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A STUDY OF THE ENVIRONMENTAL AND PHYSIOLOGICAL FACTORS INVOLVED IN PRODUCING HANGING BASKETS OF FRUITED GRAPEVINES FOR BEDDING PLANT MARKET SALES
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A STUDY OF THE ENVIRONMENTAL AND PHYSIOLOGICAL FACTORS INVOLVED IN PRODUCING HANGING BASKETS OF FRUITED GRAPEVINES FOR BEDDING PLANT MARKET SALES

By

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ABSTRACT

A STUDY OF THE
ENVIRONMENTAL AND PHYSIOLOGICAL FACTORS
INVOLVED IN PRODUCING HANGING BASKETS OF
FRUITED GRAPEVINES FOR BEDDING PLANT MARKET SALES

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Carol Lynne Hill Crankshaw

A production schedule was determined whereby fruited grapevines of Vitis 'Seyval' can be produced as hanging baskets for spring market sales in 9½ to 14 weeks at 25-30°C. Hardwood cuttings, dipped in IBA, rooted in 21 days at 28°C with bottom heat and intermittent misting. Twelve cultivars were evaluated; 'Seyval' and 'Chelois' produced clusters on 91.7% and 87.5% of the vines, respectively. SADH, CCC, BA and GA_3, sprayed on inflorescence and/or fruit clusters increased the number of fruit per cluster; GA_3 increased individual berry weight, volume and diameter. CCC produced the greatest number of berries. Three treatments proved superior: SADH (5000 ppm) at full bloom, SADH (2500 ppm) at full bloom plus GA_3 or BA 21 days later. Three levels of nitrogen and three levels of pH were tested. Plants produced using 300 ppm nitrogen had an increased number of fruit, increased foliar fresh weight and branching; but more necrotic lesions than at 100 ppm.

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INTRODUCTION

Hanging baskets of fruited grapevines are a potential addition to the bedding plant market. Hanging baskets provide an attractive and practical solution to people with limited gardening space. Since strawberry baskets and cherry tomato baskets are already popular products at many garden and retail centers, it is feasible that more crops could be adapted to hanging baskets in order to further broaden the bedding plant market. These baskets are a possible novelty item, with lush, green foliage and attractive clusters. Generally, a 10-inch basket containing four cuttings will provide three to six fruit clusters five to eight inches long.

LITERATURE REVIEW

Tendrils and inflorescences of grapevines both arise from the same primordia (45). Whether a primordium develops into an inflorescence or not is dependent upon many factors; such as presence of cytokinins, stage of root development, temperature and photoperiod.

The grape inflorescence arises from a compound bud. Each bud, which is borne on last year's cane growth, contains three buds, but usually only the primary and sometimes the secondary buds develop (75). The shoot and leaves appear first, followed closely by the pink-tinted flower bud in the case of 'Seyval.'

Rooting

Extensive research has been conducted to increase, hasten and improve rooting of grape cuttings. Various parameters have been investigated, including temperature, cutting size, storage and the effect of growth regulators.

Temperature

Temperature is a very important factor in the rooting of hardwood grape cuttings. A variety of temperature combinations have been investigated for rooting cuttings in the greenhouse; both air and soil temperatures influence rooting.

Hosoi (29) found increased rooting percentage and root number when cuttings were placed in soil heated to 25°C compared to either higher (30° and 35°C) or lower (15° and 20°C) soil temperatures. This experiment was conducted in an unheated greenhouse, so the air temperature was lower than the soil temperature; although, air temperature was not specified.

Malizewski and colleagues (38) compared cuttings rooted under mist with warm air temperature (21°C) and bottom heat to those rooted using cool air temperature (10°C) and bottom heat. The latter method was intended to retard budbreak which might result in delayed root initiation. However, the warm air method produced rooted cuttings up to two weeks earlier. Fujii and Nakano (24) reported that optimum rooting (higher rooting percentages and greater fresh weight) occurred with 'Delaware' cuttings using 21°C and 25°C bottom heat. They added that not only bottom heat, but also warm air temperature promoted budbreak.

