duncan's New Mutiple Range Test.

TABLE 5. Influence of the number of nodes retained and cane length on fruit set and quality of Vignoles grapevines at Fenn Valley vineyards. Bloom measurements taken on June 10, 1992. Harvested Oct. 16, 1992.

Treatment	Est. Flower Number v	Percent Fruit Set	Quality Berries/ Sample Cluster	pH	Titratable acidity	Soluble solids	% Rot From Cluster Sample	Cluster Rot w	Vine Rot x
Nodes Retained y (N=15+15)									
N	349 a	19	49	3.07 b	1.32 a	20.7 a	14	3.4 a	1.9 a
2N	328 a	21	55	3.08 ab	1.29 a	20.3 a	12	1.6 b	1.6 a
4N	337 a	20	58	3.12 ab	1.29 a	20.6 a	11	1.6 b	1.2 b
Unpruned	287 b	19	44	3.16 a	1.14 b	19.3 b	10	1.4 b	1.2 b
	**	ns	ns	**	*	**	ns	*	**
Cane Length z									
Short	315	20	50	3.11	1.27	20.1	13	2.2	1.6
Long	335	19	53	3.10	1.25	20.3	11	1.8	1.4
	*	ns	ns	ns	ns	ns	ns	ns	ns
Nodes Retained X Cane Length									
N Short	335	19	51	3.06	1.33	20.7	15	4.3	1.9
Long	363	19	48	3.07	1.30	20.6	14	2.5	1.9
2N Short	312	23	56	3.11	1.24	20.1	13	1.6	1.8
Long	343	19	54	3.05	1.34	20.6	11	1.6	1.4
4N Short	332	20	54	3.14	1.30	20.6	13	1.4	1.2
Long	341	21	61	3.09	1.27	20.6	9	1.8	1.1
Unpruned Short	281	20	41	3.17	1.19	18.9	11	1.4	1.3
Unpruned long	293	18	48	3.20	1.10	19.6	9	1.4	1.1
	ns	ns	ns	ns	ns	ns	ns	ns	ns

v Estimated Flower numbers based on a standard made from counts and length measurements of 32 Vignoles clusters taken on 6/10/92.

w Within cluster rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of berries within the cluster were rotten.

x Vine cluster rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of clusters on the vine were rotten.

y Nodes retained after post set pruning on July 15, 1992.

z Cane length set during pruning on 3/19/92: Short= 5 nodes; Long= 10 nodes

F values significant at 5% (*); 1% (**); or not significant (ns). Means separation within columns using Duncan's New Multiple Range Test.

TABLE 6. Influence of the number of nodes retained and cane length on Fruit set and quality of Vignoles grapevines at Fenn Valley vineyards. Bloom measurements taken on June 30, 1993. Harvested Oct. 1, 1993.

Treatment	Est. Flower Number v	Percent Fruit Set	Quality Berries/ Sample Cluster	pH	Titratable acidity	Soluble solids	% Rot From Cluster Sample
Nodes Retained y (N=15+15)							
N	292 a	21 a	49 a	3.14 b	1.25 a	22.3 a	20 a
2N	293 a	22 a	59 a	3.16 b	1.24 a	21.7 a	17 ab
4N	292 a	19 ab	51 a	3.21 a	1.16 b	20.4 b	13 ab
Unpruned	223 b	16 b	35 b	3.23 a	1.13 b	21.0 ab	10 b
	**	**	**	**	**	**	**
Cane Length z							
Short	278	19	47	3.18	1.20	21.4	17
Long	272	20	50	3.19	1.19	21.2	14
	ns	ns	ns	ns	ns	ns	ns
Nodes Retained X Cane Length							
N Short	300	19	44	3.12	1.24	22.4	23
Long	284	22	55	3.16	1.25	22.2	17
2N Short	292	23	61	3.16	1.26	22.0	18
Long	294	21	57	3.17	1.23	21.4	17
4N Short	302	20	53	3.23	1.17	20.4	15
Long	281	19	49	3.20	1.15	20.4	12
Unpruned Short	220	14	29	3.22	1.14	20.9	11
Unpruned long	235	17	40	3.24	1.12	21.0	9
	ns	ns	ns	ns	ns	ns	ns

v Estimated Flower numbers based on a standard made from counts and length measurements of 30 Vignoles clusters taken on 6/30/93.

w Within cluster rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of berries within the cluster were rotten.

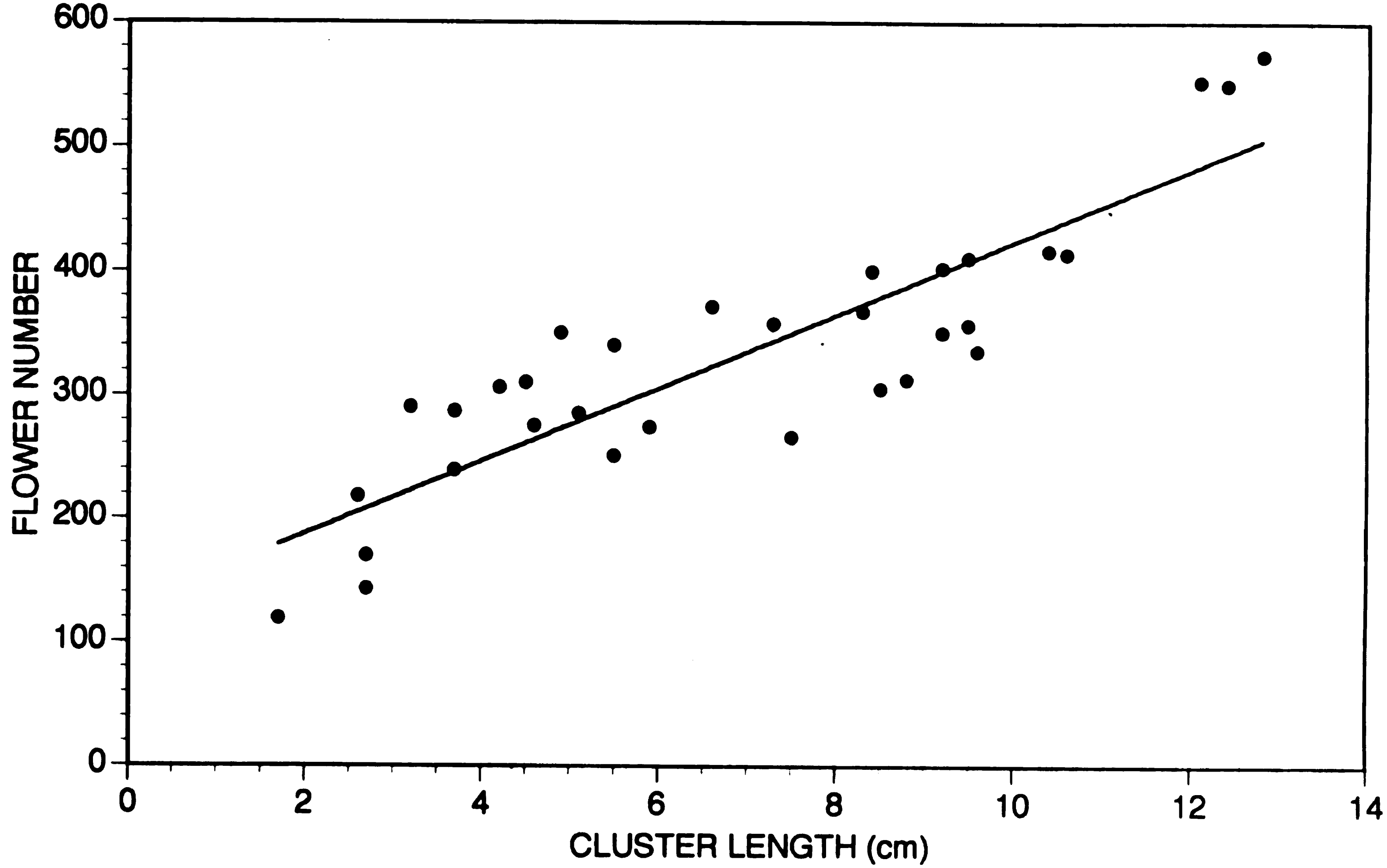
x Vine cluster rot was subjectively evaluated using a 1-5 ranking where 1=0-20%; 2=20-40%; 3=40-60%; 4=60-80%; and 5=80-100% of clusters on the vine were rotten.

y Nodes retained after post set pruning on July 21, 1993.

z Cane length set during pruning on 3/3/93: Short= 5 nodes; Long= 10 nodes

F values significant at 5% (*); 1% (**); or not significant (ns). Means separation within columns using Duncan's New Multiple Range Test.

Fig. 1. 1992 Standard for flowers per cluster measurements in Vignoles grapevines.

