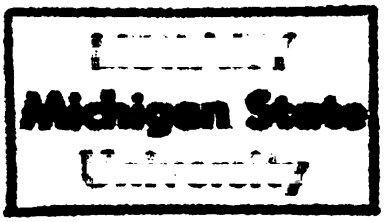

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AND THEIR EFFECT ON SCION COLD HARDINESS
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COLD HARDINESS OF GRAPEVINE ROOTSTOCKS AND THEIR EFFECT ON SCION COLD HARDINESS AND TIME OF BUD BURST

By

David P. Miller

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ABSTRACT

COLD HARDINESS OF GRAPEVINE ROOTSTOCKS
AND THEIR EFFECT ON SCION COLD HARDINESS
AND TIME OF BUD BURST

By David P. Miller

Controlled freezing tests were used to evaluate the cold hardiness of the grapevine rootstocks Kober 5BB (5BB), Couderc 3309 (3309),and Selection Oppenheim No.4 (SO4). T50 values were calculated using a modified Spearman-Karber equation and were tested for differences with Analysis of Variance for each sampling date. White Riesling grafted to all three rootstocks and growing on its own roots and Chardonnay grafted to 5BB and SO4 were evaluated for cold hardiness as well as Seyval blanc grafted to 5BB, 3309, Seyval blanc and growing on its own roots.

Clonal rootstock Couderc 3309 was found to have the greatest cold hardiness of the rootstocks tested. 5BB and SO4 were less hardy than 3309 but were similar to one another. Scions of White Riesling grafted to 3309 had hardier canes than White Riesling grafted to 5BB or growing on its own roots. Seyval blanc grafted to 3309 also had hardier canes than did Seyval blanc grafted to 5BB or growing on its own roots. Scions of Chardonnay grafted to 5BB and SO4 were nearly equal in the hardiness of their cane tissues as were scions of White Riesling grafted to these rootstocks.

Bud phenology of rootstocks and scions grafted to these rootstocks was recorded. The number of buds beyond swell-1 was compared at each sampling date using Chi-square. Grafted vines showed slightly delayed bud expansion except in Marechal Foch where the reverse was observed.

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INTRODUCTION

Changes in consumer preference in styles of wine and a broadening of viticultural knowledge in the United States have brought about a revolution in the eastern United States grape industry. An industry that once consisted predominantly of sweet "labrusca" wines now exists mainly on the production of French/American hybrids and more recently, Vitis vinifera wines. Michigan is no exception. Located in a temperate zone near large bodies of water (i.e.Lake's Michigan, Superior, Huron and Erie), Michigan's unique macro and microclimatic areas make possible the culture of a wide variety of horticultural crops, especially along the shore of Lake Michigan. However, even with the moderating effect on temperature produced by Lake Michigan, mid-winter temperature minima sometimes result in damage to grapevines, particularly the more cold-tender vinifera. Because of the sensitivity of the more valuable vinifera, viticulturists have searched for cultural means (e.g. site selection, training and pruning) to minimize losses from winter injury. Although cultural practices can influence amounts of low temperature injury, many of these are labor intensive and tend to reduce profitability. It would, therefore, be of value to growers if a means of increasing low temperature hardiness in cold sensitive vines were available. This could also have implications for other sensitive cultivated perennial plants.

The research described in this thesis was designed to examine in detail one possible means of influencing the hardiness of the above ground portion of the grapevine; grafting onto various phylloxera resistant rootstocks.

LITERATURE REVIEW

Perennial plants living in temperate zones are exposed to a variety of environmental conditions. During summer months they must withstand varying degrees of heat and water stress - in winter, extreme cold. To survive under these extreme conditions the plants have evolved the ability to alter their metabolism, physiology, anatomy,and morphology in response to environmental stimulii. Because low temperature can be lethal to tissue in over wintering plants, the ability of a tissue or plant to acclimate and resist freezing stress is crucial. Since grapevines require this ability, the topics of acclimation, deacclimation, and freeze resistance are of interest to both plant scientists and viticulturists.

INDUCTION OF PLANT COLD ACCLIMATION

Cold hardiness in plants has received much attention. Because crop loss and vine survival are associated with cold injury, this subject has become of major importance to plant scientists (68).

As day length shortens (SD) in early fall there is an onset of acclimation in perennial plants. Acclimation is the general process whereby a plant changes from the cold tender to the cold hardy condition. The quantity and quality of light received during acclimation have been determined to have an effect on the process (36,40,67). Daylength perception by the plant is phytochrome mediated. The perception is affected by the relative amounts of red and far red light received and the relative lengths of the light and dark periods to which the plant is subjected (61). McKenzie (36) states that the initial phase of acclimation in Cornus stolonifera L. is enhanced by, but not dependent upon SD photoperiods and a spectral ratio of far red to red greater than 1.0. Wolpert (68) also showed that

acclimation in grape was enhanced by short days but a one half hour light exposure as a night break did not completely prevent its occurence. This suggests the possibility that another mechanism, in addition to SD,is operating to induce acclimation (this will be discussed in a later section).

Photoperiodically induced leaves produce a hardiness promoting factor(s) that is translocated to other parts of the plant via the phloem (16,53). This appears to initiate the first phase of acclimation which allows the plant to withstand tempertaures to about -18 to -25°C (19,21,61)

ROLE OF CARBOHYDRATES

As shoot growth slows near summers end, there is a simultaneous accumulation of carbohydrates which are required for growth the following spring (18,48,67). In addition, the stored carbohydrates furnish sugars which have been implicated in freeze resistance (57). Carbohydrate accumulation may be influenced by rate of shoot growth, crop load, and canopy exposure to sunlight (18,47,67). These factors can be manipulated by the grower to improve the carbohydrate status of the vine. Hardiness at the cellular level however, is dependent on the inherent ability of the plant to withstand cold.

INDUCTION OF THE SECOND PHASE OF ACCLIMATION

As stated previously, the ratio of far red to red light and the length of the photoperiod trigger the first phase of acclimation. The second phase of acclimation , which is triggered by low temperatures under SD conditions, allows plants to achieve a much greater degree of hardiness (19,21,61,62). Sakai and Nishiyama (46) emersed winter vegetative buds of apple, gooseberry, raspberry, currant and pear in liquid nitrogen (-196°C) without damage after first exposing them to

successively lower temperatures and extra-cellular freeze dehydration.

ACCLIMATION AND WATER STATUS

The effects of low temperature on different plant phenomena are numerous. Of these, an increase in root resistance to water uptake is one of the earliest observed (68). This is thought to be due in part to a change in hormone balance (32). Increased root resistance to water uptake may aid in tissue dehydration since it is known that tissues lose water during the first phase of acclimation (35). Wolpert (68) showed that tissue water loss is highly correlated with SD induced acclimation. Greater acclimation required alterations in cellular constituents. For example, quantitative and qualitative changes have been shown in phospholipids (50,69), sugars (29,40), proteins (28,30), free amino acids (30) and nucleic acids (28,29). The precise effect of these changes on tissue and cell hardiness has not been determined. However, reports state that unsaturation of membrane lipids results in an increase in the plasma membranes permeability to water at or slightly below freezing temperatures (6,54). The movement of water out of the cell serves two purposes. First, it dehydrates the cell and thereby lessens the chance for destructive formation of ice crystals, and second; it concentrates the cell sap which effectively lowers its freezing point (1,27). This may allow the cell to escape damage from ice formation but it is a possible source of damage from dehydration contraction and the crystallization of proteins (27,54). To avoid contraction damage, the plasma membrane reportedly undergoes some basic structural changes (49,72). Sugawara and Sakai (57) showed that the particle concentration of the outer half of a freeze fractured plasma membrane changed considerably on acclimation and was reversible on deacclimation. The particles that they observed have been associated

with phospholipase-D activity which has been correlated with degree of injury. In less hardy tissue, phosphatidylcholine degradation had a strong positive correlation with degree of injury (69). Phosphatidylcholine degradation is suggested to play a role in the irreversible alteration in membranes of non-hardy plant cells. Yoshida (71) suggests that acclimation causes an alteration of other membranes as well as the plasma membrane. He gives evidence that lipid classes present in the Golgi apparatus, tonoplast, and endoplasmic reticulum are altered . As these changes are beginning to occur, there is also a major change occuring in hormone levels.

HORMONES AND COLD ACCLIMATION

As acclimation begins, there are accompanying changes in the levels of various hormones. For example, cytokinins found in xylem exudate decrease to nearly undetectable levels (33) while abscissic acid (ABA) concentrations begin to increase (10). Skoog et al. (52) demonstrated that cytokinins promote cell division in tissue culture and, it is widely accepted that they produce a wide variety of physiological and biochemical effects. They delay senescence of detached organs, stimulate lateral bud growth, and modify the plants response to certain types of environmental stress (17,24,38). Luckwill and Whyte (33) demonstrated a strong correlation between growth and cytokinin levels in xylem sap of apples. Cytokinin levels increased in spring prior to and during rapid growth and full bloom and then declined throughout fruit maturation to undetectable levels by the onset of acclimation. Although the exact mode(s) of action of cytokinin is unknown (24,38), Kende and Tavares (22) showed that it acted by slowing proteolysis. This work was further substantiated by the findings that proteases (2,4) and RNases (2) are lower in cytokinin treated leaves

than in controls.

While cytokinins are associated with growth, ABA is associated with dormancy and growth inhibition. Tucker and Mansfield (60) showed that inhibited lateral buds of Xanthium contained ABA levels up to 250 times that of controls and this level dropped dramatically upon release (i.e. removal of shoot apex). ABA levels have also been shown to increase in the buds of perennial plants upon acclimation and to decrease upon deacclimation (9). ABA, like cytokinin, produces a wide range of physiological and biochemical changes. Exogenous ABA applied to black currant (Ribes nigrum L.) and Sycamore (Acer pseudoplatanus L.) (58) induced quiescent buds and its concentration paralleled the level of dormancy in asparagus spears(Asparagus officinalis Linn. var. altilis Linn.)(34). Little and Eidt (31) and El-Antably et al. (11) showed exogenous ABA delayed bud break in non dormant cuttings and causes a cessation of growth and formation of resting buds in actively growing seedlings of Sycamore(Acer pseudoplatanus L.), White Birch (Betula alba L.) and Silky osier (Salix viminalis L.). They fail to mention, however, if the buds so formed possess any resistance to sub-freezing temperatures. VanOverbeek et al.(63) also demonstrated ABA inhibition of growth and protein synthesis in Lemna at concentrations as low as 1 ppb. Cytokinins (as benzyladenine (BA)) but not gibberellic acid(GA) or auxin could overcome this inhibition.

ABA was found to remain at relatively high levels in dormant buds but declined during deacclimation. It was first believed that ABA in bud scales was responsible for maintaining bud dormancy until it was shown that ABA levels in bud scales do not decline (13,14). The ABA of importance to dormancy seems to be that within the meristematic tissue. Corgan and Peyton (10) and Emmerson and Powell (13) demonstrated that

ABA levels in meristematic tissue declined until bud burst in peach and grape respectively. As ABA levels are declining, GA and cytokinin are increasing. Since both of these hormones have been shown to inhibit the action of ABA the question arises as to cause and effect. Do GA and cytokinin levels increase as a result of lowered ABA levels, or does ABA decline as a response to increased GA and cytokinin levels? Whatever the situation, ABA is thought to be produced primarily in leaves (71) while cytokinins are produced primarily in the roots (9,24,65). This suggests the possibility that the root and shoot of a plant may interact in the process of regulating the various phases of growth. If this is true, a similar interaction should exist between a rootstock of one cultivar and a scion of another cultivar grafted to it.

ROOTS OF GRAPEVINES

Roots are the plant organ intimately in contact with the soil which are responsible for absorption of water and nutrients. The primary functions of roots are 1) anchorage; 2) absorption of water and nutrients; and 3) storage of reserves (67). As noted, one that may be added to this list is the production of growth hormones (23). The ability of the root system to supply a scion with nutrients and water greatly influences the vigor of the scion. Richards and Rowe (42) demonstrated that when restricting the root system of peach trees, there was a corresponding loss in size of the scion. However, the root:shoot ratio was not effected. Work done regarding root: shoot ratios indicates that each plant species has a ratio that is common to it and this ratio is maintained through varying carbohydrate partitioning (3,7,43). This ratio may change for one plant grown on different soil types (44) or in grafted plants as a function of the graft part-

ners (3,59). As the plant's source of water, roots can influence the time of acclimation and deacclimation. Wolpert (68) showed that declining tissue water content was strongly and positively correlated with increasing root resistance to water flow and increasing cold hardiness during the early stages of acclimation in grape. The increase in root resistance to water flow is a prerequisite for tissue dehydration (35). Similarly, during deacclimation in spring, increasing tissue moisture had a strong inverse relationship with cold hardiness (5). As tissue water content increases, the tissues are more and more susceptible to freezing injury. The same is true of the early developmental stages of buds. The more advanced the stage of development, the more easily the tissues are injured by freezing temperatures (37,56). Various rootstock cultivars, being from widely divergent geographical areas, may respond differently to conditions conducive to growth in spring and acclimation in fall. Given these results,it is reasonable to determine whether there is an influence of the rootstock on the time and/or rate of spring deacclimation and subsequent bud development, and/or acclimation to cold in the fall.

ROOTSTOCK INFLUENCES ON HARDINESS

Many examples of the rootstock influencing hardiness have been reported in apple and peach (8,26,66,70,74).The reported differences however, are often inconsistent, and contradictory. The procedure used in selecting the plant materials for hardiness evaluations in these studies is never clearly stated. Since the location and morphology of the samples can greatly influence the hardiness(20), it seems likely that some of the observed discrepancies could be an artifact of sampling. However, it is well established that rootstocks influence vigor in apple (61) and this is also the case in grape (16,41).

Because of this, it is possible that grapevine rootstocks may influence scion hardiness as a result of excessive vigor through internal vine shading. This could also negatively influence the fruitfullness of buds retained at pruning. If the only effect of the rootstock on scion hardiness is a secondary effect due to shading, the researcher, through careful sample selection, should be able to eliminate this and sort out any direct effects of the rootstock on scion hardiness.