They concluded that developing buds on the cuttings promoted rooting and removing these buds markedly reduced the number and percentage of roots.

Conversely, Mullins and Rajasekaran (41) describe a procedure for "pre-rooting" grape cuttings to allow adventitious root formation prior to budbreak. Cuttings were placed in heated perlite rooting medium (26°C) with cold (4°C) air temperature for three to six weeks. Buds remain dormant at this temperature until the rooted cuttings are potted up and moved to a 27°C (day temperature) greenhouse. "Pre-rooted" cuttings, combined with leaf removal, resulted in inflorescences at anthesis in 40 to 50 percent of the cuttings. The advantage of "pre-rooting" was attributed to the fact that leaf and shoot growth have an inhibitory effect on fruit cluster formation at budbreak. Floral differentiation, occurring at budbreak, requires cytokinins (54) which are synthesized in the roots of established plants (68). However, since budbreak precedes rooting, cytokinins become the limiting factor in floral differentiation. Expanding leaves are stronger sinks for endogenous cytokinins than new inflorescences (40); hence the atrophy and senescence of the developing floral bud prior to good root formation. Removal of these expanding leaves, therefore, increased the survival rate of newly-developing inflorescences.

Time of Collection/Dormancy

Alley and Christensen (6,7) found that dormant 'Thompson Seedless' cuttings taken in February, March or April and placed immediately in a rooting bed, rooted better than those refrigerated for more than two months. They reported that rooting refrigerated cuttings requires

an additional one to two weeks and that fewer and smaller roots are produced. In fact, 'Thompson Seedless' cuttings stored upside down in sand at 12 to 19°C have larger roots than those stored under refrigeration (0 to 3°C) or right side up or horizontally in sand. Mullins and Rajasekaran (41) stored cuttings for their fruited test-plants in sealed plastic bags at 4°C.

Cane Segment/Cutting Weight

Cane segment and cutting weight also determine how well rooting occurs. Cuttings from the basal third of dormant canes root more rapidly and higher percentage than either the middle or apical cuttings (65). Perhaps basal cuttings root better because they are often thicker and therefore contain more nutrient and carbohydrate reserves.

The number of roots per cutting increases with increasing initial cutting weight (29) regardless of temperature. When cuttings were compared weighing three, five and seven grams, the five- and seven-gram cuttings had the greatest number of roots. Also, heavier cuttings (seven grams) resulted in greater shoot growth (measured as dry weight) when compared to three- and five-gram cuttings.

Growth Regulators

The treatment of dormant, hardwood grape cuttings with growth regulators varies considerably with cultivar. Many experiments have been conducted using indole-3-butyric acid (IBA) to improve and/or hasten rooting. Hard-to-root cultivars such as 'Salt Creek' and 'Harmony' (4) have long been shown to benefit from IBA treatment. Singh (50) tested the effect of five concentrations of IBA on 'Perlette' (0, 500,

1000, 2000 and 4000 ppm). The 500 ppm dip gave over 10 percent more rooted cuttings than the control (0 ppm) and increased the number of roots.

This experiment was repeated (51) using 'Himrod' and 'Thompson Seedless' cultivars; no significant difference was found between treatments, although 500 ppm IBA did increase rooting by five percent. Additionally, IBA reduced the number of days required for callus and root formation of 'Dog Ridge,' 'Salt Creek' and 'Harmony'(8). In later experiments, IBA (5000 ppm) improved rooting of hard-to-root cultivars ('Salt Creek' and 'Dog Ridge') when placed in a 29.5^{o}C callusing box (5). The roots of 'Salt Creek' had smaller diameters, but the number of roots increased. With easy-to-root cultivars ('Ganzin 1' and 'Zinfandel'), IBA increased the number of roots as well as the size of 'Ganzin 1' roots. Likewise, IBA (1500 and 2000 ppm) increased the number of roots when applied as a quick dip to 'Cabernet Sauvignon' (41), but had no effect on 'Thompson Seedless,' which supports the results of Singh and Singh (51).