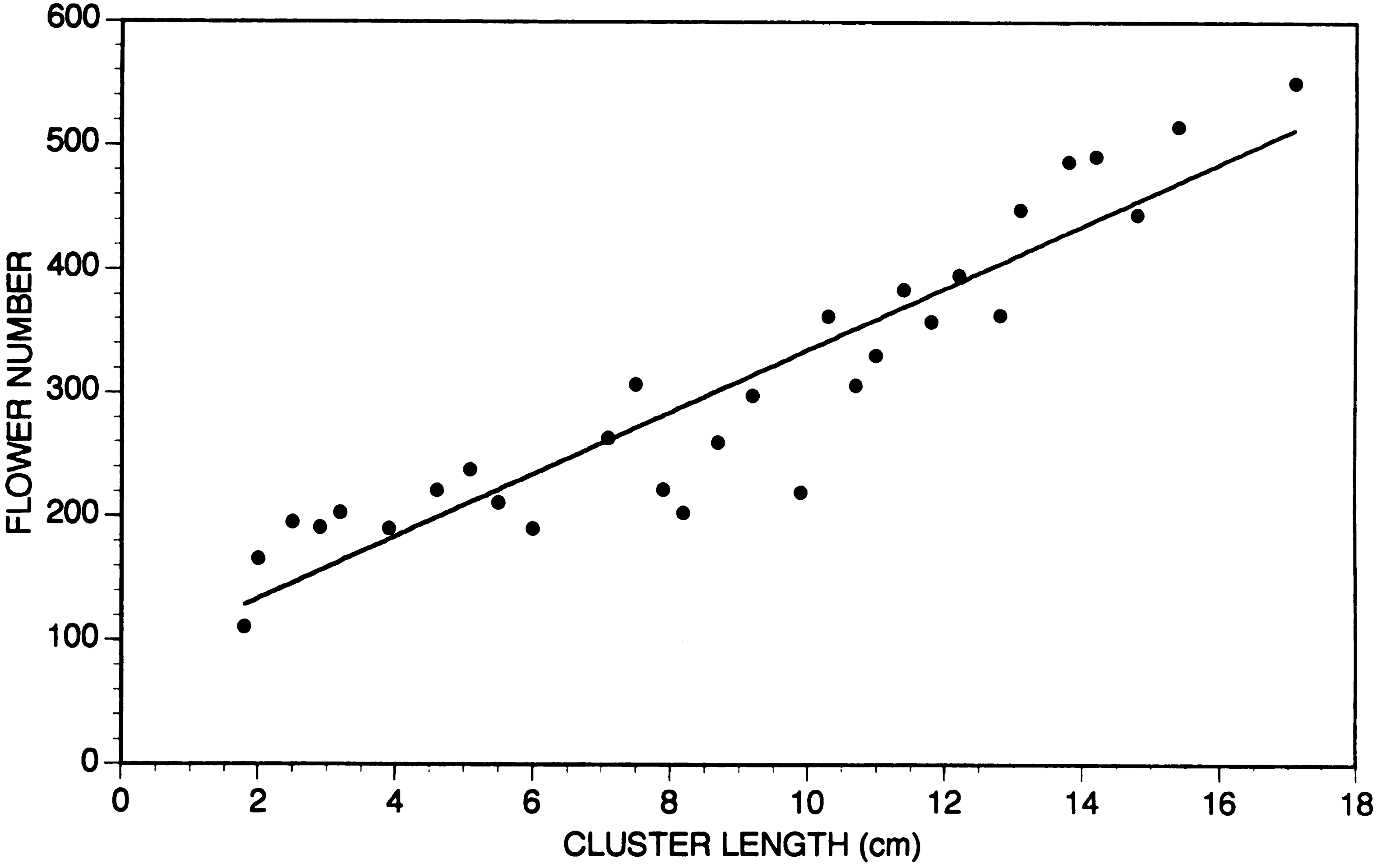


R^2 = 0.7197

R**

f(x) = 29.388 (x) + 128.825

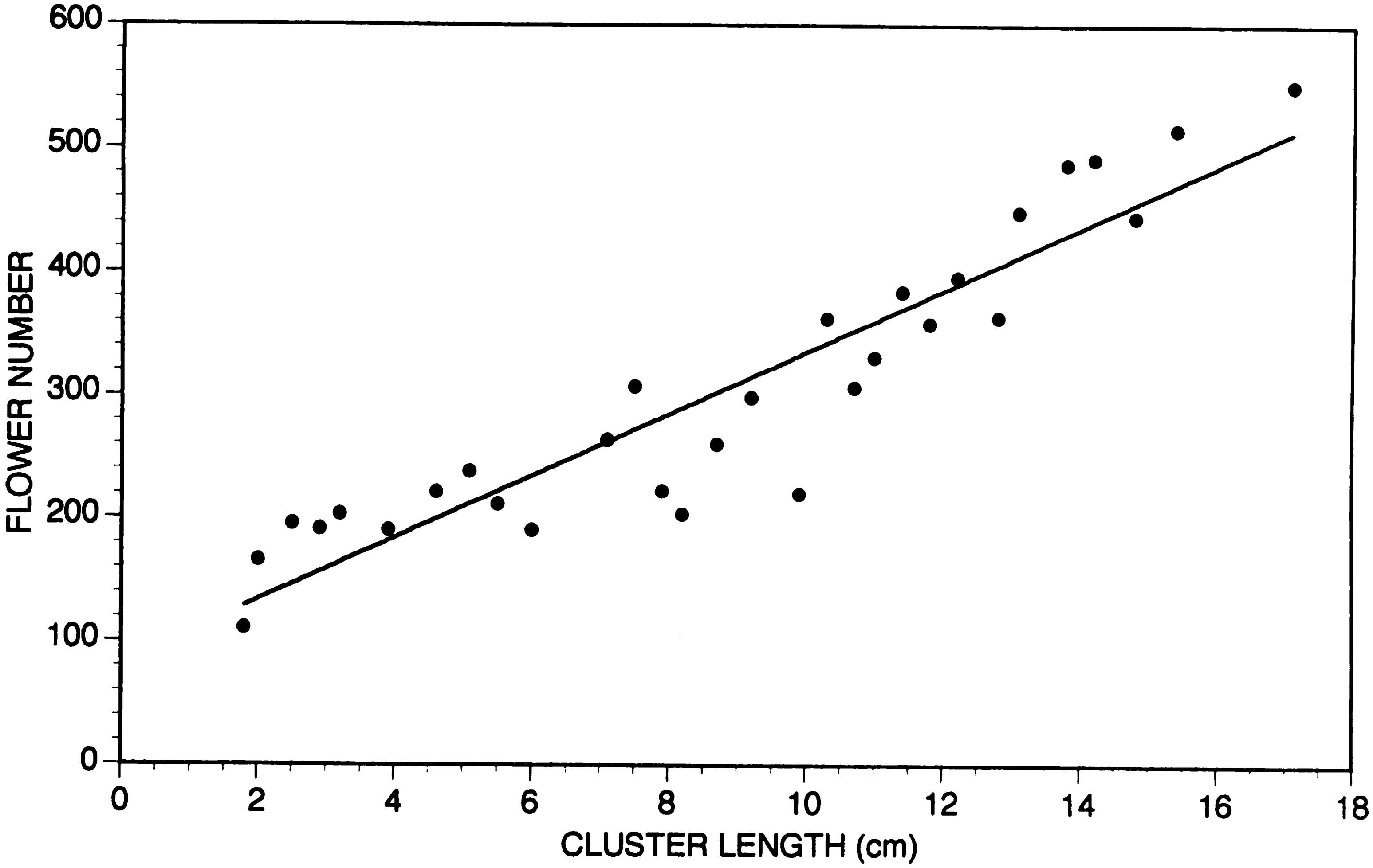
Fig. 2. 1993 Standard for flowers per cluster measurements in Vignoles grapevines.



R^2 = 0.8685
R**

f(x) = 24.977 (x) + 77.857

Fig. 2. 1993 Standard for flowers per cluster measurements in Vignoles grapevines.



R^2 = 0.8685
R**

f(x) = 24.977 (x) + 77.857

Fig. 3. 1991 and 1992 combined Vignoles primary bud hardiness evaluation.

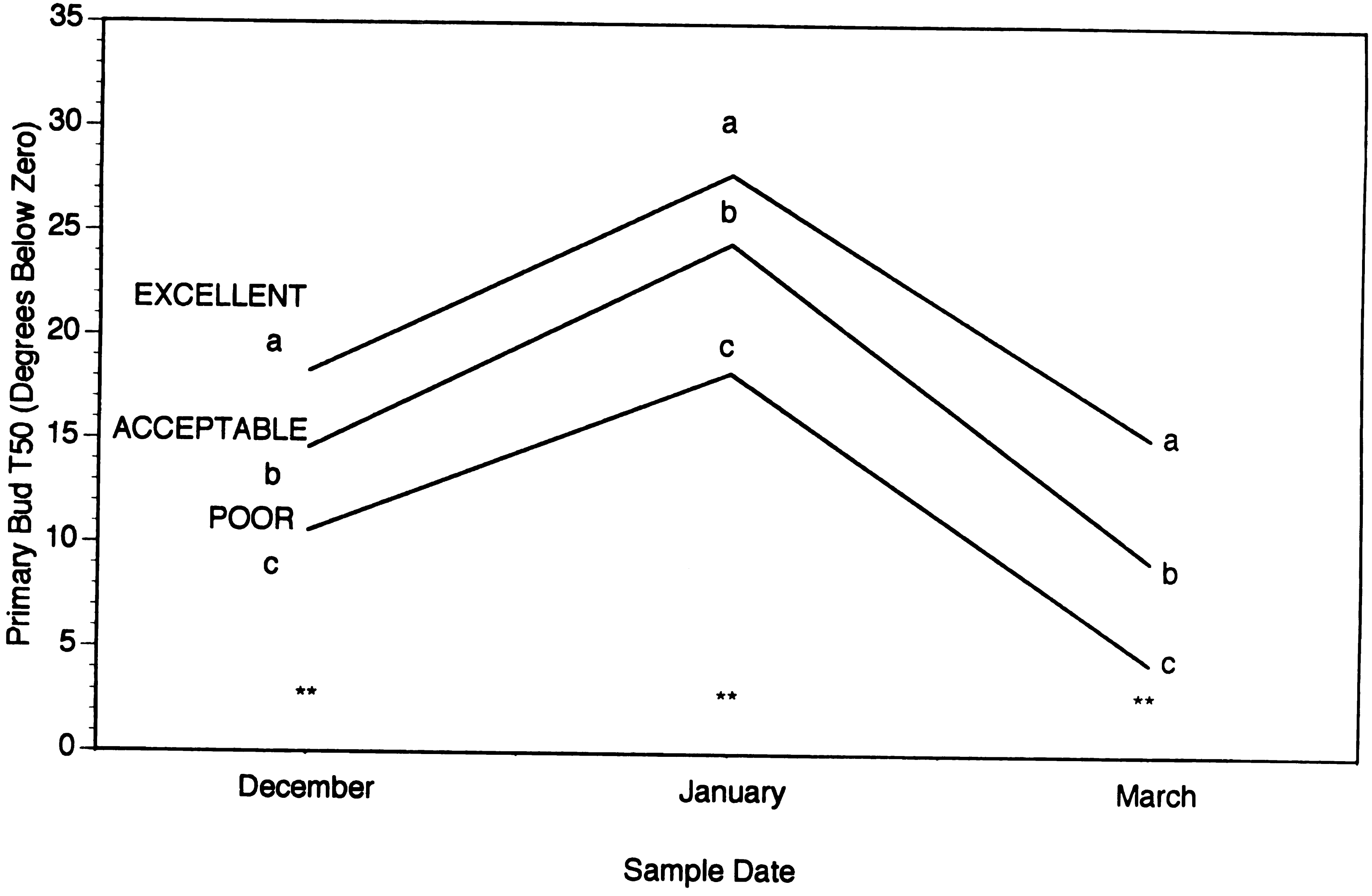


Fig. 4. 1991 and 1992 combined Vignoles periderm hardiness evaluation.

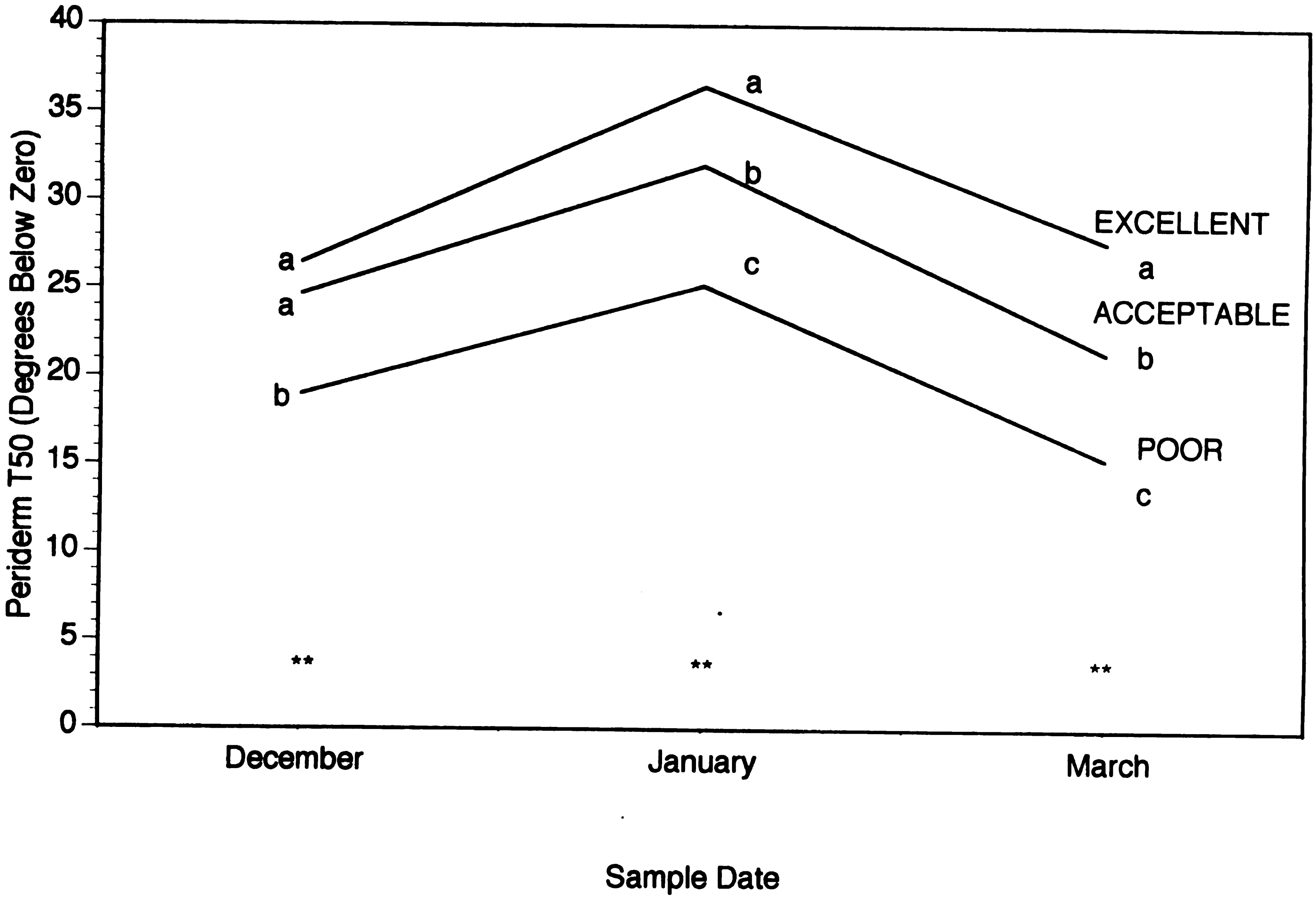


Fig. 5. Influence of pruning severity on primary shoot length (cm) in Vignoles grapevines at Fenn Valley vineyards during the 1993 growing season.