STATEMENT OF RESEARCH OBJECTIVES

The various organs of a grapevine interact intimately to maintain growth, reproduce, and respond to environmental stimuli. Much work has been done regarding root produced cytokinin influence on the scion (23), scion produced indole acetic acid (IAA) and ABA on the root (12,64), and interactions between the groups of hormones. The size and vigor of the root system and its ability to absorb water and nutrients influences the size and vigor of the scion. Conversely, the ability of the scion to produce photosynthate and respond to the substances provided by the roots will influence root mass. This seems to be fairly straight forward. When we examine the current knowledge concerning various plant hormones however, some new questions arise. Skene and Antcliff (51) showed that the rootstock on which a vine was grafted could influence the fruitfullness of that vine. If roots can influence the vines ability to produce fruit, can they also influence the processes that control cold hardiness? If a hardiness inducing factor is produced in SD induced leaves that triggers a response in the roots, do different rootstocks respond to the same extent to this signal? Also, if leaf produced growth inhibitors are responsible for bud dormancy, and root produced compounds have been shown to be antagonistic to these, do different rootstocks influence onset or rate

of deacclimation? The processes underlying the large biochemical changes seen as plants acclimate are influenced by plant hormones (e.g. proteolysis, leaf senescence, enzyme synthesis) . Since some of these processes are known to be influenced by root produced hormones, do different rootstocks effect the changes that take place? The purpose of this thesis is to examine the question; " Do roots influence the cold hardiness of scions grafted onto them?". This project was divided into two parts; 1) A study of non-grafted rootstock cultivars to determine if hardiness differences existed among cane tissues of different rootstocks; and 2) a study of various rootstock/scion combinations to determine if the rootstock cultivars impart any of their inherent hardiness differences to the scion cultivars.

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INTRODUCTION

Many horticultural crops including grapevines are grafted onto rootstocks. Since the phylloxera epidemic of the late 1800's, nearly all of the vines of Vitis vinifera (L.) are grafted. V.vinifera is the most widely grown of the grape species, so most of the worlds grapevines are grafted to phylloxera resistant rootstocks. Recently, V.vinifera cultivars have been increasingly planted in the eastern Untied States and Canada as well as the state of Washington and British Columbia. Since most V.vinifera are more sensitive to cold (28) than species traditionally grown in the region, scientists are searching for means to reduce or eliminate winter damage. Research data or empirical observation has produced the suggestion in grape (18) and other fruit crops (27) that the roostock influences a vast array of morphological and physiological characteristics of the scion cultivar, including cold hardiness. However, lacking in grapes has been a careful, precise study to determine whether differences really existed in the cold hardiness of rootstocks and in their influence on cold hardiness of the scion. If differences do exist, it should be possible to select a stock best suited for cold climates such as those in the Great Lakes region.

A systematic approach is needed. If roots contribute to the hardiness of a scion cultivar, the roots on the stock should contribute to the hardiness of the above ground tissues on the ungrafted rootstock cultivar. The first step is to measure the cold resistance of bud and cane tissues of important grape rootstock cultivars.

MATERIALS AND METHODS

Plant Material:

Two sites were used in this study. In the winters of 1981-82, 82-83, and 84-85, vines were sampled in the Plant Pathology vineyard located Michigan State University, East Lansing (site 1). This site is at 42°41'N, 84°27' W and at 273 m elevation. Vines of the rootstock cultivars Couderc 3309 (*Vitis riparia* (Michx.) x *Vitis rupestris* (Sch.)) (3309), Kober 5BB (*Vitis riparia* (Michx.) x *Vitis berlandieri* (Pl.)) (5BB), and Selection Oppenheim No.4 (*Vitis riparia* (Michx.) x *Vitis rupestris* (Pl.)) (SO4) were sampled in 1981-82 and 1984-85 while only 3309 and 5BB were sampled in 1982-83. Site 2 was located at Fenn Valley Vineyards and Winery, Fennville, Michigan. This site is at 42° 35'N, 86°07' W and 209m elevation. Vines at both sites were planted in a 3.0 m between row and 2.4 m within row spacing. At Site 1, vines were planted in two adjacent East-West rows with fifteen vines representing each treatment. 5BB and 3309 occured in one row while SO4 occured in the adjoining row. At Site 2, vines were planted in three adjacent North-South rows with fifteen vines representing each treatment. Vines were trained to a high head at 1.4 m and were cane pruned. Canes were sampled using criteria set forth by Howell and Shaulis (10) that have been shown to influence hardiness. That is,only canes which were well exposed to the sun, showed dark colored periderm, had uniform internode length of between 10 and 15 cm and a diameter of 7-9 mm were chosen.

Controlled Freezing Procedure:

Samples were prepared for controlled freezer runs as described by Howell and Weiser (7) and Howell et al.(8). Single node cane sections were placed in contact with moistened cheese cloth which served to inoculate the tissues with ice crystals and thereby prevent

supercooling. The cane sections and cheese cloth were then wrapped in aluminum foil and placed in vacuum flasks to facilitate a slow and steady decline in tissue temperature. Nodes 1-15 were used and were distributed so that each replicate at each temperature had an equal number of basal, middle, and apical nodes. In the 1981-82 and 82-83 winters, four replicates per temperature were used with four canes per replicate. In the 1984-85 winter, three replicates per temperature were used with five canes per replicate. One control per replicate was used during each of the runs. Samples were frozen in a Revco Ultra Low freezer at rates of no more than five degrees C per hour during October-November and March-April. During mid winter, rates never exceeded 10° C per hour. Samples were monitored using one copper constantan thermocouple per container inserted into the pith of a representative cane (8). Target temperatures were seperated by 3 to 5° C depending on the time of dormant season. More narrow separations were used when tissues were less hardy while wider seperations were used when tissues were most hardy. This insured that all tissues would live at the warmest temperature, and all tissues would be killed at the coldest temperature. After freezing, samples were thawed for 24 hours at 2° C and then transferred to humid chambers at 19 C, and aerated daily for one week. At this time, samples were evaluated for mortality under a binocular microscope using the browning test (26) to determine viablity. T50's were calculated using a modified Spearman-Karber equation (2) and were subsequently analysed for each date using Analysis of Variance. Total numbers of live and dead buds were pooled for the first three sampling dates, the last three sampling dates, and for the total season in an attempt to locate differences that may not have been apparent from the graphs. The pooled values were separated

using Chi-square(29).

RESULTS

The data from both sites in all years of the study show 3309 to have the hardiest canes (Figures 1-4). T50 data, when statistically significant, show 3309 to always be hardiest, 5BB least hardy,and S04 was intermediate . In every winter that S04 hardiness was compared with 3309 and 5BB, there was one occasion where 5BB and 3309 were significantly different and S04 was intermediate. There are also situations in each year of the experiment where S04 was statistically equal to 5BB and significantly less hardy than 3309 and, where S04 was statistically equal to 3309 and significantly hardier than 5BB. The 1982-83 data from Site 1, which included only 3309 and 5BB, shows 3309 to have hardier canes on every date. T50's show 3309 to be as much as 11.5 C hardier on 3-27-82 at Site 1. This was the largest difference observed. More typical differences were on the order of 3-7°C. Pooled data for early season,late season, and whole season hardiness assessments support the T50 data (Tables 1-4) for individual dates.

Significant differences between buds were less consistent. On only five occasions during the entire study were T50's of buds significantly different (Figures 1-4). Pooled data give a clearer picture of relative bud hardiness (Tables 1-4). In 1981-82 and 82-83 dormant seasons, 5BB buds were always hardiest when significant differences were found (Tables 1 and 2). However, at Site 2 the reverse was observed. 5BB had the least hardy buds when differences were found (Table 3). This same situation was true at Site 1 during the 84-85 dormant season (Table 4). As previously observed, S04 was typically equal to 5BB or intermediate between 5BB and 3309. During the 81-82 and 82-83 winters at Site 1, 5BB was from 2.0 to 7.5°C hardier than S04 in mid-winter. S04 was

roughly equal to 5BB after about mid-November. T50's fluctuated for all cultivars until this time. By mid-March, 5BB buds and canes had become considerably less hardy than 3309 during each year of the experiment and at each site. Apparently the 5BB deacclimates more rapidly than 3309. SO4 was evaluated only into March at Site 1 in 81-82 and 84-85 due to inadequate amounts of plant material. The data showed it to be intermediate between 5BB and 3309 in this case as in previous observations.

DISCUSSION

The cane and bud tissues of the rootstock cultivars in this study did show differences in their cold hardiness. These differences were very consistent for cane tissues and less so for bud tissues. Based on data in this study, 3309 has the hardiest cane tissue. Based on the bud data, it is impossible to declare buds of one rootstock as hardier than the others.

The T50 data showed that 5BB deacclimated more rapidly in all years of the study. This was significant since spring freezes have damaged the Michigan grape crop in 11 of 21 years between 1957 and 1977 (9). However, since deacclimation was not the focus of this study, lack of data prevents the drawing of precise conclusions. Deacclimation will be examined in more detail in Chapter 3. The cause(s) of the observed differences in cane hardiness are not obvious. The hardiness literature shows repeated examples of differences in cultivar resistance to cold damage. One possible explanation for these differences is the species background of parents used in breeding rootstocks. All three rootstocks have Vitis riparia (Michx.) in their parentage. This species has the widest geographic range of the American species. It ranges as far north as the -40°C line on the

Hardiness Zone maps. It is the most hardy grape species found in North America (18) and its hardiness is similar to reports on the hardiness of V.amurensis selections from China (Dr.G.S.Howell personal communication, Dept.of Horticulture, MSU).

Both 5BB and SO4 also have V.berlandieri in their parentage. According to Munson (17), this species was selected in western Texas in 1883, primarily because of its tolerance of high pH soils. Kober received selections containing V.berlandieri from Teleki and later released 5BB. SO4 was released subsequent to 5BB and according to Pongrancz (20), is very similar in growth characteristics and lime tolerance except that SO4 is more easily grafted to V.vinifera cultivars. It is the most widely used rootstock in France at present(5).

Since many of the biochemical changes accompanying acclimation are under genetic control (i.e. conformational changes in proteins, altered carbohydrates and lipids, and ion pumps (4,6,11,13,20,22,26,30,31)),it seems likely that parentage is exerting an influence on cold hardiness.

Growth rate and vine size are also under genetic control to some extent. Reynolds and Pool (23) showed that various rootstocks (and by implication their roots) can impart varying degrees of vigor to the scion. Such root influence could be the result of varying rates of water uptake, nutrient uptake, production of growth regulating hormones, or various combinations of these. We know that carbohydrate accumulation is essential for proper acclimation (13,28). It is also known that there are large changes in hormone levels accompanying acclimation (16). Wolpert (29) showed a strong relationship between declining cane water content and early acclimation (tissue dehydration is necessary during acclimation since it is rupture of cell membranes

by ice crystals that causes freezing injury in non-acclimated plants (13,14)). For these reasons,any rootstock effect on the biochemical changes and tissue hydration could presumably alter hardiness.

Water content of canes is also important during deacclmation since tissues must rehydrate for growth to begin (3). As the source of the plants water, roots may be exerting an influence during both acclimation and deacclimation on cane water content as well as other factors previously discussed.

CONCLUSION

Real and consistent differences in the cold hardiness of cane tissues sampled from the rootstock cultivars were measured. 3309 canes were consistently hardier than 5BB. SO4 canes were somewhat intermediate. Bud hardiness differences were variable. Further research should indicate whether these differences are influenced by the rootsystem, and if so, whether the root influence on hardiness will influence the hardiness of cane tissues of a scion cultivar grafted onto the rootstock in a similar manner.

Table 1. Total Numbers of Live and Dead, Bud and Cane Tissues, Site I (Ramsdell).

1981-82

		First Four Dates 1°	First Four Dates Cane	Last Four Dates 1°	Last Four Dates Cane	Season Total 1°	Season Total Cane
Kober 5BB:	#Live	124**	136*	43	74**	173	210
	#Dead	114[b]	104[a]	197	166[a]	311	270[a]
Couderc 3309:	#Live	86	158	59	164	145	322
	#Dead	137[a][z]	82[b]	181	76[b]	318	158[b]
S04	#Live	124	137	--	--	--	--
	#Dead	111[b]	103[a]	--	--	--	--

Separated with χ^2 at .05* level and .01** level of significance.

[z]Within columns, letters separate significant differences with 'a' representing the least live.

First four dates: 9-3, 9-25, 10-23, 11-16

Last four dates: 12-10, 1-17, 3-27, 4-20

Table 2: Total Numbers Live and Dead, Bud and Cane Tissues, Site I (Ramsdell).

1982-83

		First Four Dates 1°	First Four Dates Cane	Last Five Dates 1°	Last Five Dates Cane	Season Total 1°	Season Total Cane
Kober 5BB:	#Live	153**	161**	208	264**	361**	425**
	#Dead	157[b]	159[a]	182	136[a]	399[b]	295[a]
Couderc 3309:	#Live	94	208	184	326	208	534
	#Dead	180[a][z]	112[b]	209	72[b]	112[a]	184[b]

Separated with χ^2 at .05* and .01** levels of significance.

[z]Within columns, letters separate significant differences with 'a' representing the least live.

First four dates: 9-7, 9-27, 10-8, 11-1

Last five dates: 11-22, 1-31, 3-11, 3-29, 4-10

Table 3. Total Numbers Live and Dead, Bud and Cane Tissues, Site II (Fenn Valley).

1981-82

		First Four Dates 1°	First Four Dates Cane	Last Four Dates 1°	Last Four Dates Cane	Season Total 1°	Season Total Cane
Kober 5BB:	#Live	122*	154*	117**	181**	239**	335**
	#Dead	188[a]	166[a]	203[a]	139[a]	391[a]	305[a]
Couderc 3309:	#Live	173	204	157	246	330	450
	#Dead	115[cz]	106[c]	143[b]	74[b]	258[b]	180[b]
S04:	#Live	155	183	—	—	—	—
	#Dead	148[b]	137[b]	—	—	—	—

Separated with x^2 at .05* and .01** levels of significance.

[z]Within columns, letters separate significant differences with 'a' representing the least live.

First four dates: 9-2, 9-23, 10-17, 11-7

Last four dates: 12-5, 1-30, 3-25, 4-24

Table 4. Total Numbers of Live and Dead, Cane and Bud Tissues, Rootstock Site I (Ramsdell).

1984-85

		First Three Dates 1°	First Three Dates Cane	Last Four Dates 1°	Last Four Dates Cane	Season Total 1°	Season Total Cane
Kober 5BB:	#Live	67**	134	84*	217**	151*	351**
	#Dead	128[a]	61	216[a]	83[a]	344[a]	144[a]
Couderc 3309:	#Live	98	138	120	265	218	403
	#Dead	97[bz]	57	180[b]	35[b]	277[b]	92[b]
S04:	#Live	81	127	90	208	171	335
	#Dead	113[ab]	68	210[a]	92[a]	323[a]	160[a]

Separated with x^2 at .05* and .01** levels of significance.