Recently, 15 cultivars were tested by Ehrlinger and Howell (22) to determine if IBA enhanced rooting. Rooting was graded on five levels from unacceptable to excellent, based on the number of roots present after six weeks in the mist bed. IBA (3000 ppm) was applied as a talcum powder dip (using Hormodin 2). Their results showed enhanced rooting in six of the 15 cultivars; among these are 'Chelois' and 'Seyval.'

Naphthaleneacetic acid (NAA) and abscisic acid (ABA) have also been shown to improve rooting (24). ABA (200 and 500 ppm) and NAA (25 and 100 ppm) increased the number of roots on 'Delaware' hardwood cuttings.

Applications of N-6-benzyladenine (BA) also increased the percentage of cuttings to root, but did not increase the number of roots per cutting.

Budbreak

Budbreak in dormant hardwood grape cuttings occurs up to 25 days prior to root initiation (64). This presents a problem as the inflorescence usually dehydrates and senesces if roots have not already formed prior to budbreak. Further, although budbreak is dependent upon date of collection, rooting is not (65). For example, cuttings taken in January and February had earlier budbreak than those taken in October, November and December. They concluded that the later the canes were taken from the vineyard, the more rapidly the buds broke.

Growth Regulators

One way to minimize inflorescence dehydration and abscission is to inhibit budbreak until after adventitious root growth. This can be accomplished with cold air temperatures or growth regulators. Several growth regulators have been tested and their effect on budbreak assessed. Two chemicals reportedly hasten budbreak, succinamic acid dimethyl hydrazide (SADH) at 2000 ppm and BA at 1000 ppm (70,74). However, others found that BA (500 ppm) did not affect budbreak (36). The discrepancies in these findings on the effects of BA on budbreak may be due to their methods of application as well as to the differing concentrations. The former investigators (70,74) applied BA to unrooted hardwood cuttings and the latter applied the chemical to two-year old potted vines.

Many other growth regulators, however, delay budbreak of hardwood grape cuttings. One of these is the auxin benzothiazole-2-oxyacetic acid (BOA) which was found to delay budbreak at concentrations ranging from 200 to 2000 ppm (70,74). NAA (68) and potassium gibberellate (KGA_3) (200 or 20C0 ppm) (68,70) also delay budbreak, as does Ethephon (2000 ppm) and ABA (1000 ppm) (70). Further, 2-chloroethyltrimethylammonium chloride (CCC) at 200 and 2000 ppm (70,74) delays budbreak in hardwood grape cuttings.

Gibberellic acid (GA_3) at 50 ppm not only delays budbreak, but also decreases the number of buds which do break (9). However, GA_3 does not affect budbreak on grapevines that have received 21 days of chilling; this indicates that chilling may counteract the retardation effect of GA_3 (36). However, the chilled plants in this case were two-year old potted vines rather than unrooted cuttings.

Temperature

Temperature also affects budbreak as shown by Mullins and Rajasekaran (41) who reported that bud opening and initial inflorescence growth occurred more rapidly at higher temperatures (33°C day temperature/28°C night). However, at this high temperature, continued bud development was abnormal; the bud shriveled and aborted after anthesis. Bud growth and development occurred normally at the temperature regimes of 24°C day temperature/19°C night, 27°/22°C and 30°/25°C with little difference between them. As expected, at lower temperatures, more days were required to budbreak.

Flowering

Anlagen are undifferentiated primordia formed at terminal or axillary apices during one season and differentiated into either tendrils or inflorescences prior to budburst the following season (55). Inflorescences and tendrils have been shown to be homologous (45,52). Anlagen that branch repeatedly develop into inflorescence primordia whereas tendrils are produced from anlagen which branch only once or twice (52). Grapevines produce numerous anlagen but few develop into inflorescences; most grow into tendrils (56).

Additional experiments show that BA affects other species as well. Treatments with BA promote inflorescence initiation and development in Bougainvillea 'San Diego Red' (23,46).