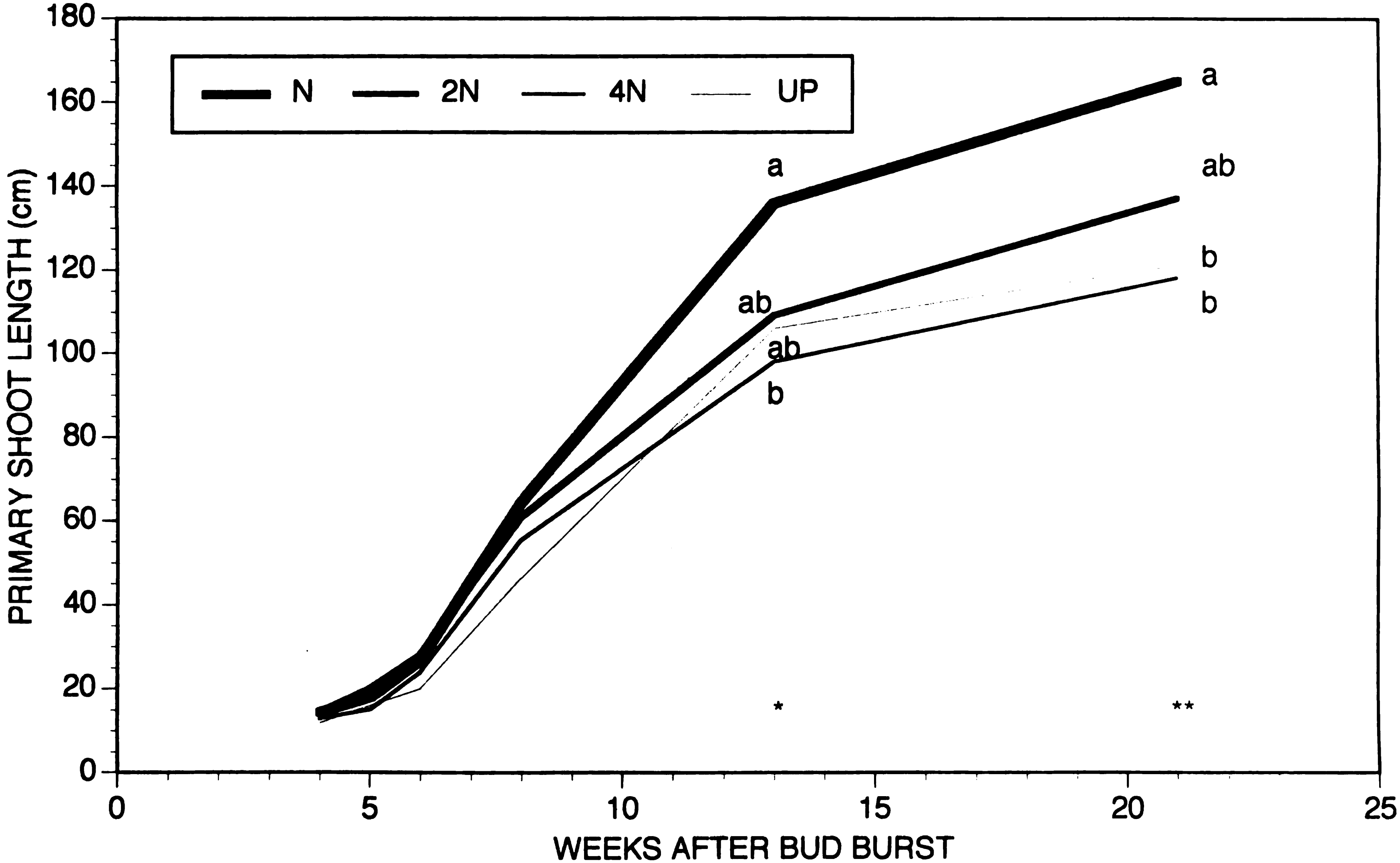


Fig. 6. Influence of pruning severity on primary shoot leaf production in Vignoles grapevines at Fenn Valley vineyards during the 1993 growing season.

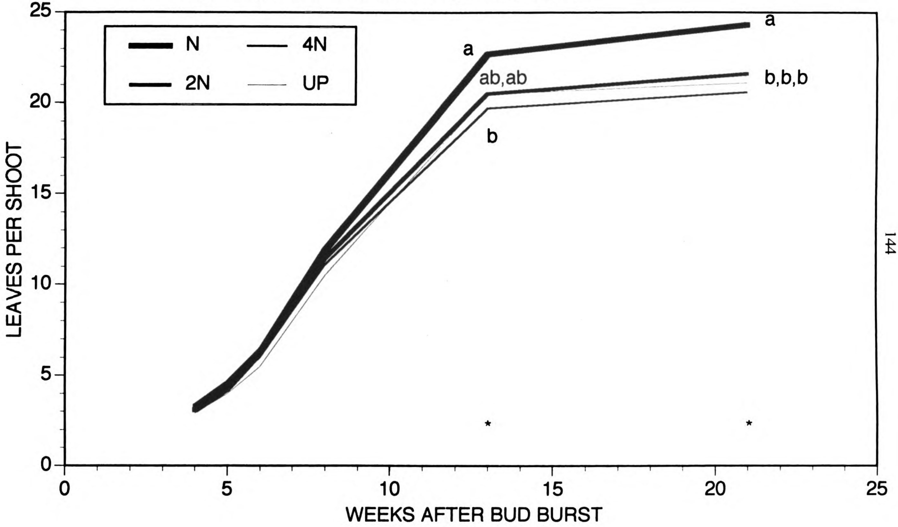


Fig. 7. Influence of pruning severity on lateral shoot production in Vignoles grapevines at Fenn Valley vineyards during the 1993 growing season.

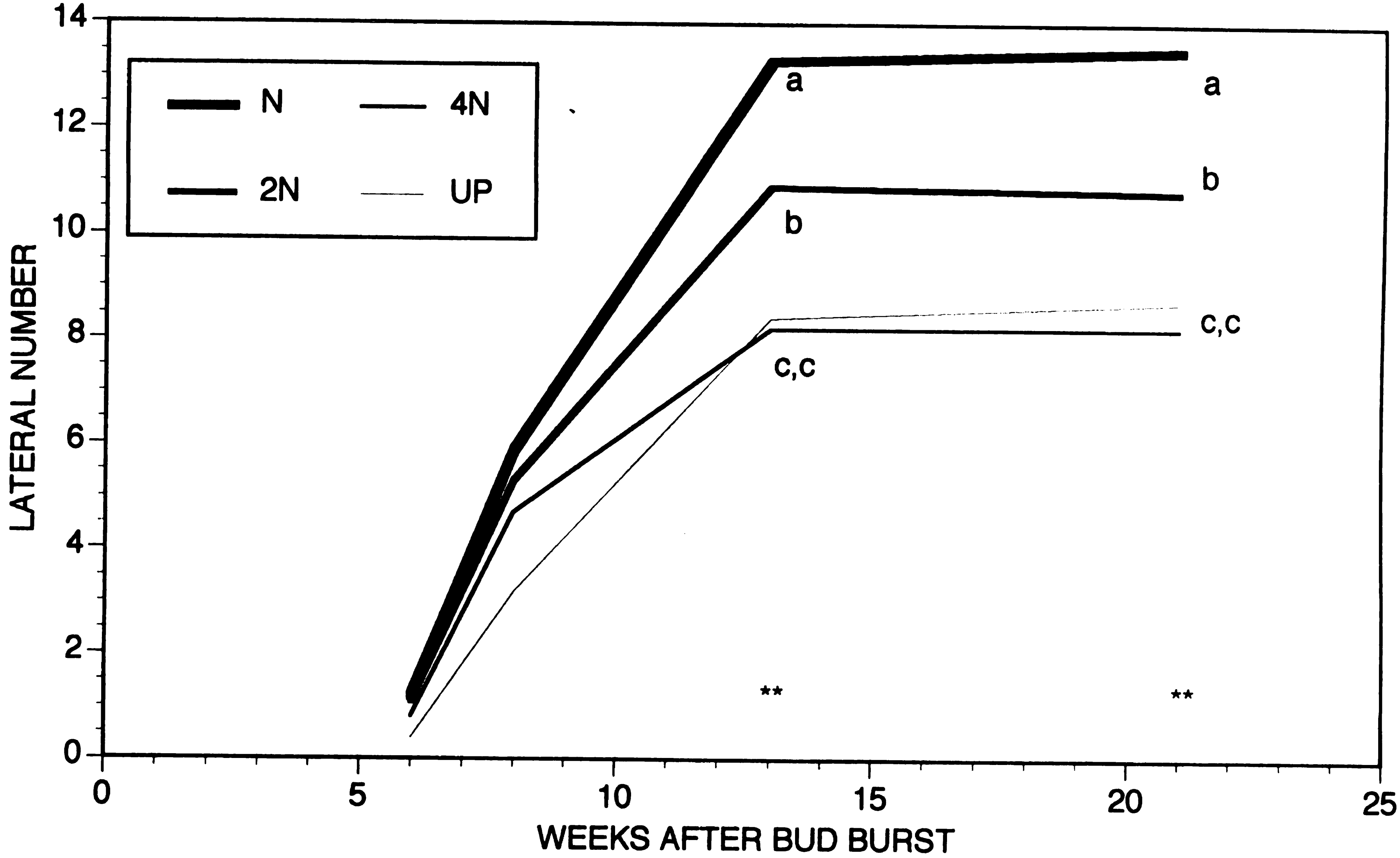


Fig. 8. Influence of pruning severity on lateral leaf production in Vignoles grapevines at Fenn Valley vineyards during the 1993 growing season.