[z]Within columns, letters separate significant differences with 'a' representing the least live.

First three dates: 10-20, 11-16, 12-10

Last four dates: 1-10, 2-8, 3-12, 3-26

Figure 1. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of the grapevine rootstock cultivars K-5BB, C-3309, and S04 during mid winter, September through April, at Site 1, 1981-82.

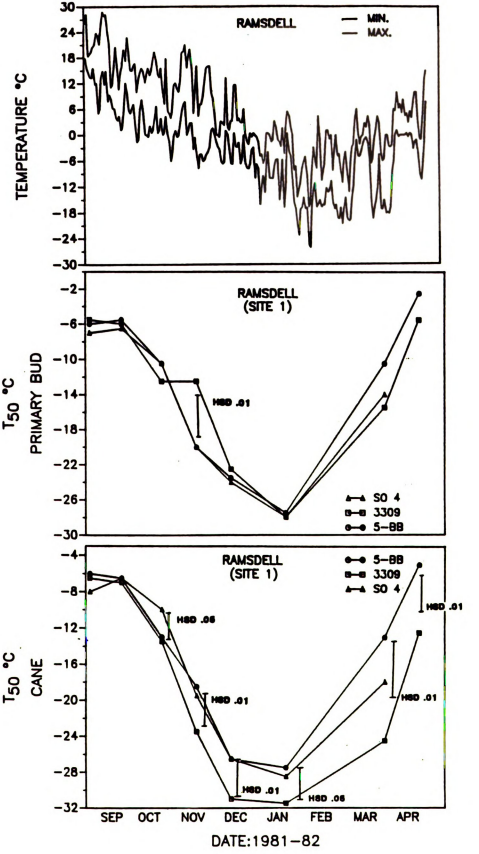

RAMSDELL
MIN.
MAX.
TEMPERATURE °C
RAMSDELL
(SITE 1)
T50 °C
PRIMARY BUD
HSD .01
SO 4
3309
5-88
RAMSDELL
(SITE 1)
5-88
3309
SO 4
T50 °C
CANE
HSD .05
HSD .01
HSD .01
HSD .01
HSD .01
HSD .05
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1981-82

Figure 2. Cold Hardiness (T50) of primary bud and cane tissues of the grapevine rootstock cultivars K-5BB, C-3309, and S04 during mid winter, September through April,at Site 2, 1981-82.

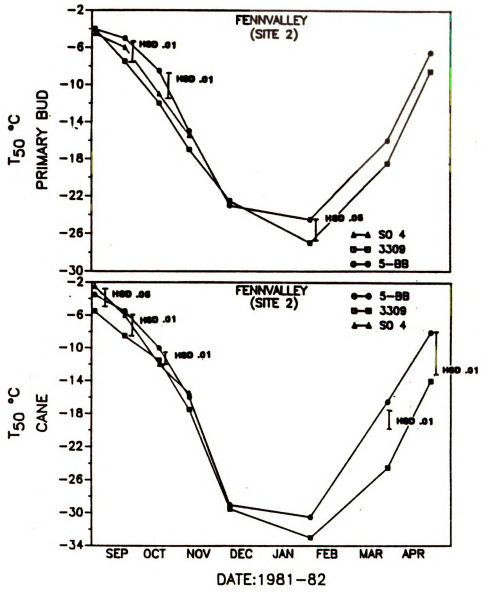

FENNVALLEY
(SITE 2)
HSD .01
HSD .01
HSD .05
SO 4
3309
5-88
T50 °C
PRIMARY BUD
-2
-6
-10
-14
-18
-22
-26
-30
FENNVALLEY
(SITE 2)
5-88
3309
SO 4
HSD .05
HSD .01
HSD .01
HSD .01
HSD .01
T50 °C
CANE
-2
-6
-10
-14
-18
-22
-26
-30
-34
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1981-82

Figure 3. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of the grapevine rootstock cultivars K-5BB and C-3309 during mid winter, Septemberthrough April, at Site 1, 1982-83.

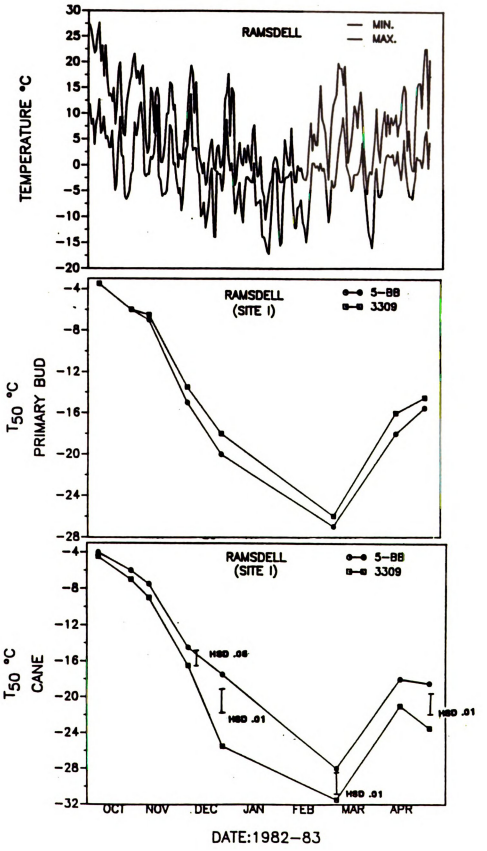
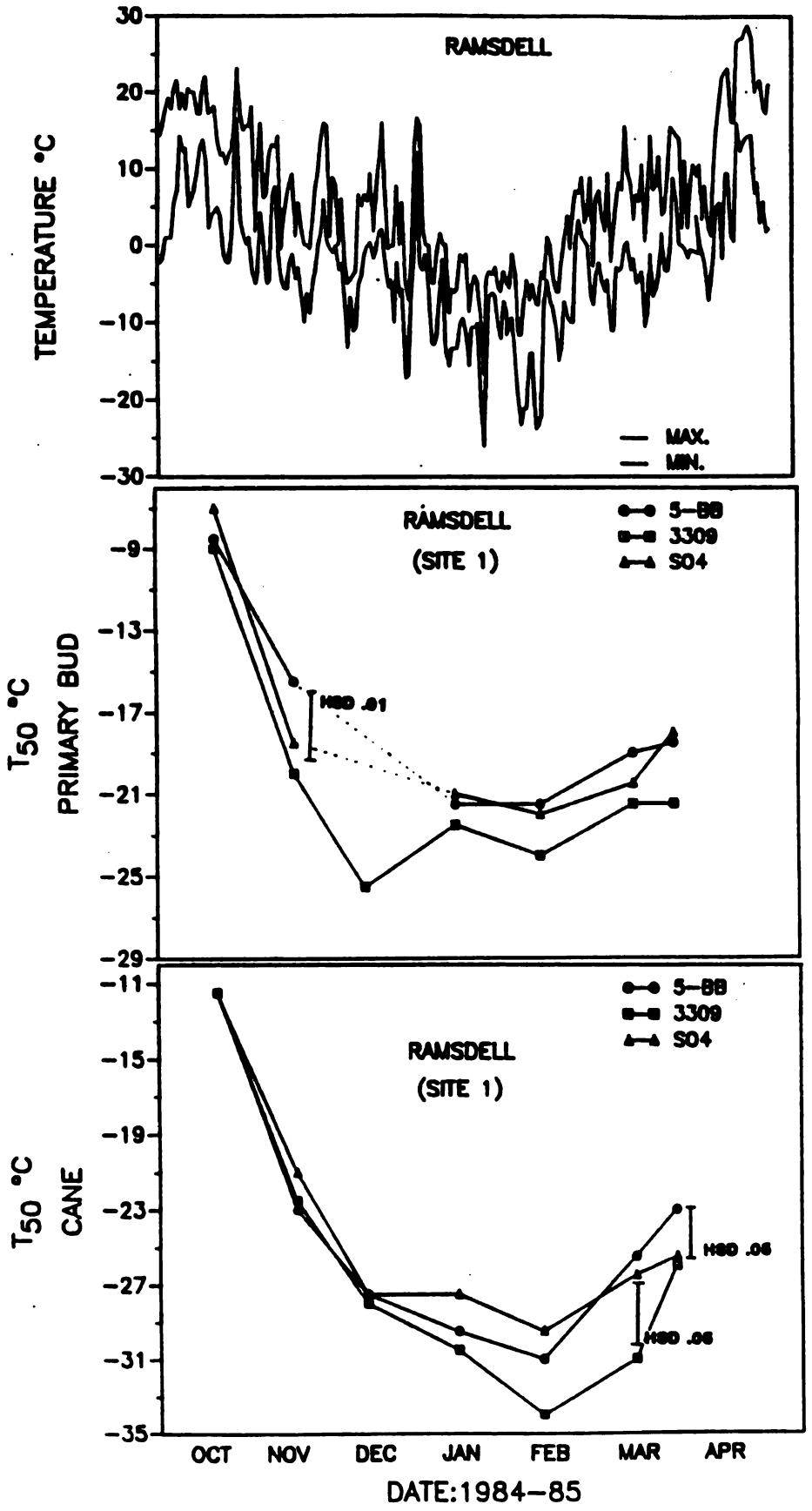

RAMSDELL
MIN.
MAX.
TEMPERATURE °C
30
25
20
15
10
5
0
-5
-10
-15
-20
RAMSDELL
(SITE I)
5-88
3309
T50 °C
PRIMARY BUD
-4
-8
-12
-16
-20
-24
-28
RAMSDELL
(SITE I)
5-88
3309
T50 °C
CANE
HSD .05
HSD .01
HSD .01
HSD .01
-4
-8
-12
-16
-20
-24
-28
-32
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1982-83

Figure 4. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of the grapevine rootstock cultivars K-5BB, C-3309, and SO4 during mid winter, September through April, at Site 1, 1984-85.


RAMSDELL
TEMPERATURE °C
30
20
10
0
-10
-20
-30
MAX.
MIN.
RAMSDELL
(SITE 1)
5-88
3309
S04
T50 °C
PRIMARY BUD
-9
-13
-17
-21
-25
-29
HSD .01
RAMSDELL
(SITE 1)
5-88
3309
S04
T50 °C
CANE
-11
-15
-19
-23
-27
-31
-35
HSD .06
HSD .06
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1984-85

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INTRODUCTION

As a result of the widespread use of rootstocks in todays perennial fruit industry, much research has focused on stock/scion relations (8,9,10,16). Many researchers have examined scion effects on the rootstock and rootstock effects on the scion in an attempt to ; 1) gain a clearer understanding of the plant as a unified system (10,14) and; 2) manipulate rootstock/scion combinations to give a desired set of characteristics to the scion cultivar portion of the plant (9,12).

A common use of apple clonal rootstocks is to reduce tree size (10,14). Grapevine rootstocks were originally chosen for their ability to tolerate some soil borne deterent to growth such as pests, nutrient deficiencies or other than optimal pH (8,12). As research continued, many more relationships were perceived between stock and scion. Nitrogen metabolism, fruit load and quality, carbohydrate reserves and hormone levels were some of the growth aspects affected by rootstock (1,8,9,11). Since it has been established that there is an interaction of the stock and scion in controlling growth, one should consider the possibility that there are interactions that could influence vine response to freezing stress. These would include time and rate of acclimation , time and rate of deacclimation and mid winter hardiness. As established in Chapter 1, differences exist in the cold hardiness of cane tissues of some rootstock cultivars. The objectives of this study were to observe differences in rootstock cane tissue hardiness as influenced by the rootsystem and to determine if a root(stock) system can influence scion cultivar cold hardiness.

MATERIALS AND METHODS

Site:

Two sites were used in this study. The first site (Site 1) is located at Fenn Valley Vineyards and Winery, Fennville, Michigan. Fenn Valley is located at 42°35'N, 86°07'W and 209m elevation. The plot is situated on a uniform Spinks sandy loam (personal communication,Dr.Delbert Mokma, Department of Crop and Soil Science, MSU) with approximately 4% slope from West to East and 3% slope from South to North.

The second site (Site 2) is located at the Clarksville Horticultural Experiment Station . Site 2 is located at 42°52'N, 85° 15'W and at an elevation of 255m. Site 2 is situated on a Kalamazoo sandy loam soil with a 1% slope from North to South.

Plant Materials:

The plot layout at Site 1 consists of; one row of White Riesling grafted to Kober 5BB (R/5BB) divided into three, five vine replicates separated from each other by one guard vine; three rows of White Riesling grafted to Couderc 3309 (R/3309) with one, five vine replicate per row and; two rows of own rooted White Riesling (OR) with two, five vine replicates in one row and one, five vine replicate in the second row. Rows containing different treatments were seperated from each other by one guard row. Vines were planted with a spacing of 2.8m between rows and 1.8m between vine within rows. Vines were planted in 1978 and were trained to a bilateral cordon at the bottom wire (4.5dm in height). Since the plot was in a growers vineyard, the experimental design had some limitations. Because of this, the viticultural data (i.e. yield, cluster#, vine size etc.) are presented in the appendix as items of information (Appendix A, Table 1).

At Site 2 the plot consists of the middle three rows of a five row plot. The rows run North to South. Four treatment combinations were used; White Riesling and Chardonnay each grafted to Selection Oppenheim No.4 and Kober 5-BB (R/SO4, R/5BB, C/SO4, C/5-BB). Each treatment combination occured once in each row to give three replicates in a Randomized Complete Block design. Vines were planted in 1981 at a spacing of 3.0m between rows and 1.0m spacing between vines within rows. Vines were trained to a head at a height of 4 dm with two 15 node canes and two, two node spurs per vine. Canes were trained to a Pendelbogen system (i.e. a low head with canes tied to form a 'wine glass'shape).