One aspect that affects branching is the presence or absence of kinins. The application of BA or 6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine (BTP) to isolated grape tendils *in vitro* resulted in inflorescence development by these tendrils (53). Later, cytokinins were applied to grapevines *in vivo* to convert tendrils to inflorescences (54). BTP was applied to shoot apices or to entire plants at various concentrations and lengths of time. BTP treatments to whole plants on alternate days for three weeks failed to convert tendrils into inflorescences. These inflorescences continued to develop into mature fruit. Srinivasan and Mullins (54) concluded that a continuous supply of cytokinins at the apex is necessary for flowering. Additionally, responsiveness to this technique depends upon the cultivar (56). They found that tendrils from male vines (*Vitis rupestris*) were more easily transformed than those of female or hermaphrodite vines, and that *V. vinifera*,

V. rupestris and their hybrids were more responsive than others.

Srinivasan and Mullins (55) further explored the effects of cytokinins, GA_3 and CCC on inflorescence formation of greenhouse-grown grapevines (V. vinifera). They found that all three compounds affect anlagen formation and tendril growth at any temperature and that GA_3 inhibited inflorescence production. They stated that GA_3 is involved in anlagen formation and elongation into tendrils. Exogenous application of CCC resulted in inhibition of anlagen formation and the growth of tendrils, yet promoted inflorescence formation from pre-formed anlagen or tendrils. CCC is known to be an inhibitor of GA_3 synthesis and may also act to enhance cytokinin production. Further, as expected, cytokinins applied to plants which had been pre-treated with CCC caused tendrils to convert into inflorescences.

Fruit Set, Size and Development

Buttrose (18) and Pratt (45) provide synopses of current knowledge regarding the anatomical and physiological aspects of bud development. The grape inflorescence is initiated in the summer preceding its flowering. The inflorescence occurs opposite a leaf bud in the same position as tendrils. Conditions dictate whether a tendril or flower primordium is formed from the meristematic tissue. For any cultivar, the number of fruiting primordia per bud can vary from season to season. This variation is due to climatic factors (18), cultural practices and disease.

The particulars of fruit set and development have not been studied extensively under greenhouse situations, although much research

has been conducted on field-grown vines. Many environmental and hormonal factors influence fruitfulness or yield. Fruit set and development are affected by pruning, nutrition, temperature, light, and the application of growth regulators.

Pruning

Pruning and its effect on yield have been researched primarily in the field (21, 32), so the information does not truly apply to greenhouse-produced plants.

Peterson and Smart (44) reported the effects of pruning 'Shiraz' grapevines at several stages of plant development. They reduced the vines to six and two leaves above the grape cluster at five stages of development. They found that the six-leaf pruning did not reduce yield (actually increased yield by the third year) while the two-leaf pruning was excessively harsh. Pruning at the time of inflorescence elongation had little effect on yield, although pruning done after that time was detrimental. This response was explained by the source-sink relationship and the demand for photosynthetic products (26).

Similarly, Buttrose (14) studied the effect of leaf removal on entire 'Gordo' grapevines. He reduced leaf area by removing the leaves below and opposite the fruit cluster and pruning off the apical part of the shoot until only one, three or six leaves remained. He maintained a constant leaf area, allowing no new growth. Berries on the pruned plants took longer to mature and had a lower fresh weight than berries on unpruned plants.

Kliewer and Antcliff (33) concluded that eight to ten square centimeters of leaf area is necessary to ripen and mature one gram of

fruit without decreasing sugar concentration. In their experiment, berry set occurred before defoliation. Pruning significantly reduced yields, with earlier and more severe defoliation causing greater reduction in berry weight and sugar content.

To produce fruiting grapevines in the greenhouse, Mullins (30) developed a technique whereby fruit set was improved through the removal of leaves below and adjacent to developing inflorescences. Leaves produced distal to the inflorescence were allowed to develop. He later improved on this method (41) by removing all leaves near the inflorescence at bud burst, excising the shoot tip, disbudding and pruning developing lateral shoots.