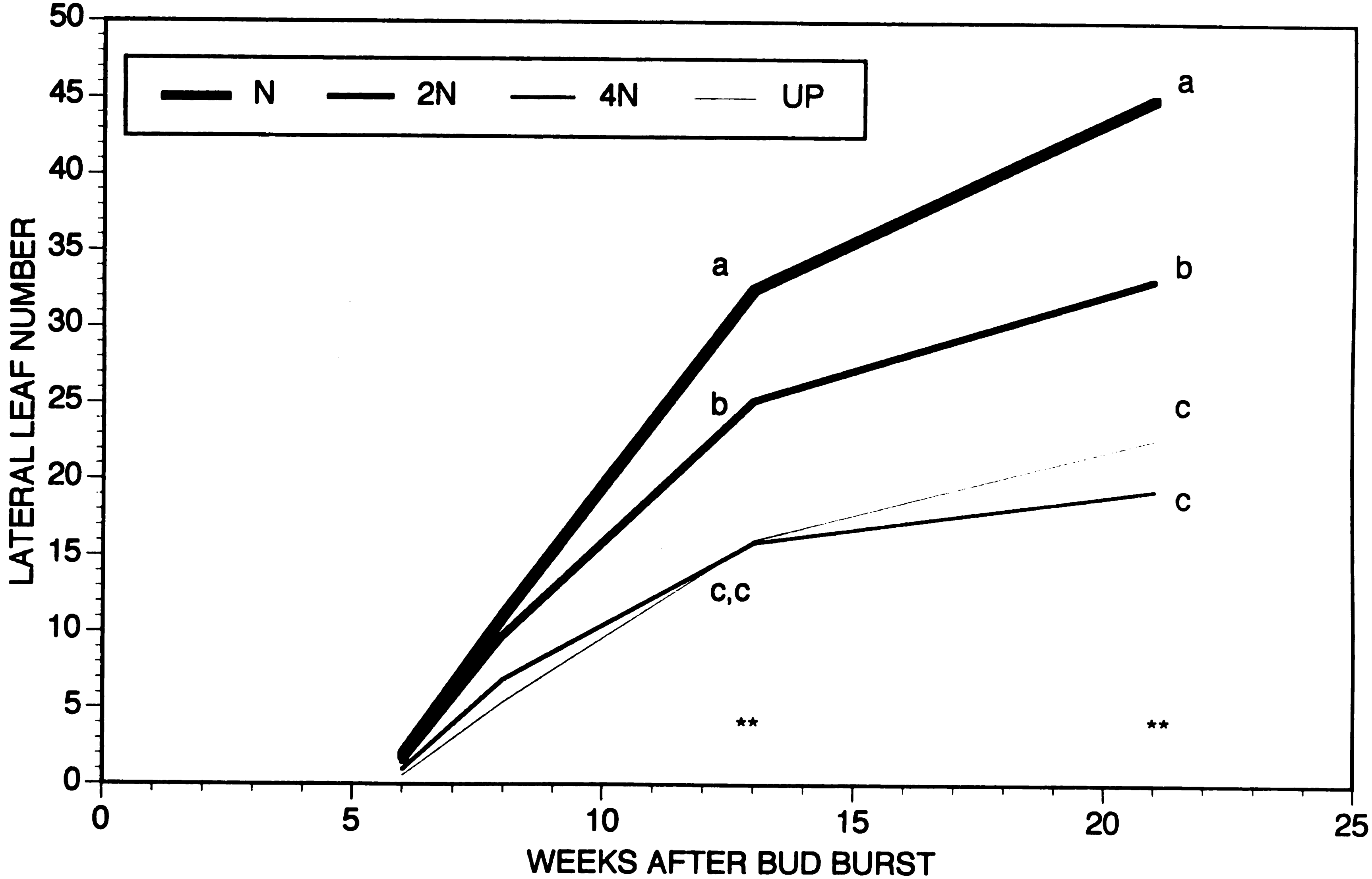


Fig. 9. Influence of pruning severity on lateral shoot length (cm) in Vignoles grapevines at Fenn Valley vineyards during the 1993 growing season.

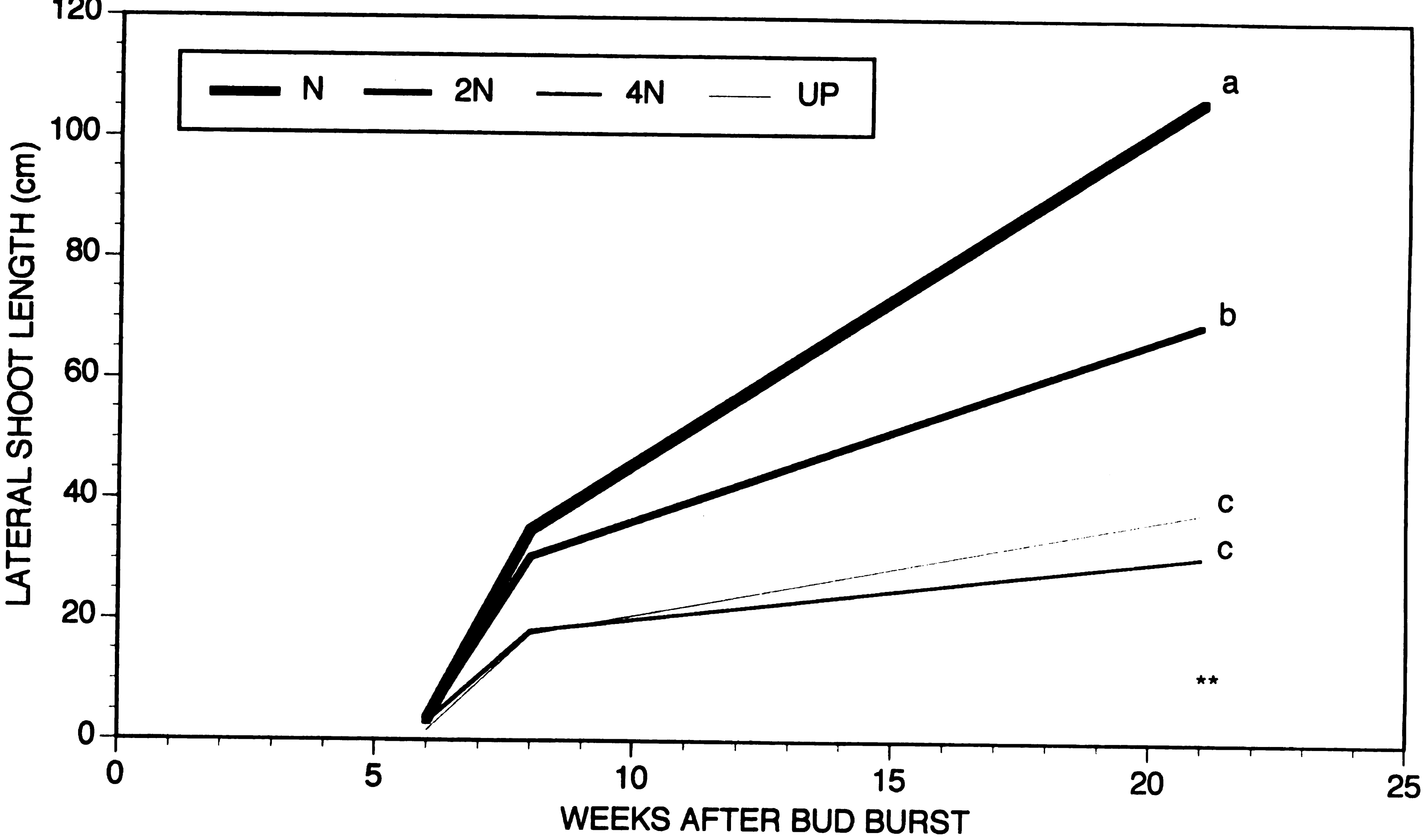


Fig. 10. Influence of pruning severity on the total vegetative length per shoot (primary+lateral) of Vignoles grapevines at Fenn Valley vineyards during the 1993 growing season.

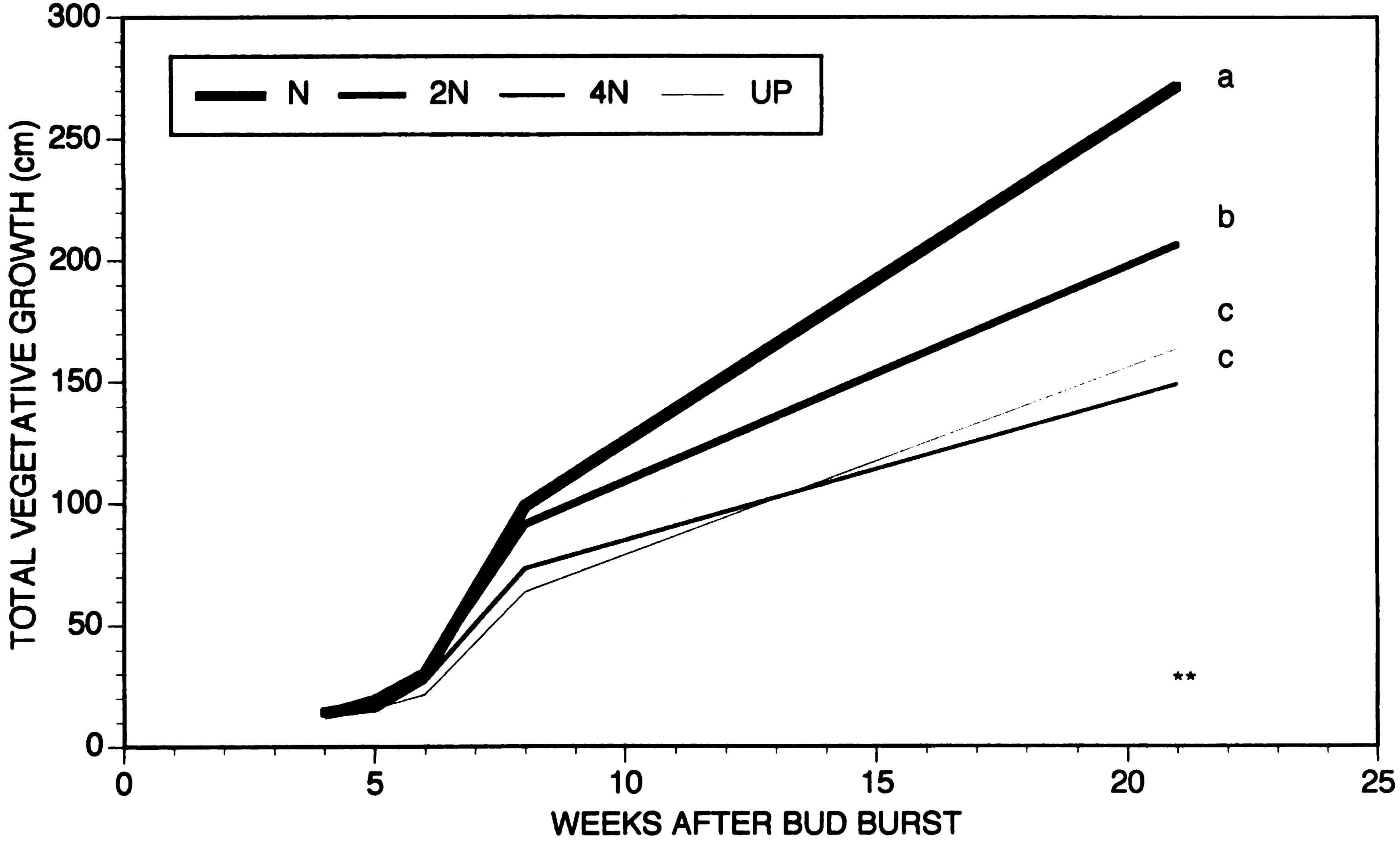
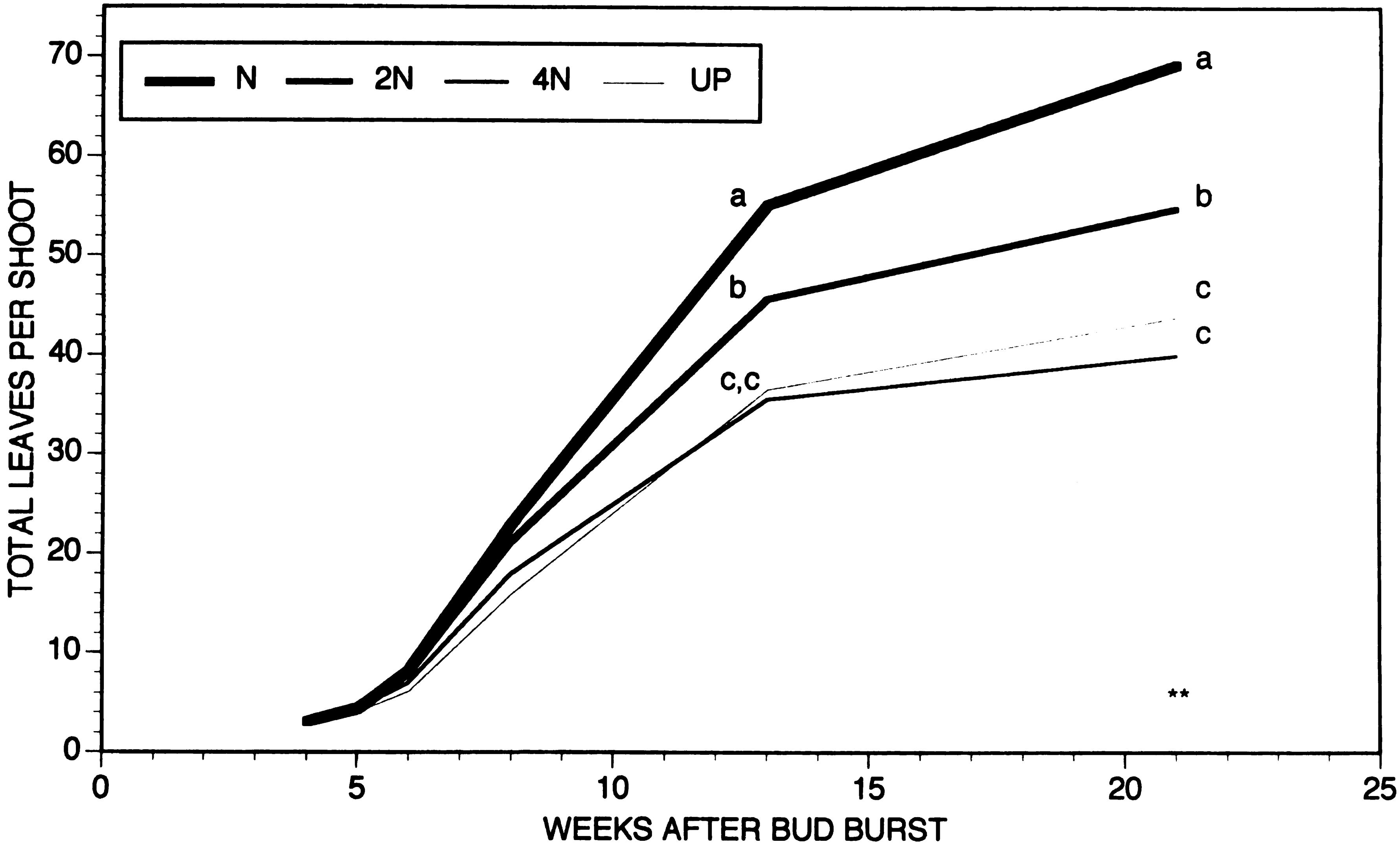