Samples:

Well exposed canes of dark periderm color, with internode length of 4 to 10 cm and internode diameter of 7 to 10 mm (as measured between the fourth and fifth nodes) were selected(5). Samples were prepared for controlled freezing tests as described by Howell and Weiser (6) and Howell et al.(4). Single node cane sections were placed in contact with moistened cheese cloth to insure ice crystal inoculation and prevent supercooling. Cane samples and cheese cloth were wrapped in aluminum foil and placed in vacuum flasks to facilitate a slow and steady decline in tissue temperature. Nodes 1 through 15 were used and were arranged to give an equal number of basal, middle and apical nodes in each replicate at each temperature. Five, one node cane sections were used for each treatment at each temperature and replicate. Four test temperatures were used with three replicates per temperature. One control was prepared and chosen at random from each replicate (i.e. five sets of canes were prepared, four were frozen, one remained as the control.) Samples were frozen in a Revco Ultra Low freezer at rates

not exceeding 10°C per hour during mid winter. Early season (October and November) and late season (March and April) samples were exposed to temperature drops of 5°C per hour or less. Samples were monitored with one copper constantan thermocouple inserted into the pith of one cane per vacuum flask. Samples were removed from the freezer at 4°C intervals, removal temperatures having been determined prior to the freezer run. After removal, samples were thawed at 2°C for 24 hours. Once thawed, samples were removed from the vacuum flasks and placed in humid chambers at 19°C and were aerated daily for on week. At this time,samples were removed and evaluated for viability using the browning test as described by Stergios and Howell (13). T50's were calculated using a modified Spearman- Karber equation (2). These were compared at each date using analysis of variance in a Completely Randomized Design. Total numbers of live and dead buds and canes were also pooled in an attempt to sort out differences which were not clear from the individual dates on the graphs. This data was analyzed using Chi-square to separate the totals (7).

RESULTS

Fenn Valley

The T50 values obtained for the three treatments at Site 1 were very similar within each season and between each season in which they were sampled. The R/5BB and R/3309 were essentially the same with the R/5BB having slightly hardier buds and the R/3309 having slightly hardier canes on most dates (Figures 1-6). With the exception of one date during the 82-83 winter, the grafted vines were always hardier than ungrafted vines during mid winter. No significant differences were found between T50 values for cane or bud tissues for any given date throughout the experiment. When the numbers of live and dead buds

at critical temperatures for each date for the first and second halves of the season and for the season as a whole,some significant differences were found (Tables 1-3). Chi-square seperations showed the canes of grafted vines to be consistently hardier than ungrafted vines in every situation where significant differences were found. In situations where differences were not statistically significant, R/5BB and R/3309 always had more live canes. The primary buds of R/5BB were always the most hardy with R/3309 fluctuating between R/5BB and OR vines (Tables 2 and 3).

Blind node data shows very little difference between treatments for the springs of 82,83, and 84 (Table 7). However, even with the small observed differences, R/3309 consistently had fewer blind nodes. In addition, R/3309 had significantly fewer blind nodes in the spring of 85 with OR being intermediate and R/5BB having the greatest number.

Clarksville

The vinifera study conducted at Site 2 during the 84-85 winter gave results consistent with those obtained at Site 1 (i.e. scions of one cultivar grafted onto different rootstocks were very similar in the cold hardiness of their bud and cane tissues (Figures 7 and 8)). Canes of R/5BB and R/SO4 showed significantly different T50's on 2-14-85 with R/SO4 beng hardier (Figure 8). This was the only significant difference found between T50's for the Riesling and Chardonnay treatments. Chi-square separations of pooled live and dead, bud and cane tissues showed no significant differences (Tables 5 and 6). Both the Riesling and Chardonnay grafted onto 5BB had slightly more live canes and buds than than those vines grafted onto SO4. Both of the Riesling treatments at Site 2 had hardier canes than the Riesling at

Site 1 on every mid-winter date until 2-25-85. At this point, the R/5BB at Site 1 began deacclimating and had become less hardy than the other grafted Rieslings at both sites.

Blind node data were very similar for both Chardonnay rootstock treatments (Table 7). The C/5BB had slightly fewer blind nodes. Both Riesling treatments also showed very small differences in numbers of blind nodes. R/SO4 had slightly fewer blind nodes than R/5BB and both Riesling treatments had fewer blind nodes than either of the Chardonnay treatments.

DISCUSSION

The grafted vines at Site 1 were hardier than ungrafted vines on most mid-winter dates. There is a possibility that this is due to a graft union effect since other data indicate that vines grafted to their own roots were hardier than own rooted vines (Appendix A; Figures 1 through 6). However, since canes of R/3309 were hardier than R/5BB, the difference cannot be explained strictly as a union effect. In support of this, canes of Seyval blanc on 3309 were hardier than canes of Seyval blanc on 5BB or Seyval blanc on its own roots (Appendix A; Figure 2). If one compares these observations with the observations from the rootstock cultivars in Chapter 1, it is clear that the scions grafted to the hardiest rootstocks are hardier than similar scions grafted to less hardy rootstocks. This relationship is true at Site 2, where scions grafted to two rootstocks that are very similar in hardiness, are also very similar in hardiness. The R/3309 at Site 1 had the fewest blind nodes of any treatment. This contradicts the total live and dead bud data which shows R/5BB to have more live buds. However, the total live and dead bud data dealt only with primary buds while blind nodes are considered to be only those nodes where no

vegetative growth arises. A possible explanation for the fact that R/3309 had fewer blind nodes while R/5BB appeared to have hardier buds lies in the fact that R/3309 had hardier canes.

Empirical field observations made in the springs of 1984 and 1985 showed that live buds on dead canes did exist. These buds would burst only to die after producing shoots of from 2 to 5cm. A second possiblity is that R/3309 may have had more live secondary and tertiary buds. This could be a result of its having more live canes although there are no data to support this.

Several factors exist other than rootstock which might explain differences between treatment T50's. 1) Cropload. It is well known that a heavy crop can limit a vines ability to acclimate and may cause it to succumb to winter damage. Yield data from Site 1 shows OR vines to have produced the largest crop in each year of the study (Appendix A, Table 1). These vines were also the least hardy. R/3309 produced the second largest crop throughout the study. This treatment however, was the hardiest. If crop load were truly controlling cold hardiness, we would have expected R/3309 to be intermedite between R/5BB and OR in hardiness. 2) Excessive vigor. Reduced vine hardiness has been attributed to excessive vigor (11). Actively growing vines in late autumn do not accumulate enough carbohydrates to sufficiently acclimate. Since vine size is an indicator of vegetative growth, one would expect the treatment with the largest vine size (i.e most vigorous) to be the least hardy. The data show again that this is not the case. R/3309 had the largest vine size and was the most hardy. This suggests that vigorous growth may actually increase hardiness rather than decrease it. More research would be needed to clarify this point. 3)Slope. Site 1 had a slight slope with the OR vines being

located lower on the slope than the other treatments. One might argue that this is causing the observed differences in hardiness since cold air accumulates in low lying areas. However, Stergios and Howell (14) and Bittenbender (3) demonstrated that plants growing in a relatively colder site achieved a greater degree of hardiness than did plants growing in a relatively warmer site. Data collected in this study involving White Riesling on 5BB at Sites 1 and 2 support this (Figures 6 and 8). The R/5BB and R/SO4 at the colder site (Site 2) were hardier, particularly in the canes than was the R/5BB at Site 1. If slope was the cause of the observed differences at Site 1, one would expect the OR vines to be the hardiest since they are lower than the other two treatments. R/3309 would be expected to be intermediate (i.e. mid-slope) and R/5BB to be least hardy (highest on slope). This is not the case so slope effect can be effectively ruled out.

The study of grafted V.vinifera at Site 2 gave results similar to those at Site 1. The differences between the T50's of a particular scion cultivar grafted onto either K5BB or SO4 were small. This is consistent with what one would expect if their is a correlation between the hardiness of a rootstock and the hardiness of a scion grafted to it. The Riesling vines at Site 2 were hardier than the Riesling vines at Site 1 (as mentioned earlier) and were always hardier than Chardonnay at Site 2.

The percentage of blind nodes was essentially the same between the Chardonnay treatments and between the Riesling treatments at Site 2. Blind node data from Site 1 supports data collected from the controlled freezer studies in that it shows R/3309 to have fewer blind nodes in each season from 1982 through 1985 (Table 2). The percentage of blind nodes is similar between treatments after a relatively severe winter

(1981-82) when all treatments had equally large primary bud mortality. The same relationship is true after a relatively mild winter (1982-83) except that relatively few primay buds were damaged in each treatment. However, after a marginally severe winter (1983-84 and 1984-85), the differences become viticulturally significant and in 1984-85, statistically significant. This suggests that as temperatures approach levels that are damaging to the least hardy vines, more tissue is damaged on these vines than on the more hardy vines provided the temperature does not continue to drop. If there is a further decrease in temperature, all vines may sustain large amounts of damage. If, on the other hand the temperature reaches levels which are damaging only to the least hardy vines, these vines will sustain much more damage than the will the hardier vines and both vitculturally and statistically significant data are produced.

CONCLUSION

Observed differences in the hardiness of a scion cultivar grafted onto various rootstocks range from 0.5 C to 3.0 C in cane hardiness. These differences appear small, but they are important. They are the source of viticulturally and statistically significant blind node data following moderately severe winters. Site and cultivar are obviously important variables in determining amounts of winter damage so they should be chosen carefully. Choice of rootstock can further reduce winter damage in some years and, evidence indicates that in the case of 3309, can improve fruitfullness of the retained live buds. We suggest that rootstock selections be made basing the decision on more factors than simply the rootstocks ability to resist soil borne pests and deficiencies.

Table 1. Total Numbers of Live and Dead, Bud and Cane Tissues
Fenn Valley Riesling 1982

		Season Total	
		1^{o}	Cane
Own Rooted:	#Live	291	473
	#Dead	349	167
Riesling/K-5BB:	#Live	316	477
	#Dead	324	163
Riesling/C-3309:	#Live	294	489
	#Dead	346	151

N.S.

Sampling Dates: 12-3, 1-18, 2-26, 3-26

Table 2. Total Numbers of Live and Dead, Bud and Cane Tissues
Fenn Valley Riesling

1983-84

		First Three Dates		Last Four Dates		Season Total	
		1^{o}	Cane	1^{o}	Cane	1^{o}	Cane
Own Rooted:	#Live	72**	148	97	102**	169**	250**
	#Dead	153^{a}	77	203	198^{a}	356^{a}	275^{a}
Riesling/ K-5BB:	#Live	$103_{}$	149	98	$154_{}$	$201_{}$	$303_{}$
	#Dead	117^{bz}	71	200	144^{b}	317^{b}	215^{b}
Riesling/ C-3309:	#Live	$78_{}$	166	116	$164_{}$	$194_{}$	$330_{}$
	#Dead	147^{a}	59	184	135^{b}	331^{ab}	194^{b}

Separated with x^2 at .05* and .01** levels of significance.

[z]Within columns, letters separate significant difdferences with 'a' representing the least live.

First three dates: 10-7, 11-11, 12-5

Last four dates: 1-14, 2-10, 3-8, 4-12

Table 3. Total Numbers of Live and Dead, Bud and Cane Tissues Fenn Valley Riesling

1984-85

		First Three Dates		Last Four Dates		Season Total	
		1°	Cane	1°	Cane	1°	Cane
Own Rooted:	#Live	37*	148	83	184	170**	332
	#Dead	137[a]	77	217	116	354[a]	193
Riesling/ K-5BB:	#Live	120[b]	157	93	196	213[b]	353
	#Dead	105[b]	68	207	104	312[b]	172
Riesling/ C-3309:	#Live	112[b]	170	83	185	195[ab]	355
	#Dead	113[b]	55	217	115	330[ab]	170

Separated with χ^2 at .05* and .01** levels of significance.

[z]Within columns, letters separate significant difdferences with 'a' representing the least live.

First three dates: 10-13, 11-19, 12-4

Last four dates: 1-3, 1-31, 3-5, 4-2

Table 4. Percentage of Blind Nodes - Fenn Valley Riesling

	82	83	84	85
R/5BB	61.9	29.9	35.8	41.8b*
R/3309	61.4	24.2	29.9	29.9a
OR	65.4	27.1	37.4	37.9ab

* Means separated with Tukey's at .05* level of significance.

Table 5. Total Numbers of Live and Dead, Bud and Cane Tissues, Clarksville Chardonnay.

1984-85

		First Three Dates		Last Three dates		Season Total	
		1°	Cane	1°	Cane	1°	Cane
Chardonnay/ 5BB:	#Live	131	163	66	190	197	353
	#Dead	94	62	159	35	253	97
Chardonnay/ S04:	#Live	116	155	73	175	189	330
	#Dead	99	70	152	50	251	120

N.S.

First three dates: 10-26, 11-20, 12-18

Last three dates: 1-17, 2-14, 4-2

Table 6. Total Numbers of Live and Dead, Bud and Cane Tissues, Clarksville Riesling

1984-85

		First Three Dates		Last Three Dates		Season Total	
		1°	Cane	1°	Cane	1°	Cane
Riesling/ 5BB:	#Live	137	179	68	188	205	367
	#Dead	88	46	157	37	245	83
Riesling/ S04:	#Live	138	176	59	194	197	360
	#Dead	87	49	166	41	253	90

N.S.

First three dates: 10-26, 11-20, 12-18

Last three dates: 1-17, 2-14, 4-2

Table 7. Percentage of Blind Nodes - Clarksville Vinifera.

	1985
Chardonnay/5BB	30.0
Chardonnay/SO4	32.5
	N.S.

	1985
Riesling/5BB	25.9
Riesling/SO4	24.8
	N.S.

Figure 1. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of White Riesling grafted to the rootstocks K-5BB and C-3309 and growing on its own roots, during mid winter, October through March, at Site 1, 1982-83.

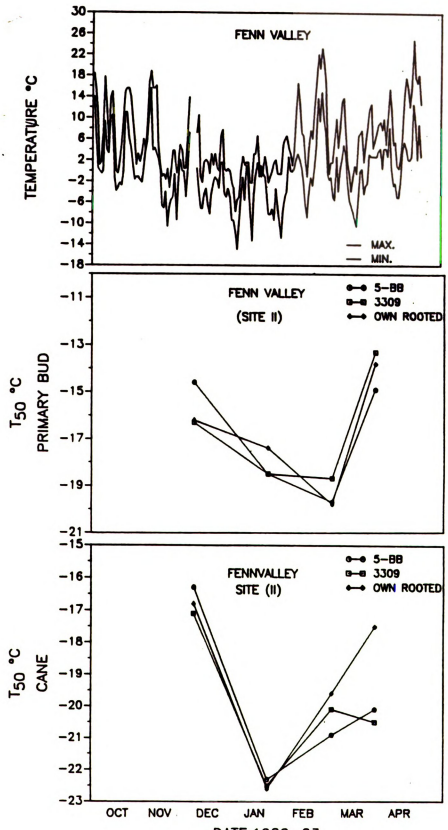

FENN VALLEY
TEMPERATURE °C
MAX.
MIN.
FENN VALLEY
(SITE II)
5-BB
3309
OWN ROOTED
T_{50} °C
PRIMARY BUD
FENNVALLEY
SITE (II)
5-BB
3309
OWN ROOTED
T_{50} °C
CANE
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1982-83

Figure 2. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tisues of White Riesling grafted to the rootstocks K-5BB and C-3309 and growing on its own roots, during mid winter, October through March, at Site 1, 1983-84.