Growth Regulators

Gibberellins, cytokinins and auxins are involved with fruit set and growth (72). Many experiments on various fruits, including grapes, have shown that exogenous applications of auxins, cytokinins and gibberellins are quite effective in influencing fruit set, development and size (69,72). Research on various growth regulators began in the late 1940's. At that time, two auxins, 4-chlorophenoxyacetic acid (4-CPA) and BOA showed potential; and 4-CPA was used commercially (63). Applying 4-CPA to grape foliage increases cluster size, but results in very tight clusters which rot easily (66). BOA acts to delay fruit maturation (63) and has not been used commercially.

GA_3 is currently used on most 'Thompson Seedless' crops grown as dessert grapes to thin clusters, increase berry size, prevent berry shrivel and loosen clusters (63). Weaver and McCune (66) tested the effect of GA_3 sprayed onto grape foliage with the fruit clusters covered

which resulted in increased fruit size. Later, they dipped clusters or sprayed entire vines and clusters with GA_1, GA_3 or KGA_3 (5 to 500 pm) (67). All three chemicals resulted in increased berry size; and the clusters formed were looser and more elongated. No significant differences were observed between the effects of GA_1, GA_3 and KGA_3. This study also found that gibberellins applied at prebloom or full bloom resulted in the development of small, seedless berries.

Researchers have reported that GA_3 (5 and 10 ppm) applied during bloom increased fresh berry weights, but had no effect on the number of berries per cluster (31). Applying GA_3 at 100 ppm 11 days after full bloom to 'Concord' vines increased fruit set and the fresh weight of the clusters (13).

In summary, prebloom sprays of GA_3 loosen clusters by reducing fruit set and elongating the central rachis (62). While GA_3 applied at bloom produces loose clusters by reducing the number of berries set, it also causes increased berry size (19) and results in elongated berries (62).

Currently, Weaver (63) notes that the recommended vineyard procedure involves two GA_3 applications, one at full bloom (5 to 20 ppm) to thin the clusters, and the second (20 to 40 ppm) at fruit set to increase size of 'Thompson Seedless' (19). A third spray approximately two weeks after fruit set will further increase berry size (62).

Cytokinins have also been shown to increase berry size (71) and induce fruit set in V. vinifera (72). Experiments with BA and BTP applied either as a spray or dip to various V. vinifera cultivars increased the number of fruit per cluster and, in some cases, fruit size (73). Berries were progressively larger with increased cytokinin concentration

(0 to 1000 ppm). For example, BTP applied to 'Black Corinth' clusters increased berry size three- to four-fold. Since BTP is more soluble and mobile than BA, it is more effective in influencing berry size and set. Both BA and BTP applied at shatter (1000 ppm) resulted in an increase in berry size and number of 'Thompson Seedless' grapes. A mixture of BTP and GA_3 applied at full bloom produced the largest berries ('Black Corinth' and 'Thompson Seedless') and greatly increased the percentage of 'Thompson Seedless' fruit set (73).

Additionally, cytokinins affect fruit retention. Clusters of several cultivars were dipped in 1000 ppm BTP at full bloom. At shatter, the BTP-treated clusters dropped far fewer ovaries or berries than control (73). Rao (47) found that 500 ppm of BA significantly reduced post-harvest berry drop. Also, BA has reduced pre-harvest berry abscission (38).

In summary, exogenous applications of gibberellins usually act to induce fewer, but larger, elongated berries while cytokinins and auxins produce many small, round berries. Therefore, gibberellins likely affect fruit growth and development while auxins and kinins primarily affect fruit set (73).

Two growth retardants, SADH and CCC, influence set and yield of grape clusters. SADH increased 'Himrod' fruit set by 100% when sprayed at 2000 ppm just prior to anthesis (cap fall) (58). Likewise, SADH (500 to 1000 ppm) applied either at or before bloom to 'Concord' increased fruit set and yield (59). Also, 2500 and 5000 ppm SADH applied one to two weeks before anthesis increased the number of berries set per cluster in greenhouse-grown *V. labruscana* vines (42). Coombe (21) reported similar results with SADH on field-grown *V. vinifera*.