Fig. 11. Influence of pruning severity on the total leaves per shoot (primary+lateral) of Vignoles grapevines at Fenn Valley vineyards during the 1993 growing season.



CONCLUSIONS

The data presented here leads to the conclusion that the competition among fruitful sinks (clusters) during anthesis has a greater influence on reducing fruit-set than vegetative competition. Lower berry set provides a loose cluster architecture and thus reduced *Botrytis* bunch rot. Reduced pruning severity and post-set thinning produces greater numbers of fruitful sinks during anthesis, resulting in a greater response in Seyval grapevines. Reductions in yield due to decreased fruit-set can be overcome by increasing the number of clusters thinned. Thus, the level of sink competition can be manipulated by pruning severity without adversely affecting yield. However, the vine's capacity limits the level of vegetative sink (apical meristems) competition it can accommodate and mature both fruit and wood. This is also evident in the Vignoles cultivar. However, because they bear smaller clusters, the fruit-set response to greater fruitful sink competition is less notable. In order to reduce berry-set sufficiently in Vignoles and improve cluster architecture, pruning severity must be reduced to the point where vegetative sink competition adversely affects vine health. The hypothesis discussed in the introduction concerning reductions in fruit-set to reduce *Botrytis* infection may have some practical applications as to how large clustered cultivars are managed, but appear to be impractical for smaller clustered cultivars.

Hedging Seyval grapevines increases the number of nodes within the canopy each year. Greater numbers of shoots increase early filling of the trellis area with foliage, but little leaf area production occurs after veraison. Thus, older leaves are responsible for photosynthate production during fruit and wood ripening. Due to the early leaf area production, hedged canopies become shaded by the time of veraison. The shoots are considerably smaller and grow upright for much of the season. This contributes to leaf layer formation which increases canopy density and shading, reducing cane cold hardiness. Canopy density also promotes *Botrytis* infection. If hedging is the preferred pruning method, then cordon renewal is recommended after four to five years.

A moderate pruning severity in Seyval grapevines (30+40 in Michigan) that adequately spaces shoots along the cordon allows for early filling of the trellis area with foliage. Shoots are more developed before bloom facilitating berry development, resulting in greater yields. Shoots produce laterals after bloom that bear new leaves during fruit ripening and wood maturity. The optimal shoot spacing inhibits leaf layer formation and shading is rarely a problem. Thus, cold hardiness is improved and *Botrytis* infection reduced. Optimal shoot spacing within the canopy should be the primary consideration during pruning.

If mechanization is necessary to reduce labor costs, then mechanical fruit thinning needs to be developed for highly fruitful cultivars such as Seyval and Vignoles. Hand pruning to ensure proper shoot spacing and sink competition, along with mechanical fruit thinning, would be a more cost effective method for controlling *Botrytis* infection and maintaining vine health of these cultivars.

APPENDIX I

INFLUENCE OF CANE CHARACTERISTICS ON PRIMARY BUD AND PERIDERM COLD HARDINESS

Summary

Striegler and Howell (1991) demonstrated a clear response in cold hardiness to varying cane characteristics in Seyval grapevines. Three classifications (excellent, acceptable, and poor) were developed from this work and from hardiness evaluations made in December of 1991 and January of 1992 on canes from Seyval grapevines. Primary bud and periderm T50's were determined for variations within four cane characteristics, and over node positions along the cane. Canes having a medium diameter (7-10 mm) (Figs. 1 and 2), medium internode length (6-8 cm) (Figs. 3 and 4), and dark periderm (Figs. 5 and 6) were found to have superior primary bud and cane cold hardiness. Persistent laterals (Figs. 7 and 8) and node position (Figs. 9 and 10) did not have any influence on cold hardiness. Samples of canes within the three classifications were evaluated for cold hardiness in December, January, and March following the 1992 growing season. Excellent canes were superior and poor canes were inferior to acceptable canes in both primary bud and periderm cold hardiness at each date and over dates (Figs. 11 and 12). These results were similar to those found by Striegler and Howell (1991). Using the three classifications was a rapid and effective way to evaluate the relative cold hardiness of each treatment vine (see Chapters 1 and 3).

Fig. 1. Influence of cane diameter on the primary bud cold hardiness of Seyval grapevines. Small: <7 mm; Medium: 7-10 mm; Large: >10 mm.

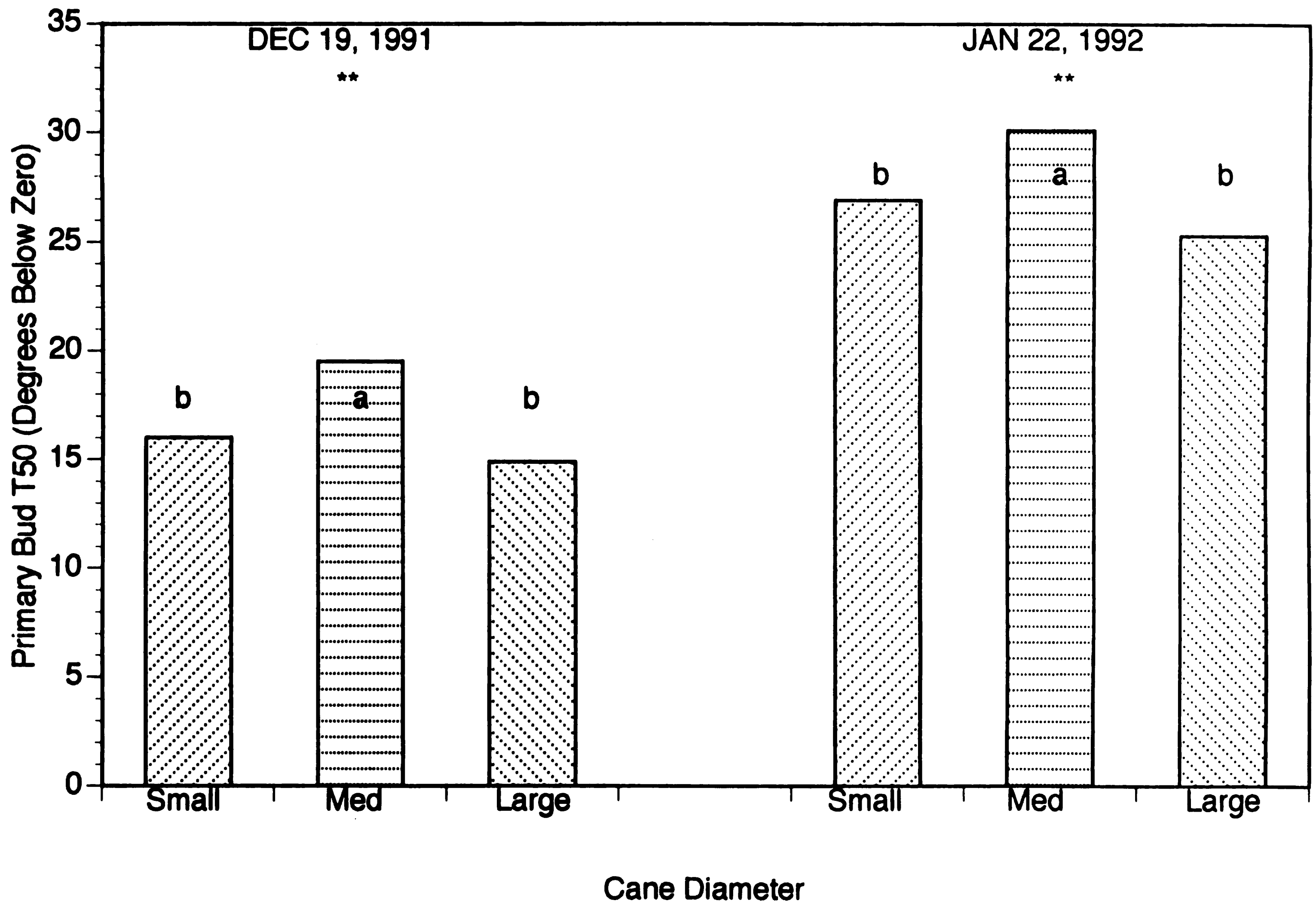


Fig. 2. Influence of cane diameter on the periderm cold hardiness of Seyval grapevines. Small: <7 mm; Medium: 7-10 mm; Large: >10 mm.

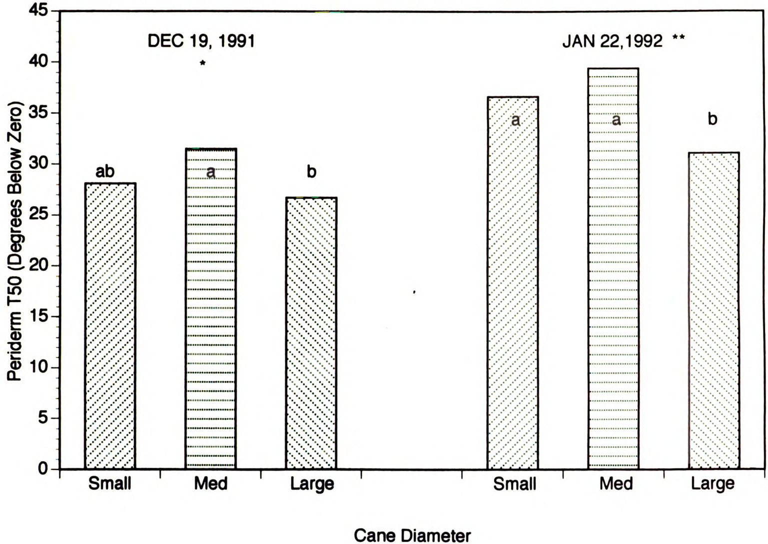


Fig. 3. Influence of internode length on the primary bud cold hardiness of Seyval grapevines. Short: <6 cm; Medium: 6-8 cm; Long: >8 cm.