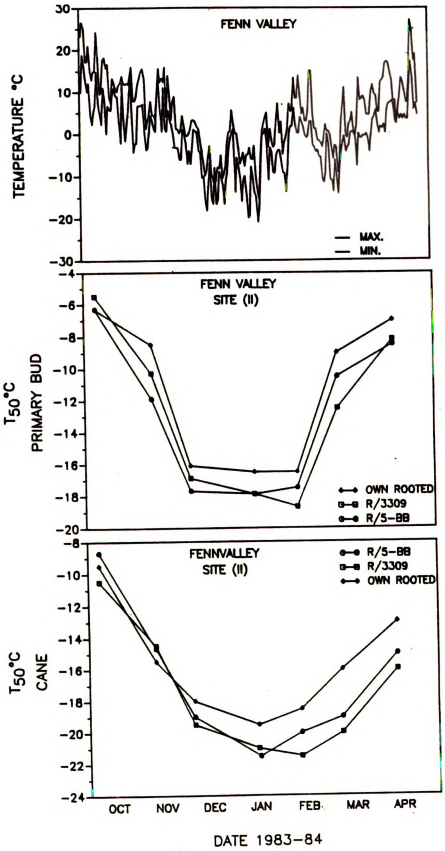

FENN VALLEY
TEMPERATURE °C
MAX.
MIN.
FENN VALLEY
SITE (II)
T50°C
PRIMARY BUD
OWN ROOTED
R/3309
R/5-BB
FENNVALLEY
SITE (II)
R/5-BB
R/3309
OWN ROOTED
T50°C
CANE
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE 1983-84

Figure 3. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of White Rieslinggrafted to the rootstocks K-5BB and C-3309 and growing on its own roots, during mid winter, October through March, at Site 1, 1984-85.

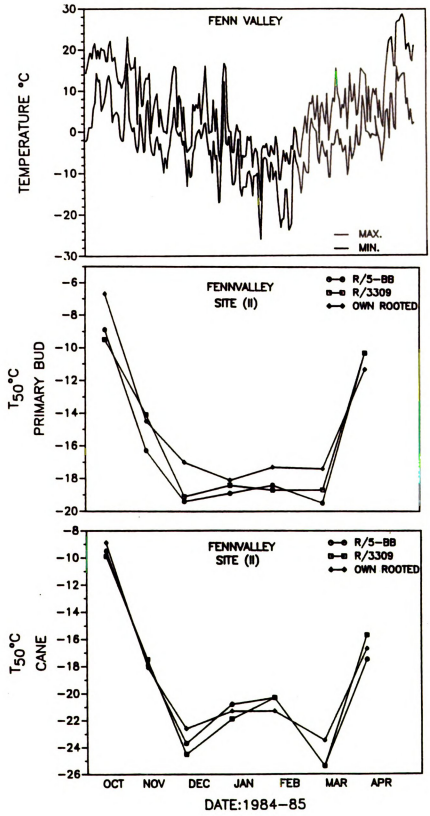
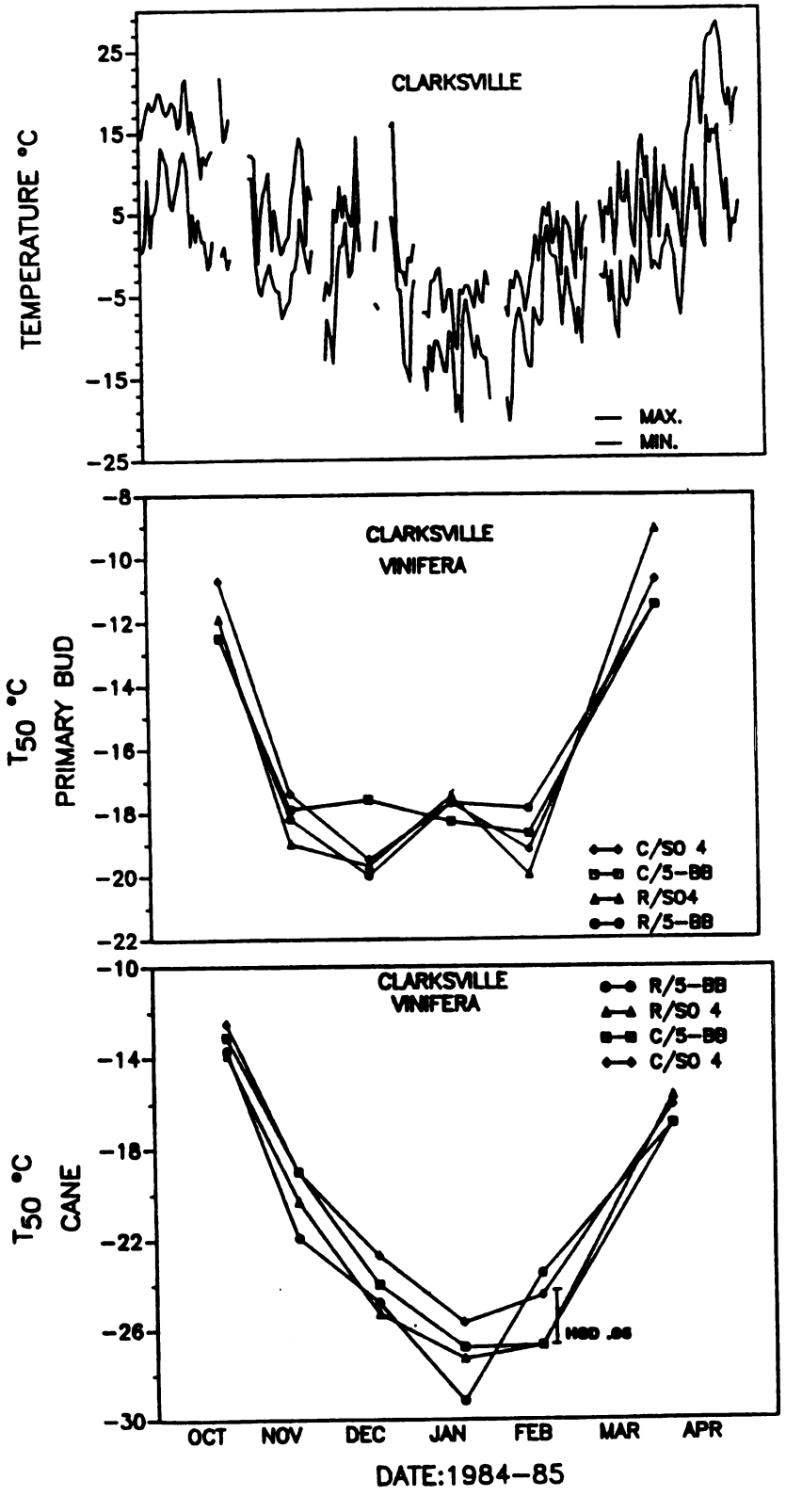

FENN VALLEY
TEMPERATURE °C
MAX.
MIN.
FENNVALLEY
SITE (II)
R/5-BB
R/3309
OWN ROOTED
T50°C
PRIMARY BUD
T50°C
CANE
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1984-85

Figure 4. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of White Riesling and Chardonnay grafted to the rootstocks K-5BB and SO4 during mid winter, October through March, at Site 2, 1984-85.


CLARKSVILLE
TEMPERATURE °C
25
15
5
-5
-15
-25
MAX.
MIN.
CLARKSVILLE
VINIFERA
T50 °C
PRIMARY BUD
-8
-10
-12
-14
-16
-18
-20
-22
C/SO 4
C/5-BB
R/SO4
R/5-BB
CLARKSVILLE
VINIFERA
R/5-BB
R/SO 4
C/5-BB
C/SO 4
T50 °C
CANE
-10
-14
-18
-22
-26
-30
HSD .05
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1984-85

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INTRODUCTION

Spring freeze damage is a major source of economic loss to the United States grape industry. In Michigan, spring freezes resulted in substantial crop reduction in 11 of 21 years between 1957 and 1977 (4). Damage from spring freezes can be minimized by careful site and cultivar selection (14). In addition, however, Johnson has shown that stage of phenological development is a critical factor in spring bud hardiness (5). The more advanced the bud is in its development, the less hardy it becomes. Hence, even a vineyard located on a very good site may suffer considerable damage from a late frost if the cultivar is early in bud burst.

Some researchers support the theory that time of spring bud burst is under the control of the buds (i.e. the scion) (1,10). Bachelard and Wightman (1) produced data that suggested the bud sent a hormonal ,signal' to the roots. The roots, upon receiving this ,signal', begin growth (i.e.water and nutrient uptake, cytokinin production). This causes an acropetal translocation of water, nutrients, and hormones which stimulates further growth in the bud. The validity of this hypothesis has not been proven to date. However, translocation between root and shoot is essential for the breaking of dormancy. Anything effecting the xylem then, could possibly alter the time of bud burst as well as growth. Lockard and Schneider (9,11) give a lenghty review of impedence of transport of growth regulators by various apple rootstocks and interstocks and, Perold (11) states that "sap flow" may be modified by a graft union. Given these facts, it is possible that grafting , in and of itself, may alter time of bud break. Additionally, one cannot exclude the possibility that genetically different rootstocks might also alter the time and rate of bud burst.

The questions to be addressed in this chapter are; 1) Do genetically different rootstocks differ in their time and rate of bud burst? and, if differences exist, 2) Are scions grafted to these rootstocks affected in their time and/or rate of bud burst?

MATERIALS AND METHODS

Sites

Site 1 was located at Fenn Valley Vineyards and Winery. This is situated at 42°35'N, 86°07'W, and at an elevation of 209m. Vines were planted in 1978 in North-South rows with a spacing of 2.8m betweeen rows and 1.8m between vines within rows. Vines were trained to a modified bilateral cordon at the bottom wire at a height of 4.5dm. Three treatments were used at this site; White Riesling growing on its own roots (OR), White Riesling grafted to Kober 5BB (R/5BB), and White Riesling grafted to Couderc 3309 (R/3309). Being located in a growers vineyard, the plot conformed to the planting. This gave a plot with one row of R/5BB containing three, five vine replicates; three rows of R/3309 each containing one, five vine replicate; and two rows of OR vines, one containing two, five vine replicates, the other containing one, five vine replicate. All vines were growing on a uniform Spinks sandy loam soil.

Site 2

Site 2 was located at Clarksville Horticultural Experiment Station, Clarksville, Michigan. It is situated at 42°52'N, 85°15'W, and at an elevation of 254m. Three sets of treatments were studied here. 1) Vinifera. Four year old Chardonnay and Riesling vines, each grafted to Kober 5BB and Selection Oppenheim No.4 were used to give four treatments (R/5BB, R/SO4, C/5BB, C/SO4). The vines were planted in North-South rows with 3.0m between rows and 1.0m between vines within rows and were trained to a low head at a height of 2dm. Five rows of

vines were planted in this block and the middle three rows were used in this study. Treatments were planted so that each treatment occured once in each row to give three replicates per treatment in a Randomized Complete Block Design. Five vines were chosen at random as data vines from each twenty five vine treatment replicate.

2) Seyval blanc. Two year old Seyval blanc grape vines grafted to Kober 5BB (S/5BB), Couderc 3309 (S/3309), Seyval (S/S), and growing on their own roots (OR) were used. Rows were oriented North to South and vines were spaced with 3.0m between rows and 2.4m between vines within rows and were in the process of being trained. Each treatment occured as two adjacent rows of vines. Fifteen vines were used for each treatment and each vine was considered as a replicate.

3) Marechal Foch and Vidal blanc. One and two year old vines of Marechal Foch and Vidal blanc were used. All possible graft combinations were made between the two cultivars to give four grafted treatments and two ungrafted treatments as follows; Foch/Foch (F/F), Foch/Vidal (F/V), Foch (F), Vidal/Vidal (V/V), Vidal/Foch (V/F), Vidal (V). Vines were planted in North-South rows with a spacing of 3.0m between rows and 2.8m between vines within rows. The vines were in the process of being trained onto the trellis. The plot was laid out as a Randomized Complete Block with three replicates and five vines per replicate.

Site 3

Site 3 was located at the Plant Pathology vineyard on the Michigan State University campus and was studied in 1982. It is situated at 42° 41'N, 84° 21'W, and at an elevation of 273m. Vines of the rootstock cultivars Couderc 3309 (3309), Kober 5BB (5BB), and Selection Oppenheim No.4 (SO4) were used. These were planted in East-West rows with a

spacing of 3.0m between rows and 2.8m between vines within rows. Vines were trained to a four arm Kniffin system. Each treatment occured in only one row so fifteen vines of each were used and each vine was treated as a replicate.

Data Collection

Canes used for data collection were prepared in the same manner for every treatment except those at Site 3. Canes at Sites 1 and 2 were cut to ten nodes and were tied in an upright position. One cane on each vine was used to give a total of 150 buds per treatment. Canes at Site 3 were cut to ten nodes but were not tied in any particular orientation. At this site, every cane left after pruning was used so numbers of buds per treatment varied. Data collection was at three and four day intervals. Phenological stages used were the same as those described by Proebsting et al. 1978 (12). Scale crack (SC), swell 1(S1), swell 2 (S2), and burst (B) used in this study correspond to Proebsting's scale crack, first swell, full swell, and burst. Only primary buds were used due to delayed expansion of secondary and tertiary buds. Since S1 is the first easily definable stage of development, it was used as the deliniation point for data analysis. All buds beyond S1 were calculated as a percentage of the total bud number for the treatment. These percentages were used in constructing the graphs in this chapter. Data analysis was performed using an R X 2 contingency table and Chi-square (5). Analyses were performed comparing numbers of buds beyond S1 and those that had not yet reached S1 between treatments.

RESULTS

Rootstock Cultivar Phenology

Data from the rootstock study showed that differences do exist in the time and rate of bud development between the rootstock cultivars (Figure 1). At every sampling date during the spring of 1982, 3309 was at a significantly more advanced stage of development than either S04 or 5BB. Data analysis showed 5BB and S04 to be essentially equal in time and rate of bud development. However, S04 was intermediate between 5BB and 3309 on 5-5-82 and, 5BB was significantly more advanced on 5-8-82 than S04 but significantly less advanced than 3309. By 5-15-82, S04 had again returned to a positon intermediate between 5BB and 3309. At this point nearly all buds had burst. At the point where 50% of the 3309 buds were beyond S1 (5-7-82), only 25% and 15% of the 5BB and S04 respectively had reached the same stage of development.