Another growth retardant, CCC, increases the number of flowers per inflorescence whether applied repeatedly as a spray or soil drench (43). Applications of CCC resulted in increased berry set, although the berries were smaller than normal (21). Fruit set and cluster weight increased in 'Himrod' using 750 to 1250 ppm CCC (12). CCC applied to field-grown vines 20 days before full bloom (1000 to 3000 ppm) and again 10 days later (1000 to 2000 ppm) gave the best results by reducing flower bud drop and increasing the total number of bunches per vine (11).

Photoperiod and Light

Light intensity and duration have various important effects on bud initiation and flower and fruit development. Bud initiation, in particular, has been the subject of extensive research and numerous publications. In 1972, Jackson and Sweet (30) wrote a summary on the general subject of flower bud initiation in temperate woody plants. Also, Buttrose (18) described the climatic factors that affect fruitfulness in grapevines. Bud initiation can be affected by vigor, nutrition, carbohydrate level, gravity, growth regulators, water stress, temperature, photoperiod and total light energy (18).

Fruit crops vary greatly in their response to daylength. Under eight hour days, blueberries form flower buds, but no vegetative growth occurs. Conversely, under 16 hours of light, vegetative growth takes place, but no flower buds are formed (27). On the other hand, apple flower bud initiation is stimulated by long days (25). In working with the effect of daylength on grapevines, vines of the cultivar 'Muscat Gordo Blanco' responded to daylength; vines grown under 16-hour days

were four times as fruitful as those grown under eight- or 12-hour days (15). A one-hour light interruption in a long night did not affect fruitfulness. However, an acceptable substitute for 16-hour days was 12 hours light/4 hours dark/4 hours light/4 hours dark. In 1970, Buttrose expanded his work to include four additional cultivars: 'Rhine Riesling,' 'Shiraz,' 'Ohanez' and 'Thompson Seedless.' Each cultivar responded differently to the various conditions, although 'Thompson Seedless' and 'Ohanez' were not fruitful under any of the experimental conditions. Plants were treated with either eight hours at 3,600 ft-c or 16 hours at 1,800 ft-c. 'Gordo' was one-third as fruitful and 'Rhine Riesling' was one-half as fruitful under eight hours of light compared to 16 hours. 'Shiraz' was not affected by this change and was found to be greatly dependent on light intensity for fruitfulness. Buttrose (17) concluded that grapevines likely do not respond strictly to daylength, but to the increased quantity of light available under long days.

Mullins and Rajasekaran (41) tested the effect of light on 'Cabernet Sauvignon' grape cuttings. There were five treatments: 1) natural greenhouse illumination (spring and summer), 2) greenhouse, with shade applied to inflorescences and leaves, 3) growth chamber with continuous illumination, 4) growth chamber with eight hour days (short days) and 5) growth chamber with 16 hour days (long days). The inflorescences of plants which were shaded or kept under continuous illumination abscised. At least 70 percent of the inflorescences survived to anthesis in all other treatments. However, fruit production (number of berries per cluster) was greater under a 16-hour photoperiod with high light intensity.

Temperature

Temperature plays an important role in inflorescence and berry development; although, the effects of temperature are closely interrelated with light intensity. In an experiment in 1958, Tukey (57) studied the effects of temperature on berry development. His temperature treatments began at bloom and continued for 10 or 13 days. The berries grown at 26°C and 28°C exhibited fastest daily growth and maximum berry size. However, temperatures as high as 32°C reduced berry growth, perhaps as a result of another limiting factor such as water or carbon dioxide. Further, he found that an optimum temperature regime involved a 28°C night temperature for the first eight days and thereafter a night temperature of 22°C. Maximum growth was achieved when the average day temperature was 23.5°C. In general, increased night temperatures for 10 to 13 days after flowering increased the rate of berry enlargement.

Studies by Alexander (1) were designed to determine if high temperatures were responsible for poor fruit set. He found that high night temperatures (19° to 25°C) favored rapid shoot growth; but had little or no effect on fruit set. He suggested that a loss of fruit set under high temperatures was due primarily to moisture stress. Woodham and Alexander (2) kept the roots of 'Thompson Seedless' at 11°, 20°, or 30°C with a common air temperature. Increased root temperatures improved the growth of roots, inflorescences and shoots.