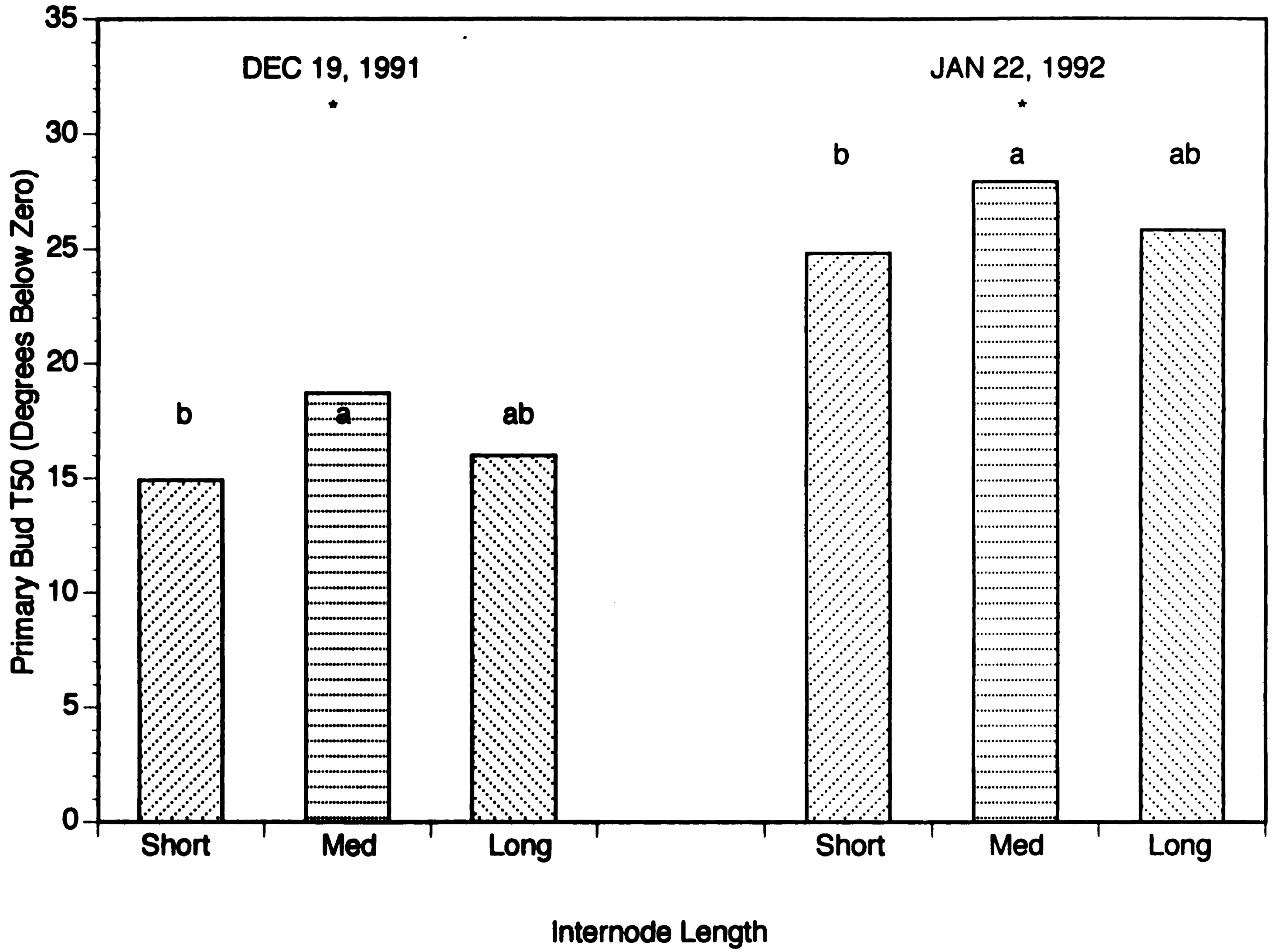


Fig. 4. Influence of internode length on the periderm cold hardiness of Seyval grapevines. Short: <6 cm; Medium: 6-8 cm; Long: >8 cm.

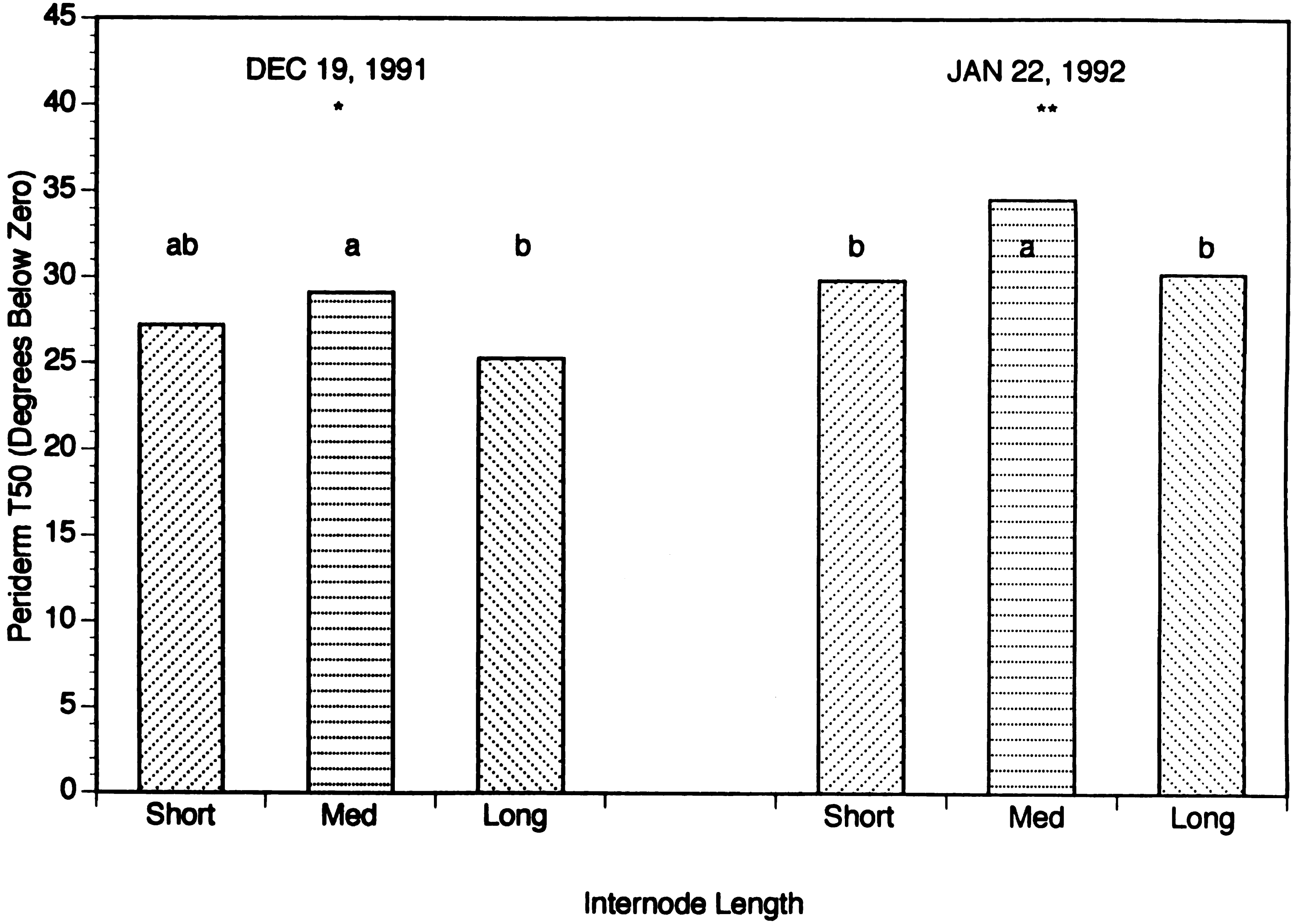


Fig. 5. Influence of periderm color on the primary bud cold hardiness of Seyval grapevines.

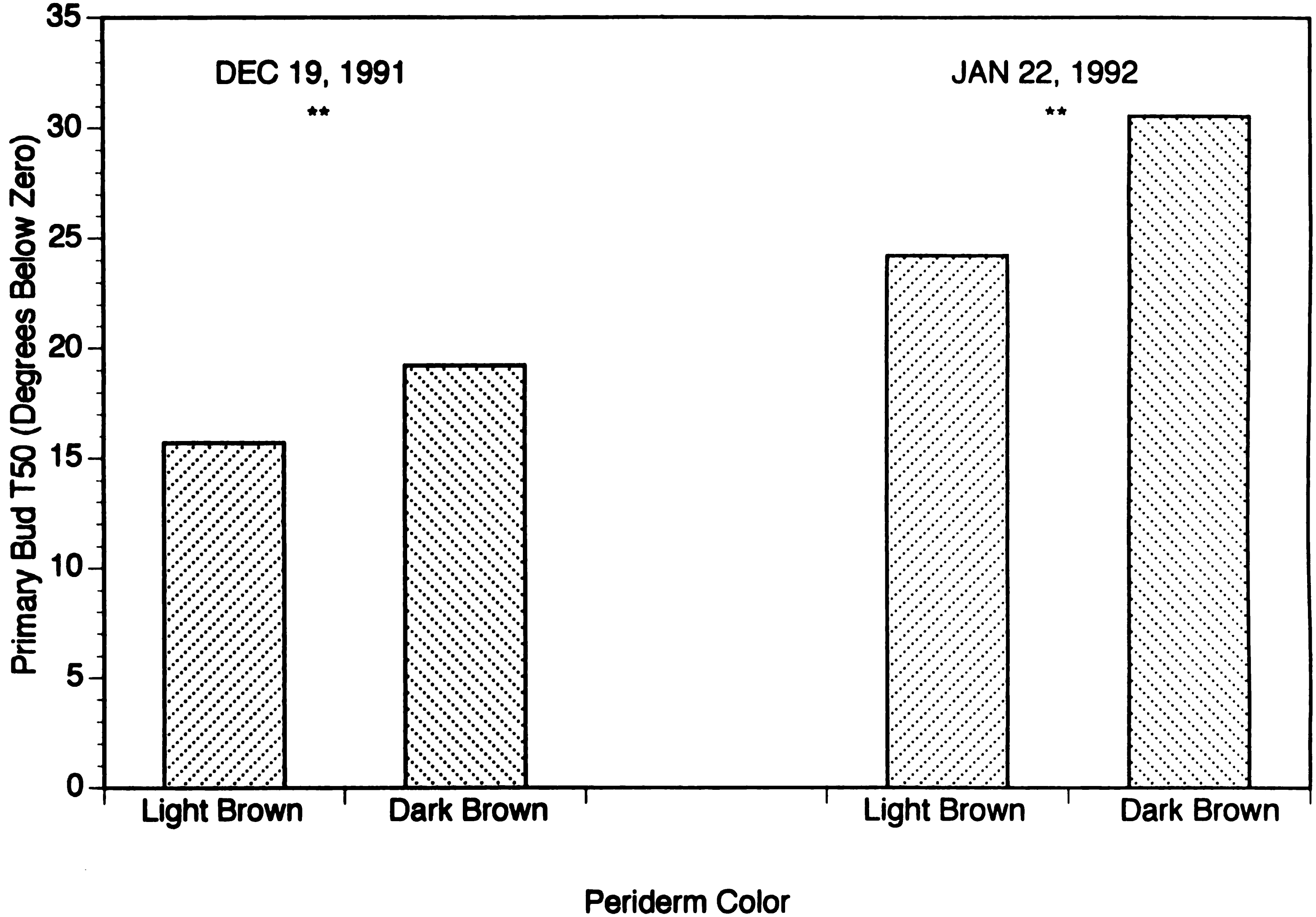


Fig. 6. Influence of periderm color on the periderm cold hardiness of Seyval grapevines.