Grafted Vines

Data collected at Site 1 showed OR vines to be the most rapidly developing with R/3309 being intermediate and R/5BB developing the most slowly (Figure 2). SIgnificant differences were found on 4-27-85 and 4-30-85. OR vines were significantly more advanced in their stage of development than were R/5BB or R/3309. R/3309 was intermediate in its development. On 4-27-85 the buds on OR vines were 52% beyond S1 while the R/3309 and R/5BB were 35% and 25% beyond S1 respectively. On 4-30-85, 64% of the buds on OR vines were beyond S1 while R/3309 and R/5BB were at 46% and 25% respectively.

Clarksville

The Riesling at Site 2 developed at almost exactly the same rate on S04 and 5BB (Figure 3). The curves were nearly superimposed once the buds had reached 50% beyond S1. No significant differences were

found. However, the R/5BB vines did begin to develop at a faster rate. On 4-23-85, the R/5BB vines were at 27% beyons S1 while the R/SO4 were at 15%. After this, the rates converged. Chardonnay buds showed more rapid development on 5BB than on SO4 (Figure 4). Although only one siginificant difference was found (4-23), the C/5BB was always more advanced than C/SO4 until both had more than 95% of their buds beyond S1. Again, the significant difference on 4-23 showed that the C/5BB had begun to develop at a faster rate than the C/SO4 just as was observed for the Riesling treatments. The buds of the C/5BB were at 65% beyond S1 while those of C/SO4 were at 45%.

Seyval blanc

Grafted Seyval blanc vines showed slower development than ungrafted vines. The S/S vines were essentially the same as OR vines but the trend still persisted for the OR vines to develop more rapidly (Figure 5). One significant difference appeared between treatments on 4-27-85. At this point, S/3309 was least advanced, S/5BB was intermediate and OR vines were most advanced. S/S was intermediate between but not significantly different than OR and S/5BB. The differences in development on 4-27 were fairly large. OR buds were 80.5% beyond S1 while S/3309 buds were at 50% beyond S1. S/S and S/5BB buds were at 75% and 65% beyond S1 respectively. The development curves were essentially the same with the rate being effected by grafting onto various rootstocks. In this case, S/3309 showed the slowest rate of development throughout bud burst. S/5BB was somewhat faster but the curves converged at about 90% beyond S1. S/S was closer to OR than either S/5BB or S/3309 but it was still slightly slower. The curves for S/S and OR nearly converge at about the 90% level, and on the same date as the curves converged for those vines grafted onto

rootstocks.

Marechal Foch and Vidal blanc

Marechal Foch buds developed rapidly in each of the treatments (Figure 6). However, F was the slowest developing of the treatments until 4-30 when it reached 100% beyond S1 first. In this set of treatments, the grafted vines developed more rapidly than the ungrafted with F/V being the fastest. One difference found on 4-30 showed F/V to be significantly more advanced than either F/F or F. These treatments all had similar curves which were not changed greatly by grafting to Vidal blanc.

Data from Vidal blanc scions show grafting to slow the development of its buds (Figure 7). On every sample date, V was significantly more advanced than V/F and on all but one date (4-23), V was significantly more advanced than V/V. Buds of V were 36.5% beyond S1 on 4-23 while those of V/F were at 1%. Similarly, on 4-27, buds of V were 77.5% beyond S1 while V/F and V buds were 48.5% and 57 % respectively. The developement curves of grafted and ungrafted vines were of the same form, rate was the factor altered by grafting.

DISCUSSION

From the data presented, it is clear that the scion variety has the greatest amount of control over time of bud burst. Bachelard and Wightman (1) suggest that the scion controls time of bud burst. Luckwill and Whyte (10) also support this hypothesis. If this were indeed the case, one would expect all of the scions of a cultivar to develop at the same rate whether or not they were grafted. This is not the case. Early researchers gave evidence that the graft union slowed transport of metabolites in both xylem and phloem (11,13) creating a so called 'graft union effect'. Auxin being synthesized primarily in

shoot tips, (3) and translocating basipetally, is essential for cell elongation (among other processes) (16). Similarlly, cytokinin, produced primarily in the root (7) and transported in an acropetal direction, is essential for cell division and is associated with the regulation of protein synthesis. Auxin from the shoots was shown to be necessary for root growth (8) and cytokinin from the roots is known to be necessary for shoot growth (7,16). It seems obvious then that any impedence to the flow of these materials could inhibit plant growth. Data from Sites 1 and 2 support this theory. The grafted Riesling at Site 2 devloped more slowly than did ungrafted vines. Similarly, grafted Vidal blanc and Seyval blanc vines developed more slowly than ungrafted vines.

A second mechanism through which the roots might alter rate of scion bud development is water uptake and tissue rehydration. Wolpert (17) showed that tissue dehydration accompanies acclimation. It is also known that water relations are important in deacclimation since tissues must rehydrate before bud growth can begin (2). Roots, being the primary plant organ involved in water uptake, could alter the rate at which tissues rehydrate and subsequently bud burst if uptake were to begin at different times for different rootstocks.

If transport inhibition was the only factor affecting time of bud burst, one would expect all grafted vines to develop at the same rate. This, however, is not the case. Scions grafted to different rootstocks developed at different rates. This suggests that one or more root controlled phenomena are involved. Data from Riesling at Sites 1 and 2 and Chardonnay at Site 2 strongly support this since scion development on the rootstocks used parallels the relative rootstock rate of development. However, there appears to be more involved than a direct

rootstock effect. Seyval blanc vines developed at rates that did not follow the trend for the rootstock on which they were grafted. Similarly, Marechal Foch did not react as the previous hypothesis would have predicted. In fact, Marechal Foch developed most rapidly on the rootstock which would have been expected to begin growth the latest (i.e.Vidal blanc). This suggests some type of interaction between stock and scion. Research on apple has produced evidence that hormones (specifically Auxin) may be altered during transport in the rootstock (8,15). Lockard and Schneider (9) suggest that the dwarfing mechanism in apple is due to the effect of rootstock or interstock on Auxin which passes through it. Given this, it is apparent that the rootstock may exert subtle influences on growth. The effect on deacclimation will obviously be different than the effect on dwarfing, but the concept of genetically different rootsocks interacting in various ways with the scion appears valid.

CONCLUSION

Grafting of vines in and of itself influences the rate at which buds begin growth in the spring. The rootstock further influences growth suggesting a rootstock effect in addition to the graft union effect. This may be of importance in avoiding spring freeze damage when buds are beginning to develop and should be evaluated further to assess viticultural utility.

Figure 1. Percent of primary buds of rootstock cultivars K-5BB, C-3309, and S04 beyond swell-1, at Site 3, during the spring of 1982.

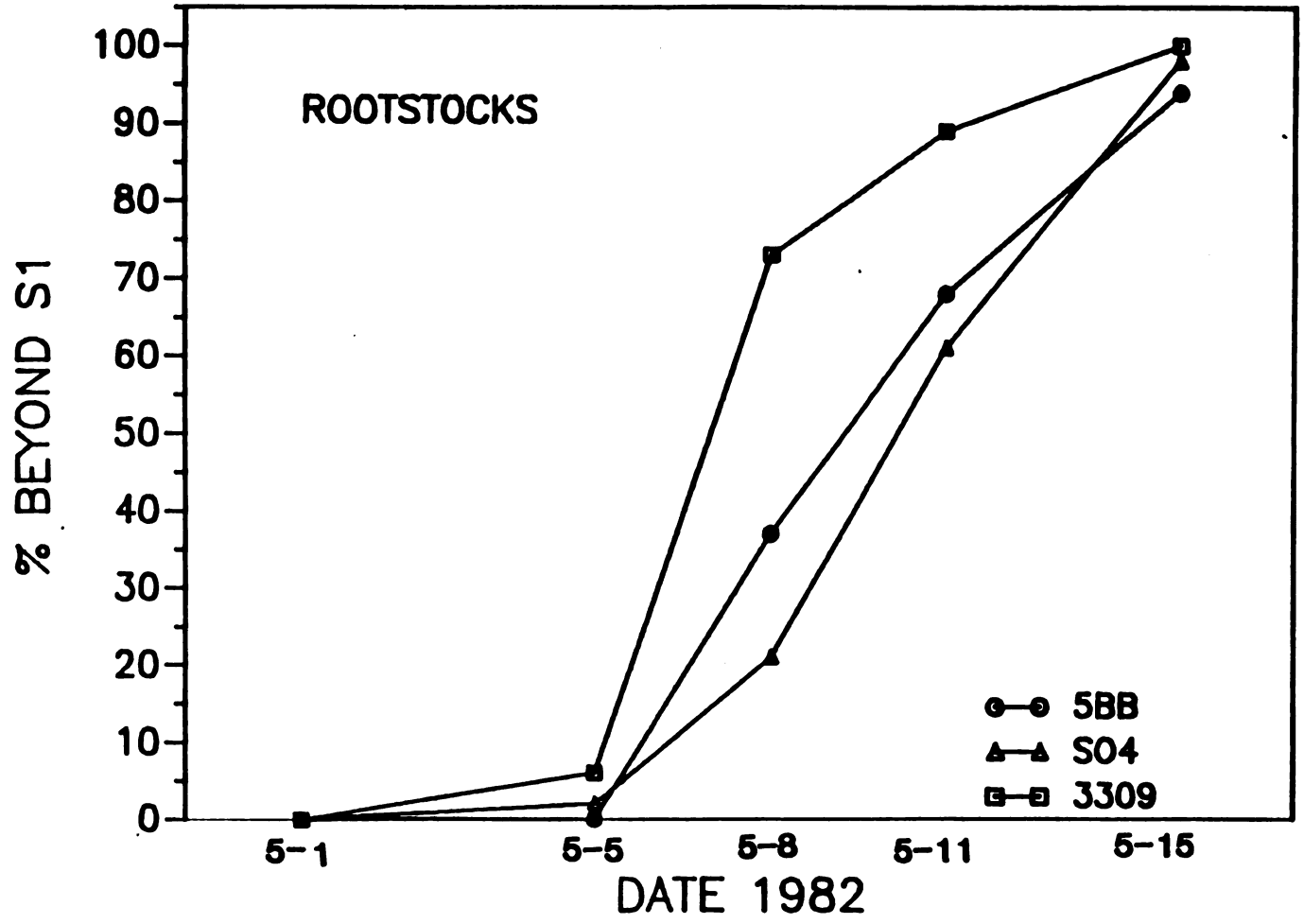
ROOTSTOCKS
% BEYOND S1
100
90
80
70
60
50
40
30
20
10
0
5-1
5-5
5-8
5-11
5-15
DATE 1982
5BB
S04
3309

Figure 2. Percent of primary buds of White Riesling grafted to K-5BB, C-3309, and growing on its own roots, beyond swell-1, at Site 1, during the spring of 1985.

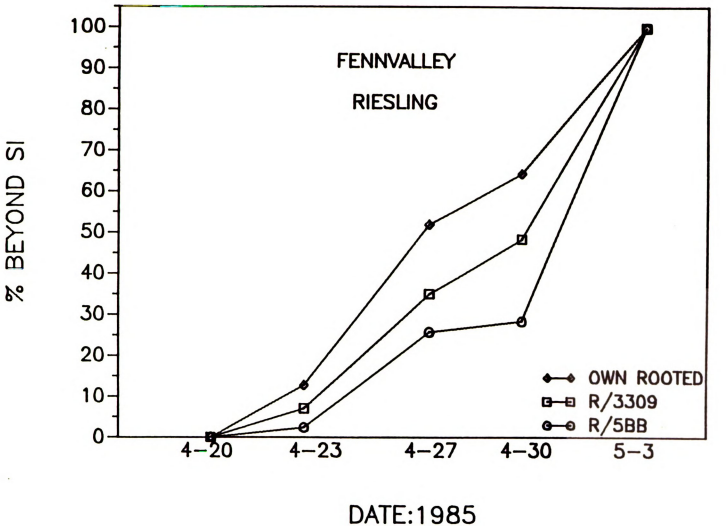
FENNVALLEY
RIESLING
% BEYOND SI
100
90
80
70
60
50
40
30
20
10
0
4-20
4-23
4-27
4-30
5-3
DATE:1985
OWN ROOTED
R/3309
R/5BB

Figure 3. Percent of primary buds of White Riesling grafted to K-5BB and S04, beyond swell-1, at Site 2, during the spring of 1985.

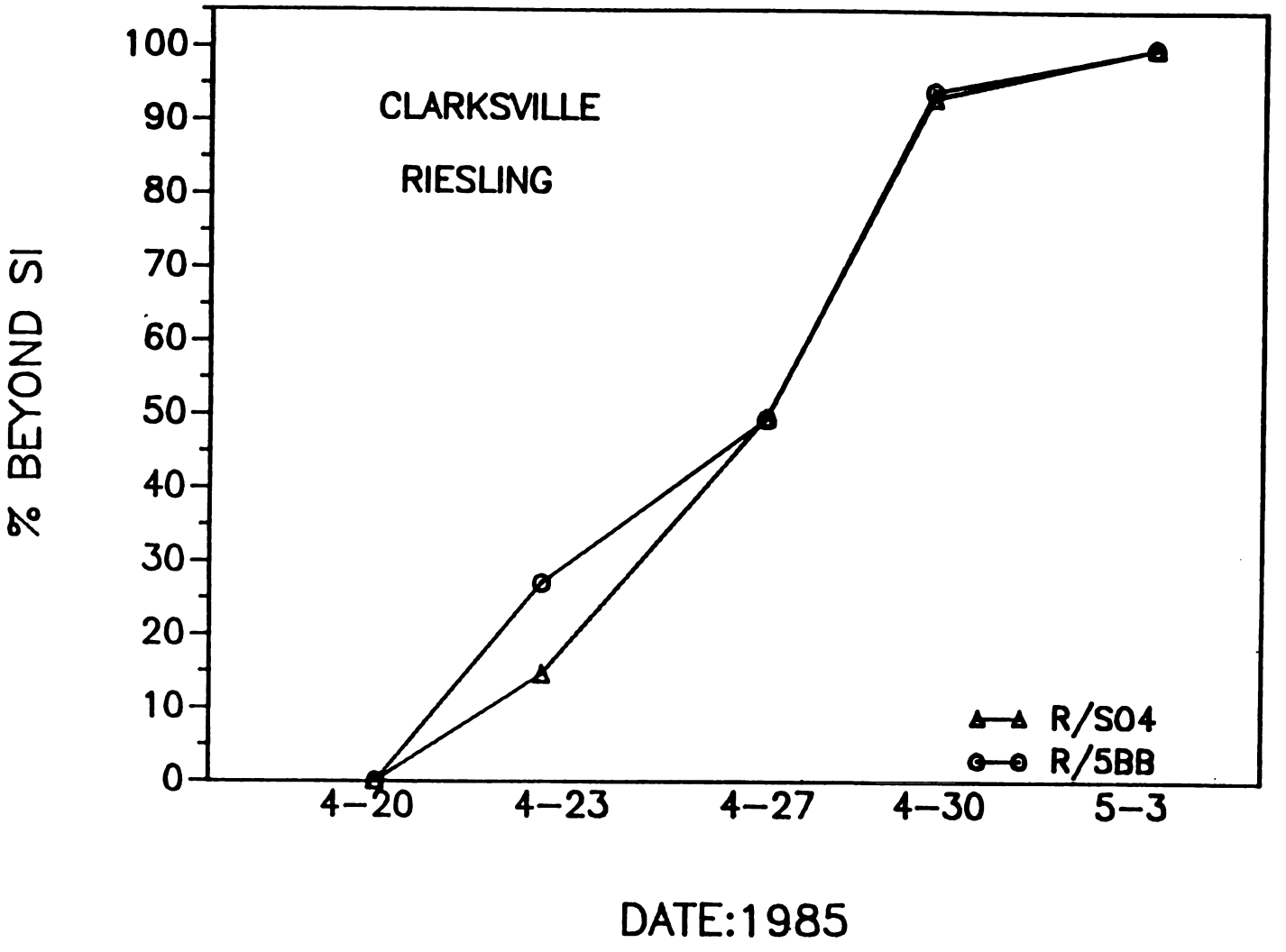
CLARKSVILLE
RIESLING
% BEYOND SI
100
90
80
70
60
50
40
30
20
10
0
4–20
4–23
4–27
4–30
5–3
R/S04
R/5BB
DATE:1985

Figure 4. Percent of primary buds of Chardonnay grafted to K-5BB and SO4, beyond swell-1, at Site 2, during the spring of 1985.