Grapevines grown in growth chambers remained barren after 13 weeks of temperatures under 20°C, but were fruitful at temperatures between 25° and 35°C (16, 17). Buttrose concluded that temperature affected rate of bud development as well as the actual number of bunch

primordia differentiated. However, there was a light/temperature interaction. Below 1800 ft-c, temperature exhibited little effect on primordia weight; however, at higher intensities the effect was significant. The optimum temperature for grape leaf photosynthesis has been shown to be between 25° and 30°C (35, 37).

"Pre-rooted" cuttings of 'Cabernet Sauvignon' were grown under four temperature regimes: 25°C day/19°C night, 27°/22°C, 30°/25°C, and 33°/28°C with natural greenhouse light (41). At 33°/28°C, bud opening was quicker than at lower temperatures, but the inflorescences grew abnormally and soon dehydrated and died. At the other three temperature regimes, no real differences in inflorescence growth occurred. However, plants grown at 27°/22°C produced the greatest number of berries per cluster.

Using scanning electron microscopy, Srinivasan and Mullins (52) showed that anlagen (undifferentiated primordia) on vines grown at high temperatures (33°C day/28°C night) formed inflorescence primordia. Vines grown at lower temperatures (21°/16°C and 18°/13°C) contained anlagen that grew into tendril, rather than inflorescence, primordia. This leads to the conclusion that temperatures between 25° and 30°C result in superior fruit set. Temperatures higher than 30°C are detrimental and those under 20°C result in vegetative growth.

Greenhouse Container Viticulture

Grapevines are generally propagated from dormant, hardwood cuttings which, even under favorable growing conditions, may not produce fruit the first year. In 1963, Alexander and Woodham (3) developed a

procedure to produce, for experimental purposes, small plants which bear fruit in their first year. They succeeded in producing mature fruit on 60 percent of the 'Thompson Seedless' vines propagated by air layering. However, air layering proved too time consuming and costly when large numbers of plants were desired.

By removing all leaves below the inflorescence, Mullins (39) produced small experimental plants with fruit clusters from one-node cuttings from one-year old vines in 12 weeks. Having determined that the inflorescence frequently abscised if leaf removal did not occur, he theorized that abscission may be due to the inability of the inflorescence to compete with adjacent leaves for nutrients. Leaf removal allowed the inflorescence to develop normally, although the fruit clusters were considerably smaller than vineyard-produced clusters.

Mullins published a revised method in 1981 (41) in which he reported the effects of "pre-rooting," temperature and light on inflorescence growth and fruit set of many Vitis cultivars. Cuttings were rooted in a heated container (26^{o}C) in a 4^{o}C room (buds remained dormant). In four weeks, the cuttings were potted and moved to a greenhouse (27^{o}C day and 22^{o}C night temperature) with 16-hour photoperiod. Leaves below and adjacent to the inflorescence were removed at budburst and the shoot tip was excised. Consequently, ripe fruit (about half normal size) was produced in 16 to 18 weeks on 30 to 50 percent of the vines.

Alexander (2) rooted softwood cuttings in a heated mist bench. These cuttings were grown on in the greenhouse, and 25 percent produced fruit which ripened two months earlier than field vines. In 1979, Robitaille and Janick (48) reported rooting softwood cuttings of 'Seyval' after fruit set had occurred. They describe a method for producing

grapevines with small clusters in eight weeks by rooting softwood cuttings with developing fruit in a mist bench.

Malizewski et al. (38) reported a preliminary study on producing fruited grapevines in hanging baskets. They evaluated the performance of three Vitis cultivars: 'Seyval,' 'Concord,' and 'Vignoles' and compared two rooting methods: 1) 21°C air temperature with bottom heat in a mist bench, and 2) 10°C air temperature with bottom heat in a growth chamber. The latter method was intended to reduce or prevent budbreak and allow root initiation. IBA (Rootone) was applied to both treatments. 'Seyval' required three to seven weeks at 10°C from stick to transplant and three to five weeks at 21°C. 'Vignoles' took five to ten weeks at 10°C, but only four to seven weeks at 21°C. Overall, cuttings with warm air in the mist bench rooted faster, leafed out more rapidly and were considered "further along" when planted in the hanging baskets.