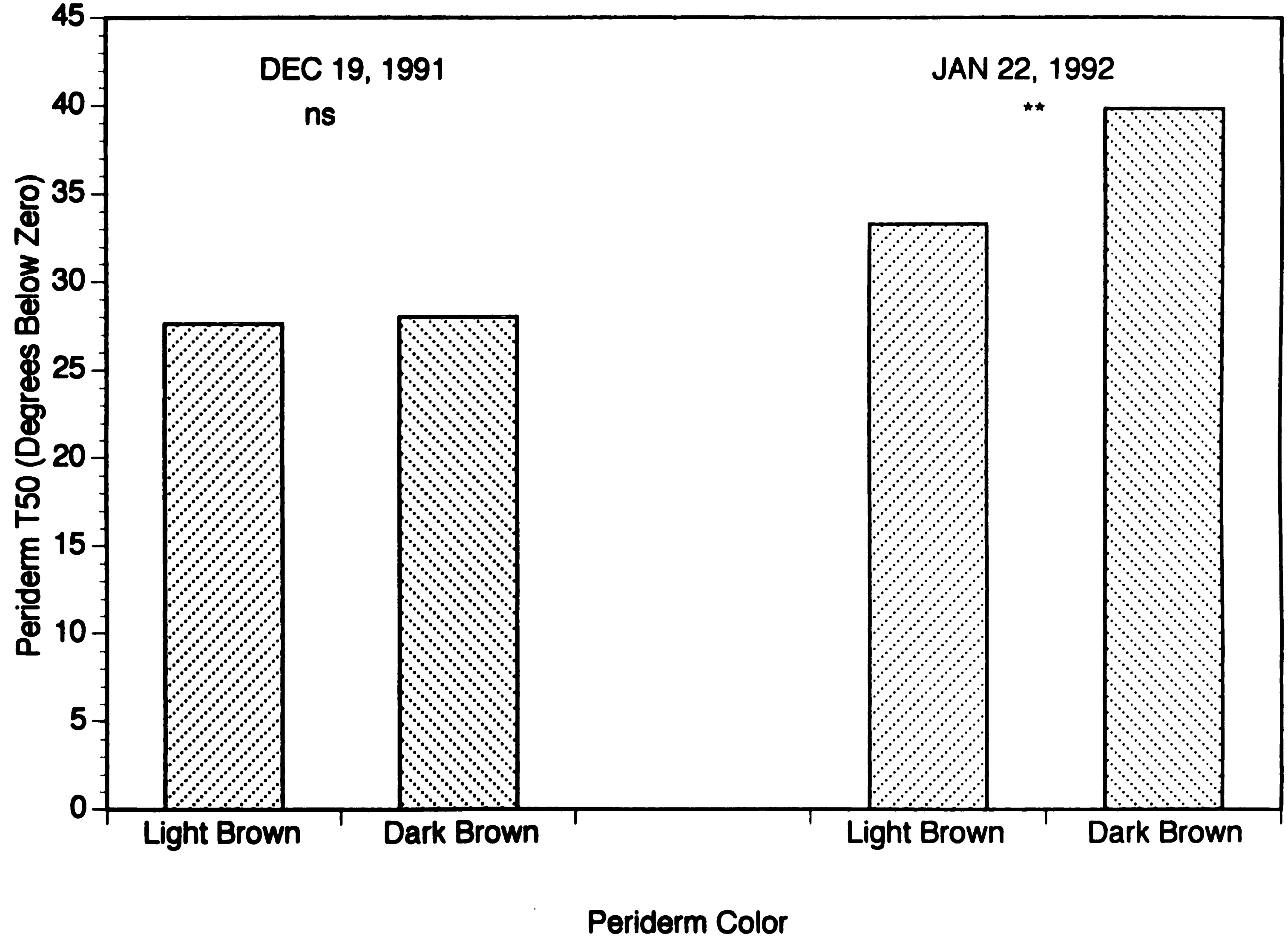


Fig. 7. Influence of lateral status on the primary bud cold hardiness of Seyval grapevines.

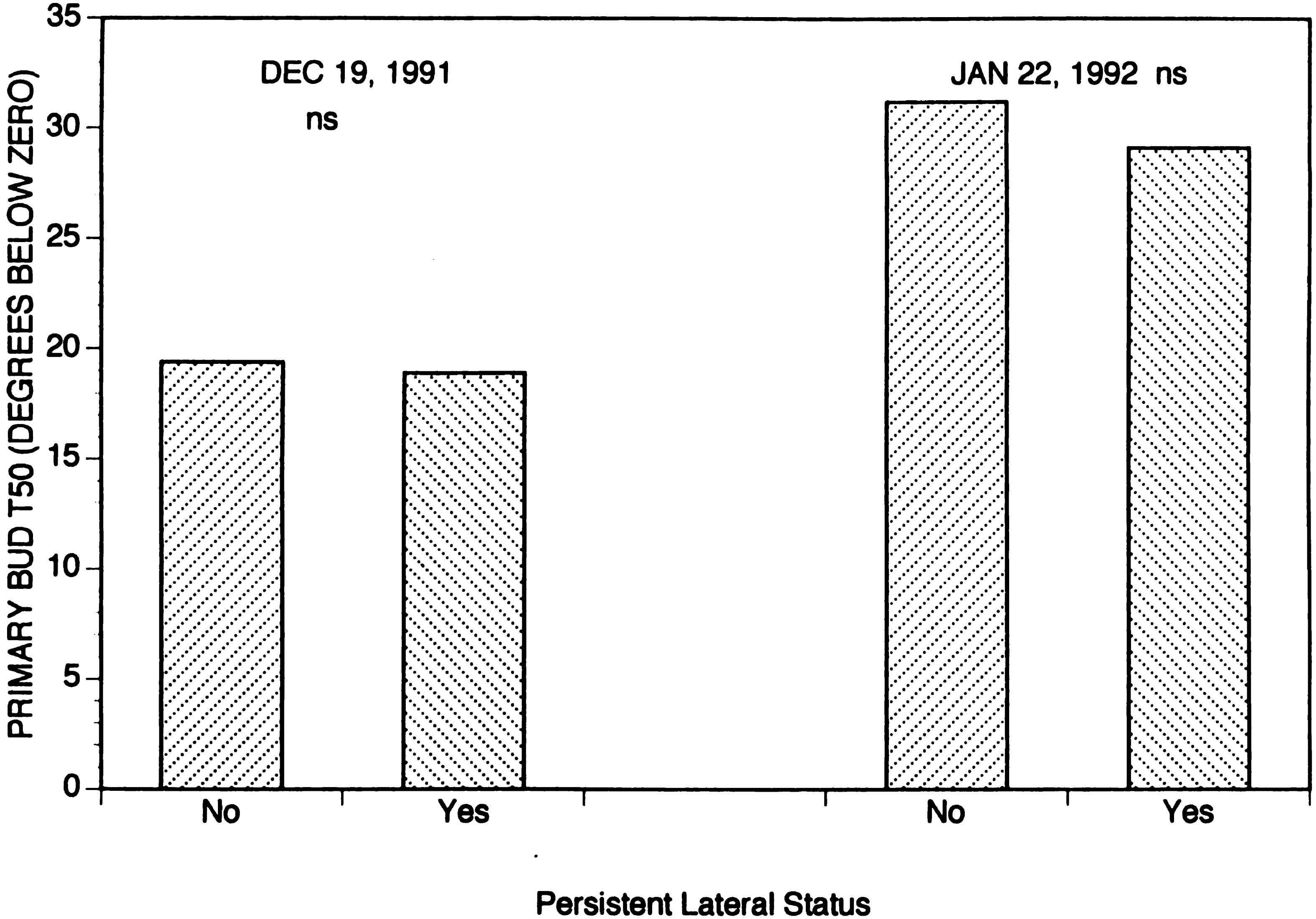


Fig. 8. Influence of lateral status on the periderm cold hardiness of Seyval grapevines.

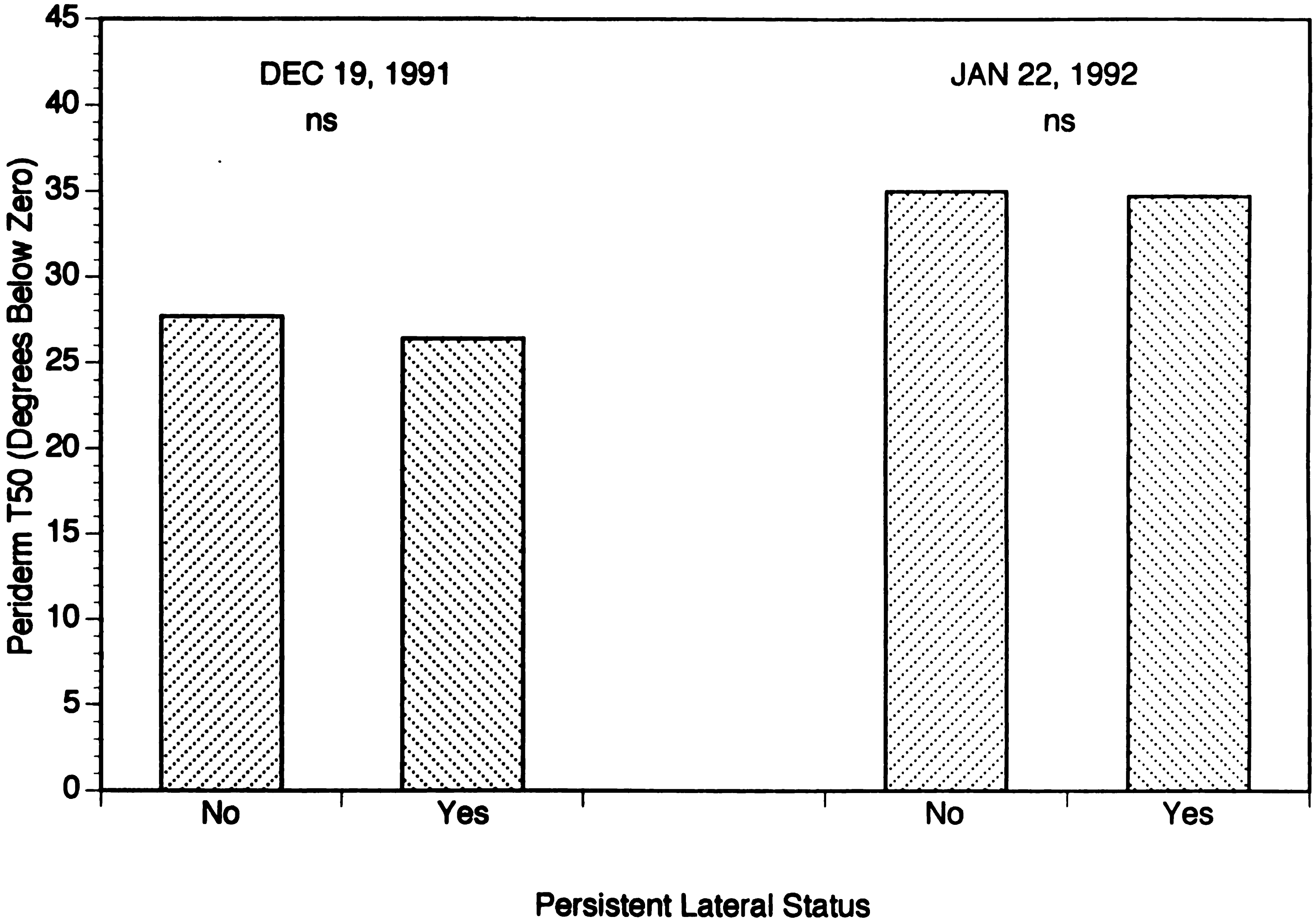


Fig. 9. Influence of node position along the cane on the primary bud cold hardiness of Seyval grapevines.