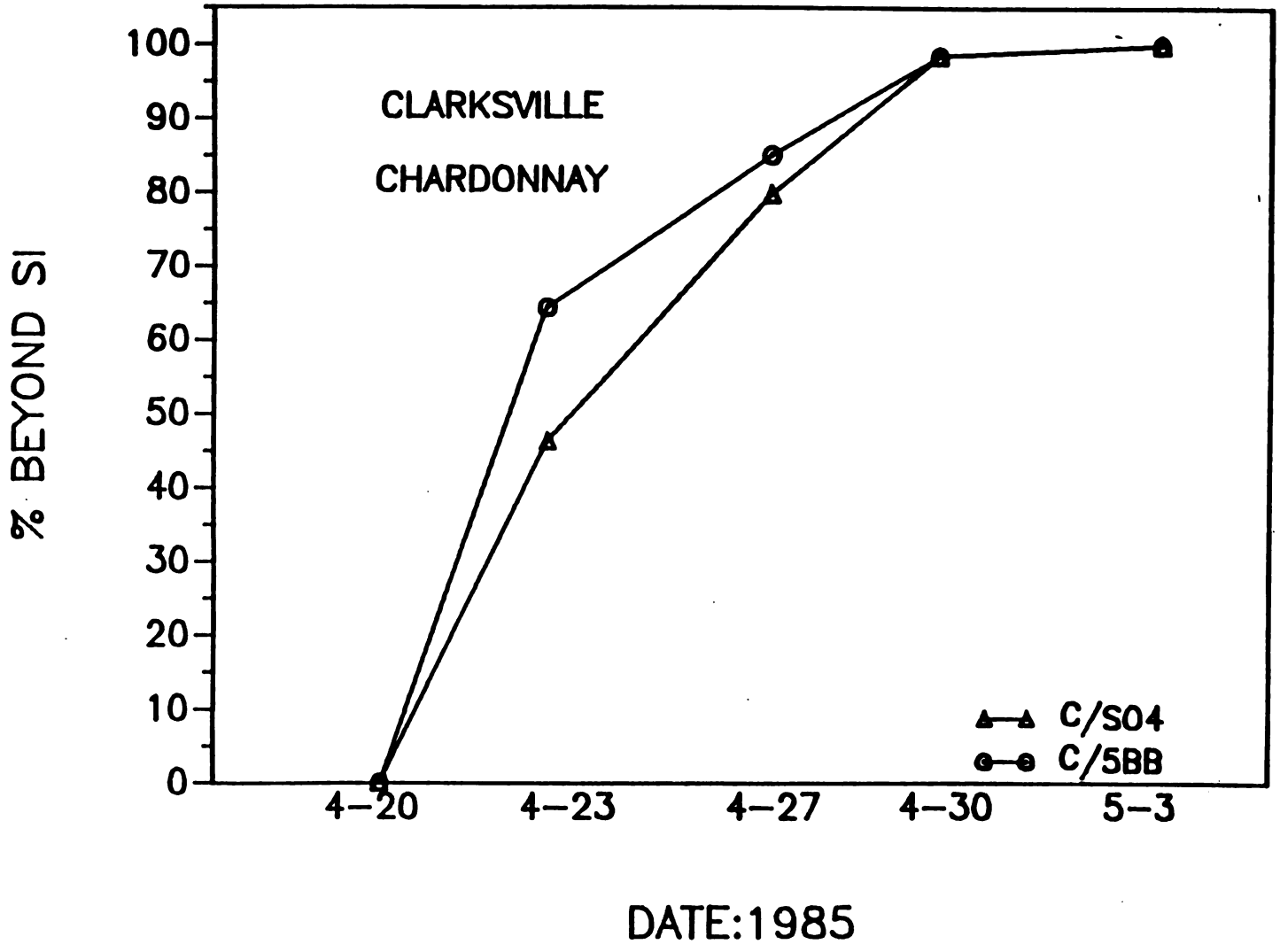
CLARKSVILLE
CHARDONNAY
% BEYOND SI
100
90
80
70
60
50
40
30
20
10
0
4–20
4–23
4–27
4–30
5–3
C/SO4
C/5BB
DATE:1985

Figure 5. Percent of primary buds of Seyval Blanc grafted to C-3309, K-5BB, Seyval Blanc, and growing on its own roots, beyond swell-1, at Site 2, during the spring of 1985.

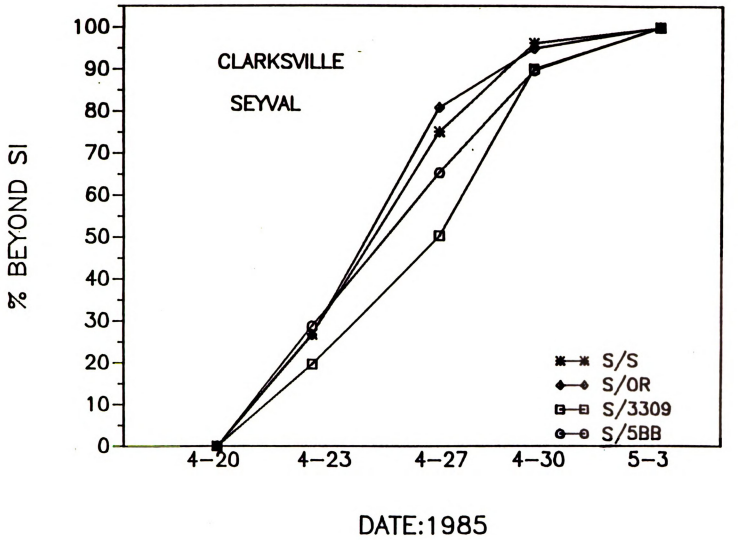
CLARKSVILLE
SEYVAL
% BEYOND SI
100
90
80
70
60
50
40
30
20
10
0
4-20
4-23
4-27
4-30
5-3
DATE:1985
S/S
S/OR
S/3309
S/5BB

Figure 6. Percent of primary buds of Marechal Foch grafted to Vidal Blanc, Marechal Foch, and growing on its own roots, beyond swell-1, at Site 2, during the spring of 1985.

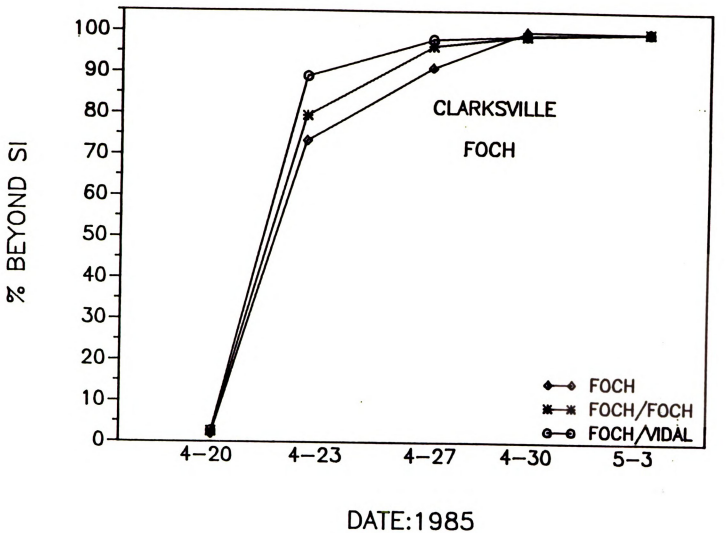
% BEYOND SI
100
90
80
70
60
50
40
30
20
10
0
CLARKSVILLE
FOCH
FOCH
FOCH/FOCH
FOCH/VIDAL
4-20
4-23
4-27
4-30
5-3
DATE:1985

Figure7. Percent of primary buds of Vidal Blanc grafted to Marechal Foch, Vidal Blanc, and growing on its own roots, beyond swell-1, at Site 2, during the spring of 1985.

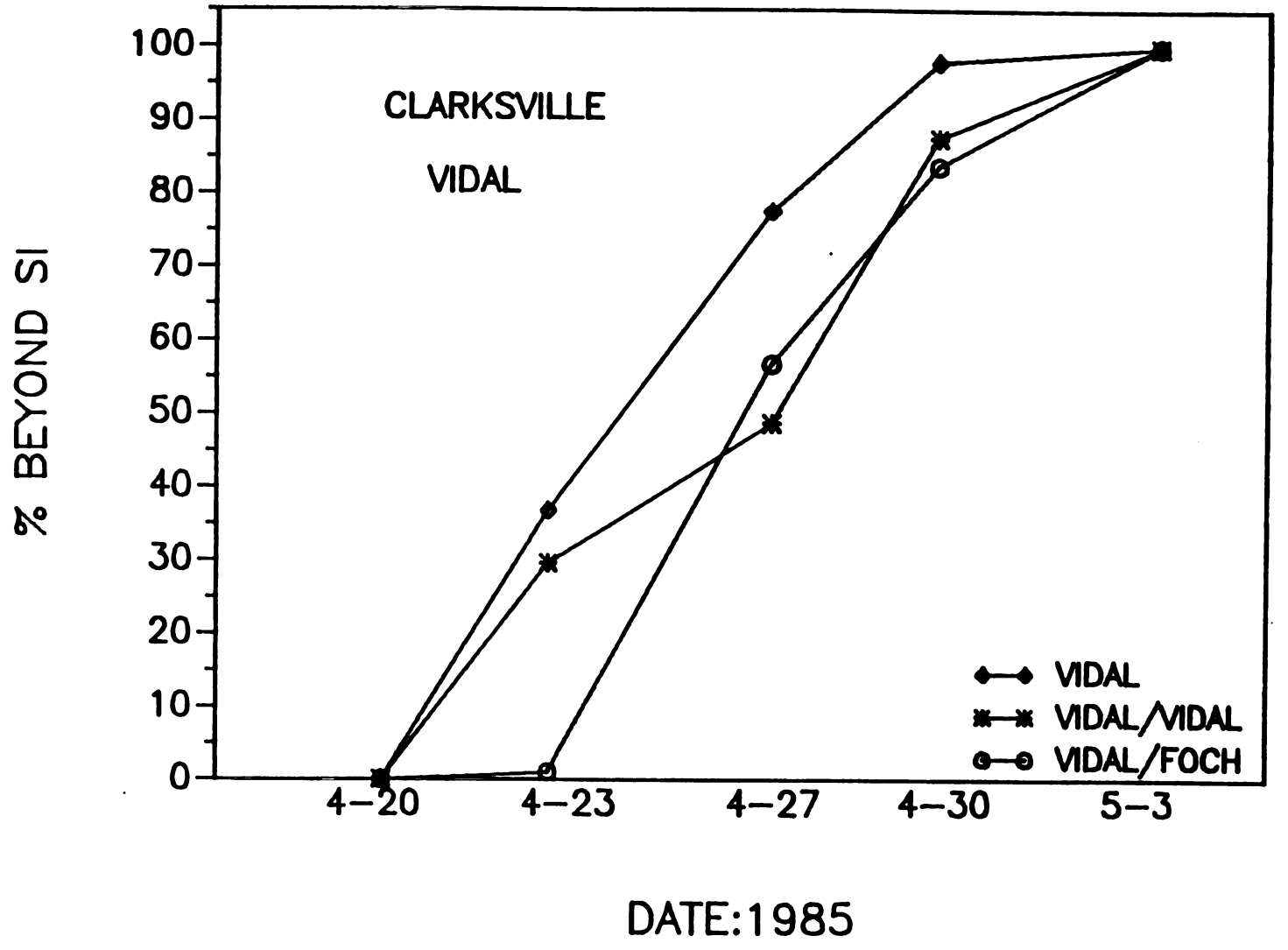
CLARKSVILLE
VIDAL
% BEYOND SI
100
90
80
70
60
50
40
30
20
10
0
4-20
4-23
4-27
4-30
5-3
DATE:1985
VIDAL
VIDAL/VIDAL
VIDAL/FOCH

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Figure 1. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of Seyval blanc grafted to C-3309, K-5BB, and Seyval blanc andgrowing on its own roots, during mid winter, October through March, at Site 2, 1984-85.

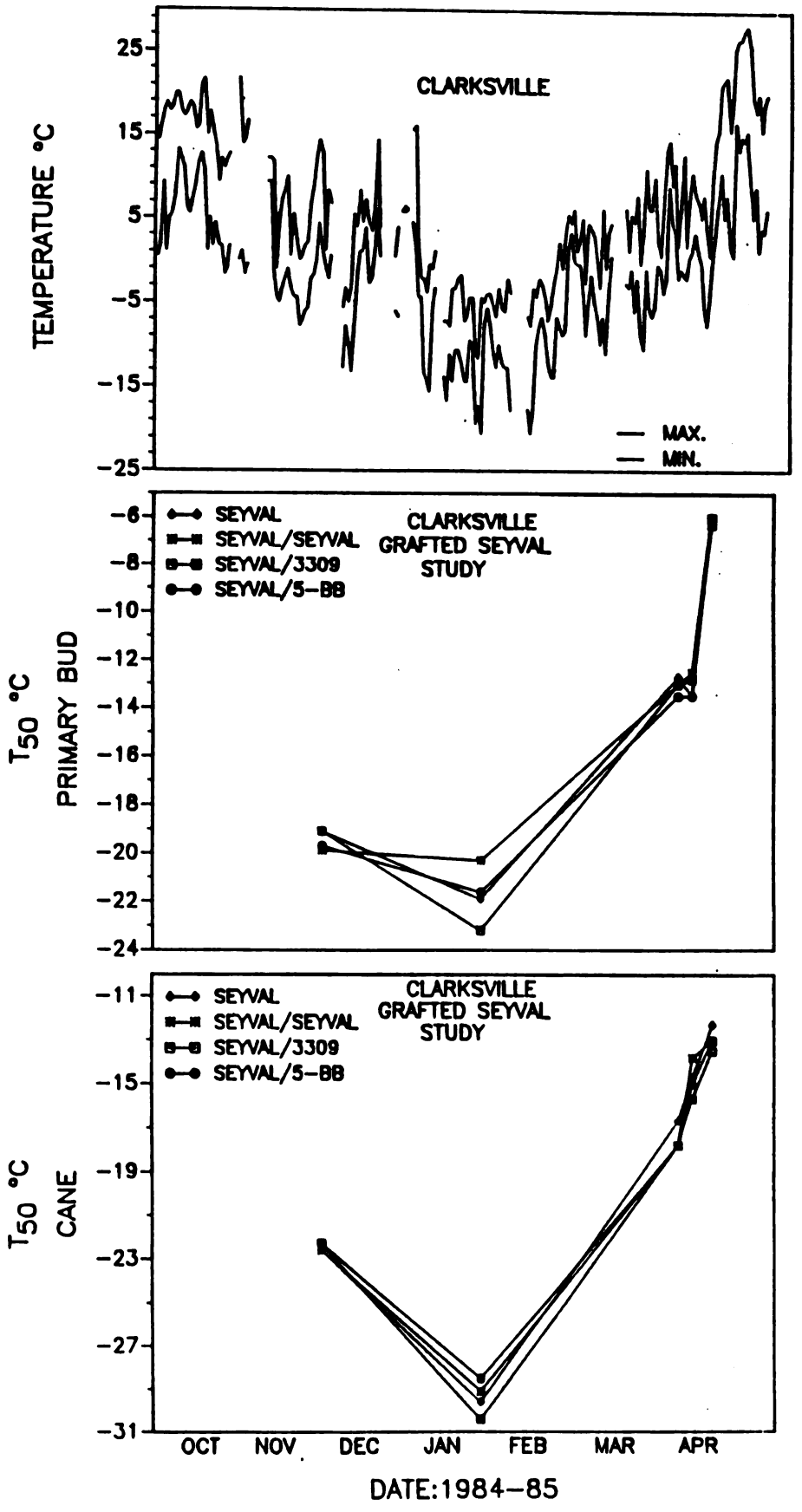
CLARKSVILLE
TEMPERATURE °C
25
15
5
-5
-15
-25
MAX.
MIN.
SEYVAL
SEYVAL/SEYVAL
SEYVAL/3309
SEYVAL/5-BB
CLARKSVILLE
GRAFTED SEYVAL
STUDY
T50 °C
PRIMARY BUD
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
SEYVAL
SEYVAL/SEYVAL
SEYVAL/3309
SEYVAL/5-BB
CLARKSVILLE
GRAFTED SEYVAL
STUDY
T50 °C
CANE
-11
-15
-19
-23
-27
-31
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1984-85

Figure 2. Max-min temperature profile and the cold hardiness (T50) of primary bud and cane tissues of Marechal Foch grafted to Vidal blanc and Marechal Foch, and growing on its own roots during mid winter, October through March, at Site 2, 1984-85.

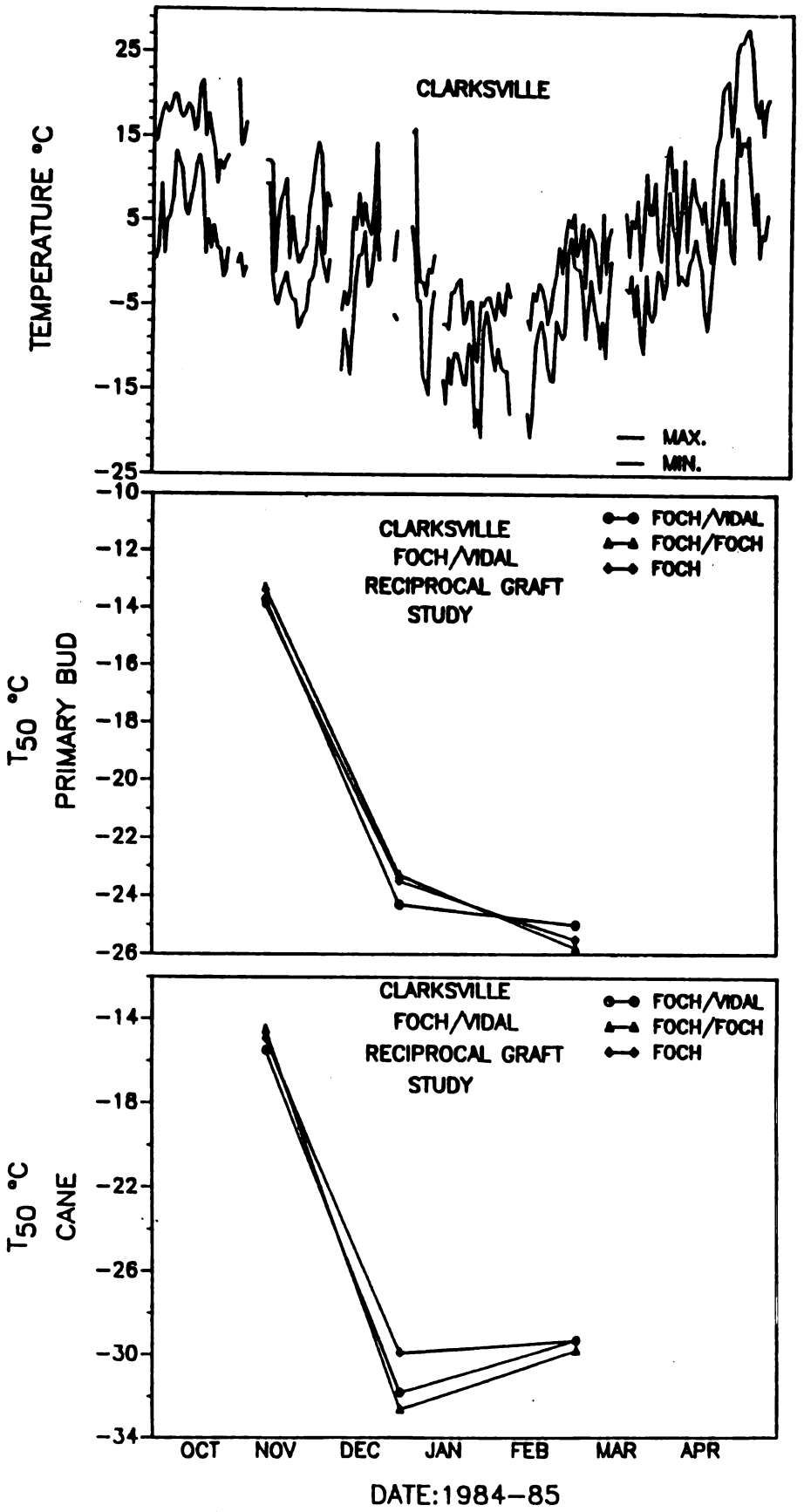
CLARKSVILLE
TEMPERATURE °C
25
15
5
-5
-15
-25
MAX.
MIN.
CLARKSVILLE
FOCH/VIDAL
RECIPROCAL GRAFT
STUDY
FOCH/VIDAL
FOCH/FOCH
FOCH
T50 °C
PRIMARY BUD
-10
-12
-14
-16
-18
-20
-22
-24
-26
CLARKSVILLE
FOCH/VIDAL
RECIPROCAL GRAFT
STUDY
FOCH/VIDAL
FOCH/FOCH
FOCH
T50 °C
CANE
-14
-18
-22
-26
-30
-34
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1984-85

Figure 3. Max-min temprature profile and the cold hardiness (T50) of primary bud and cane tissues of Vidal blanc grafted to Marechal Foch and Vidal blanc, and growing on its own roots during mid winter, October through March, at Site 2, 1984-85.

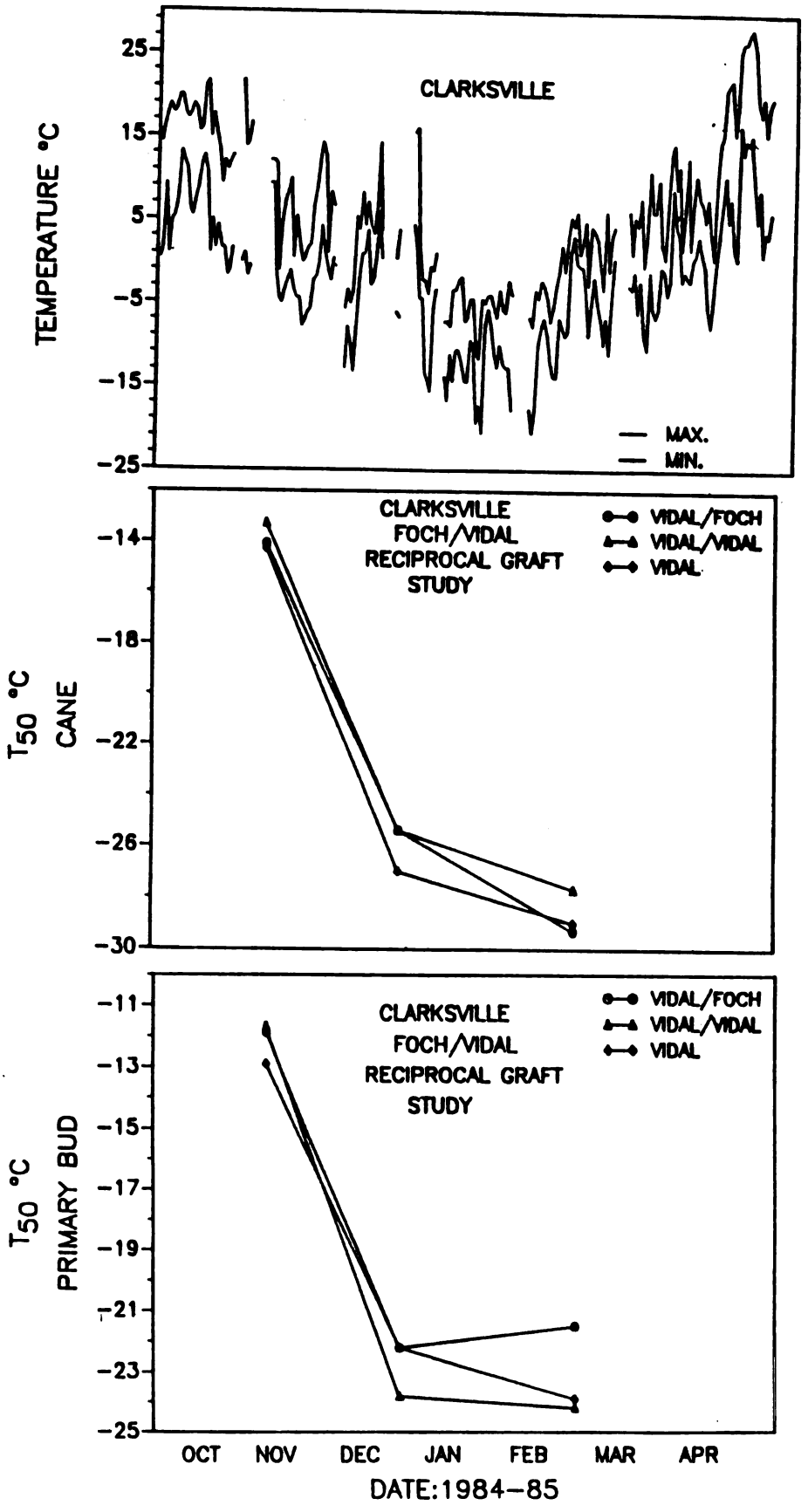
CLARKSVILLE
TEMPERATURE °C
25
15
5
-5
-15
-25
MAX.
MIN.
CLARKSVILLE
FOCH/VIDAL
RECIPROCAL GRAFT
STUDY
VIDAL/FOCH
VIDAL/VIDAL
VIDAL
T50 °C
CANE
-14
-18
-22
-26
-30
CLARKSVILLE
FOCH/VIDAL
RECIPROCAL GRAFT
STUDY
VIDAL/FOCH
VIDAL/VIDAL
VIDAL
T50 °C
PRIMARY BUD
-11
-13
-15
-17
-19
-21
-23
-25
OCT
NOV
DEC
JAN
FEB
MAR
APR
DATE:1984-85

Table 1. Harvest and fruit quality data for Site II White Riesling, from 1982 through 1984 and puning weights from 1982 through 1985.

HARVEST DATA

	150 Berry wt. (gms)		Yield (kg.)			Cluster #			Pruning wt. (kg.)				% Soluble Solids			Titratable Acidity			pH		
	82	83	82	83	84	82	83	84	82	83	84	85	82	83	84	82	83	84	82	83	84
R/588	202.1	219.0	2.33	4.15	4.09	47.3	60.1	39.3	0.77	1.21	0.64	0.66	20.2	18.8	16.2	1.42	1.03	1.06	3.21	3.53	3.26
R/3309	207.1	201.3	3.05	5.24	4.98	61.1	73.3	49.1	0.74	1.31	0.74	0.87	20.5	17.9	15.4	1.27	1.15	1.03	3.25	3.55	3.26
OR	194.5	219.3	4.75	5.71	4.50	77.4	73.9	38.4	0.46	0.88	0.37	0.55	18.4	17.0	15.4	1.34	1.15	1.12	3.11	3.42	3.15
					N.S.										N.S.						