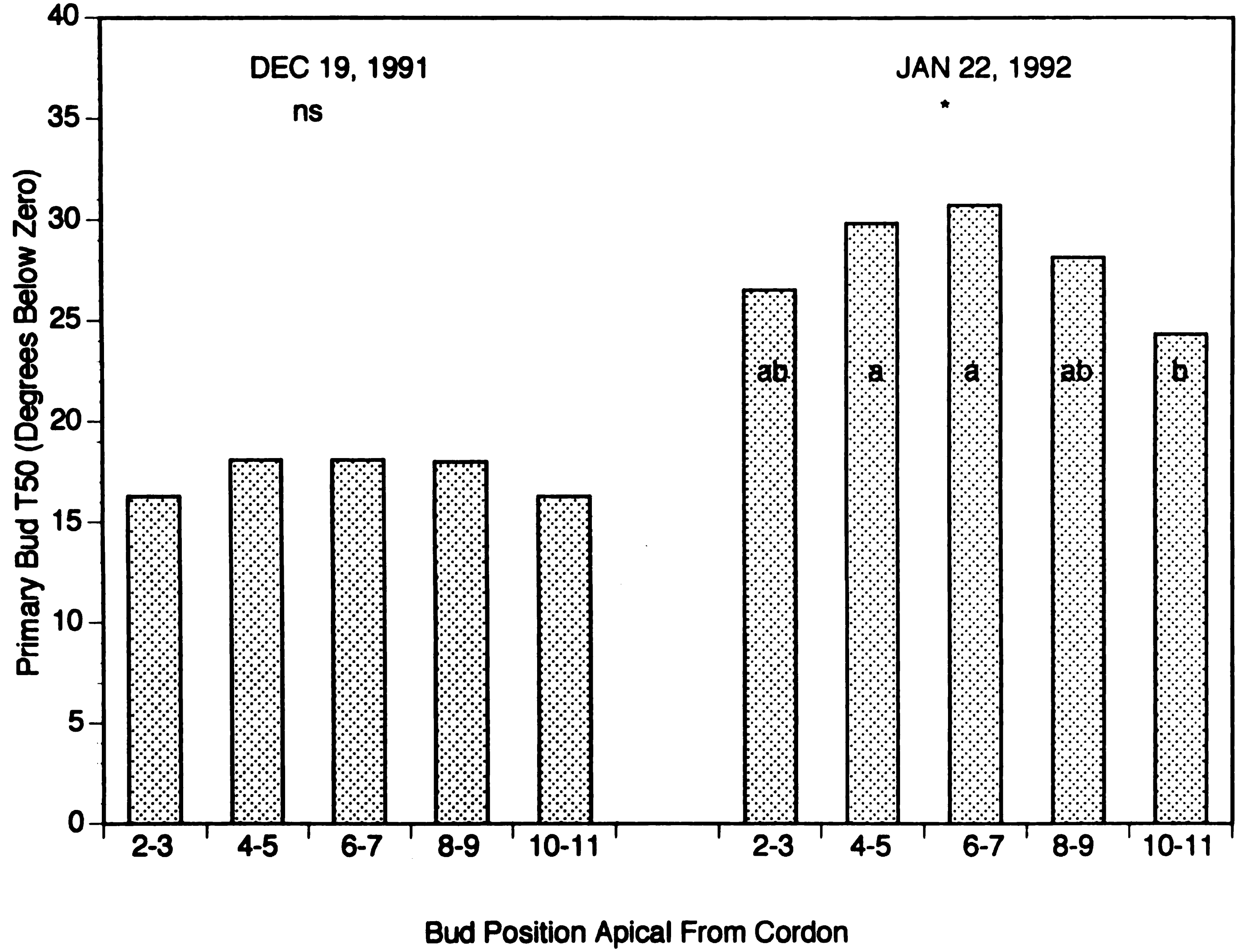


Fig. 10. Influence of node position along the cane on the periderm cold hardiness of Seyval grapevines.

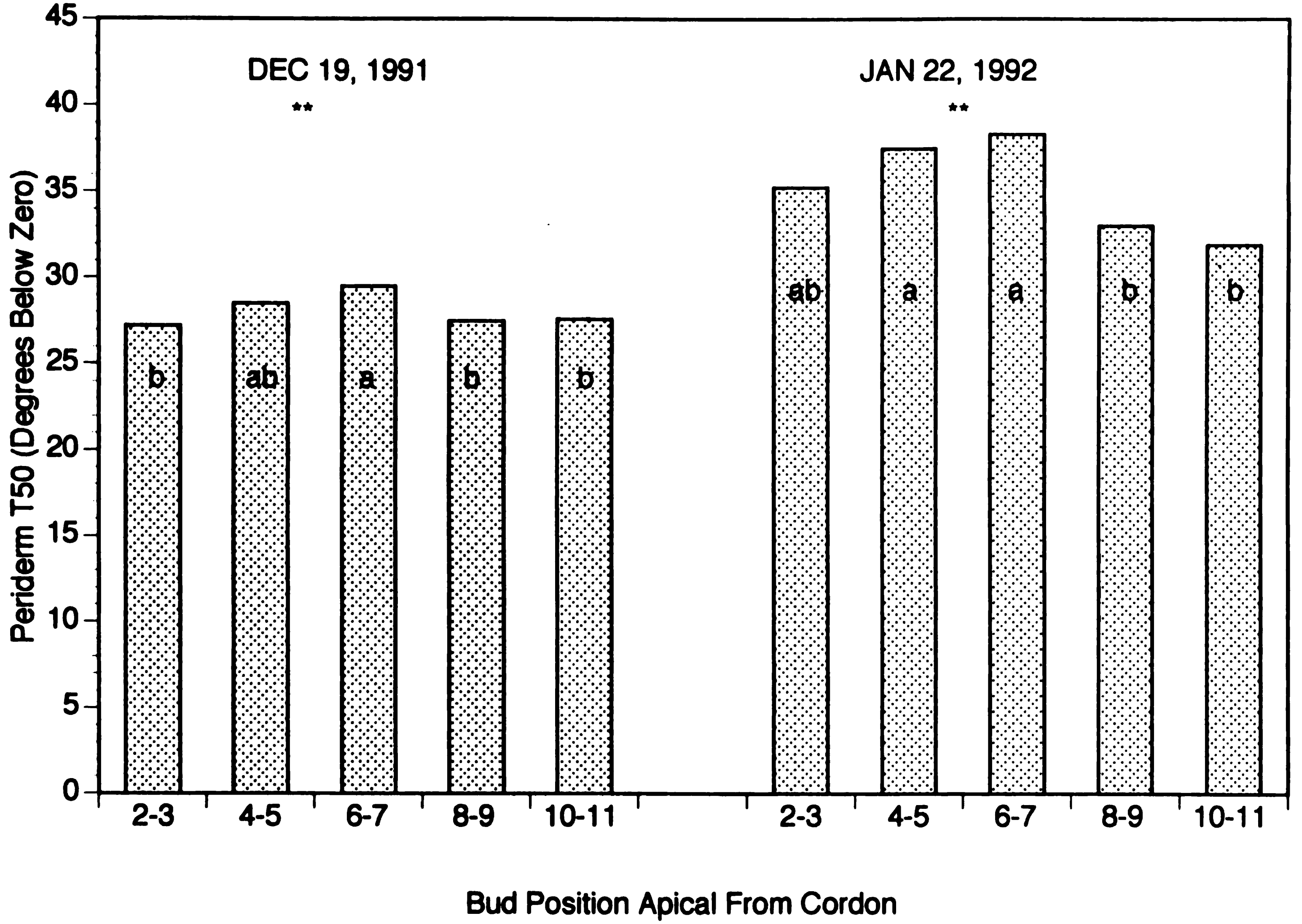


Fig. 12. Influence of cane characteristics on periderm cold hardiness of Seyval grapevines at Fenn Valley vineyards.

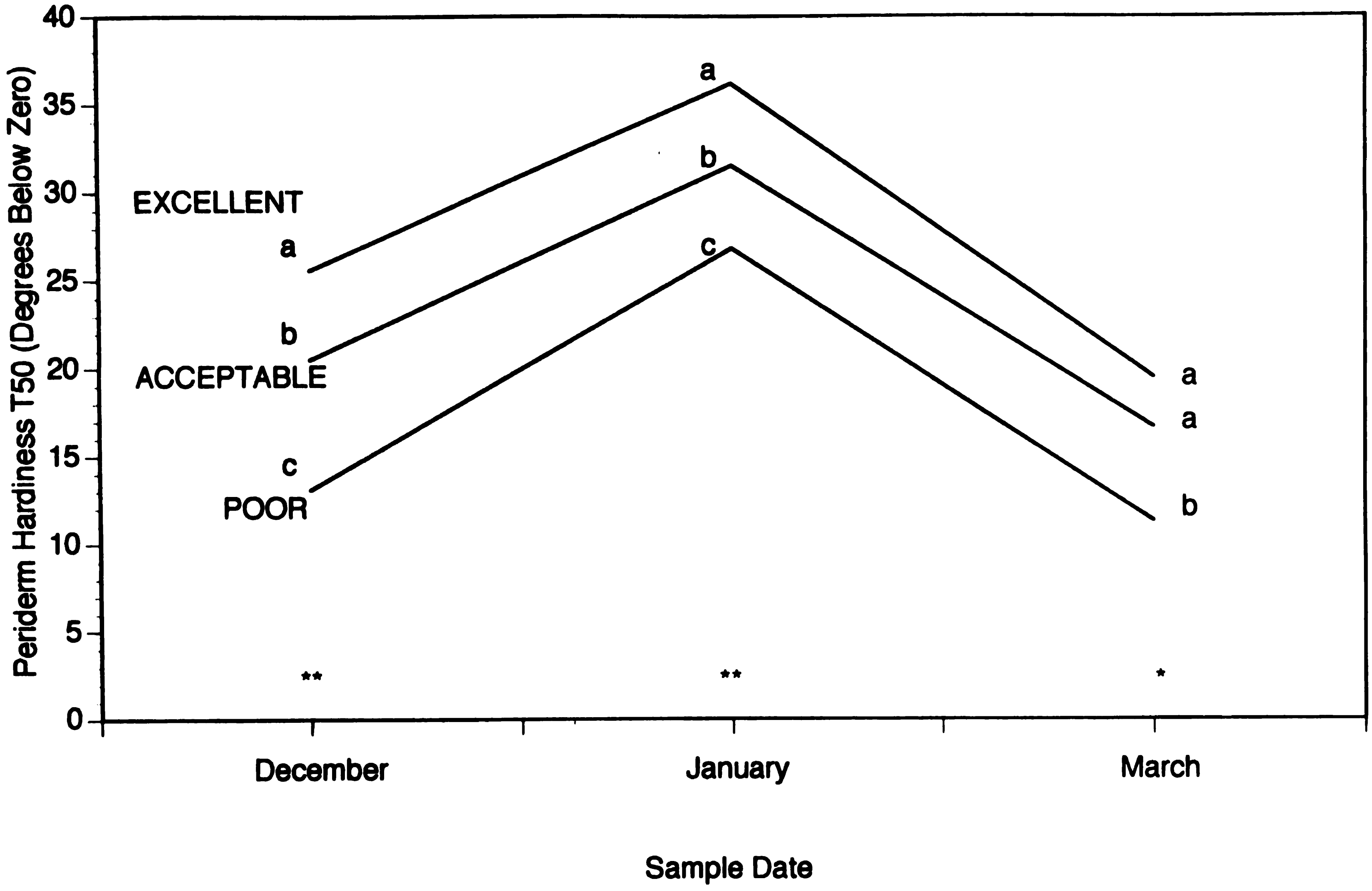


Fig. 11. Influence of cane characteristics on primary bud cold hardiness of Seyval grapevines at Fenn Valley vineyards.