Of the three cultivars evaluated, 'Seyval' showed the best potential. 'Vignoles' failed to flower; and while 'Concord' produced a few fruit clusters, its leaves and growth habit were too large for a 10-inch basket. The time required for 'Seyval' from stick to pea-sized fruit was 13 to 14 weeks.

Since berries on the 'Seyval' clusters oftened abscised prematurely, BA was applied to the young clusters to prevent abscission. After pruning, secondary growth developed, containing new flower clusters.

This experiment raised many questions. Additional clusters need to be investigated, particularly table grape and seedless cultivars with compact growth, early fruiting and attractive foliage. Improving rooting uniformity and decreasing rooting time are also important.

OBJECTIVES

The objective of this study is to develop the techniques necessary to produce grape baskets for the spring bedding plant market. According to preliminary work at Michigan State University (38), the Vitis hybrid 'Seyval' was the most promising cultivar tested for hanging basket culture. Thus, experiments were conducted to determine optimum practical greenhouse production techniques using 'Seyval.' Elements of production tested include: determining proper rooting procedures, enhancing fruit set and development, determining nutritional and environmental requirements and pruning needs, as well as cultivar trials and production time scheduling.

Specific objectives of this study are as follows:

1) To determine optimal rooting procedures and temperatures for hardwood cuttings of 'Seyval' and to reduce the number of days required for rooting.

2) To determine if inhibiting budbreak with various growth regulators will improve fruit set of 'Seyval.'

3) To enhance cluster appearance by improving fruit set, size and retention of 'Seyval' by using various growth regulators.

4) To determine the correct fertilization and soil pH levels necessary to produce healthy, fruit-bearing 'Seyval' grapevines.

5) To determine which cultivars can be easily adapted to this technique.

6) To develop a step-by-step production schedule to enable growers to produce fruited grapevines in hanging baskets for spring marketing.

SECTION ONE:

THE EFFECT OF ENVIRONMENTAL CONDITIONS AND GROWTH REGULATORS ON ROOTING TIME AND BUDBREAK OF *VITIS* HYBRID 'SEYVAL'

THE EFFECT OF ENVIRONMENTAL CONDITIONS AND GROWTH REGULATORS ON ROOTING TIME AND BUDBREAK OF *VITIS* HYBRID 'SEYVAL'

Introduction

Production time can be minimized by reducing the time necessary to root cuttings. Extensive research has been reported on all aspects of rooting. Of interest in this trio of experiments are the effects of temperature, growth regulators and cutting size on ease of rooting. Warm temperatures hasten rooting (7), but temperatures above 35°C impair rooting (29). Heavier cuttings produce an increased number of roots and greater shoot growth (29).

The effect of growth regulators on root initiation varies widely with cultivar. Dozens of experiments conducted using indolebutyric acid (IBA) show excellent results with some cultivars and poor results with others. Ehrlinger and Howell (22) tested the effect of IBA on rooting of 15 cultivars. 'Seyval' was one of the six cultivars listed as benefitting from IBA treatments. Additionally, naphaleneacetic acid (NAA) improves rooting (24).

It has been reported that budbreak occurs up to 25 days prior to root initiation (64) which encourages inflorescence dehydration and senescence. Inflorescence survival might be enhanced if budbreak was delayed until after root growth occurs.

Material and Methods

Three rooting experiments were conducted to determine the optimum rooting procedures for 'Seyval' hardwood cuttings. Experiment I was a factorial experiment, comparing various humidity conditions and various growth regulators. Experiment II compared two different temperatures for rooting. Experiment III compared the effect of various growth regulators on budbreak, and consequently rooting and fruit set.

In all three experiments, dormant hardwood cuttings (eight nodes) of one-year old canes were collected from mature 'Seyval' vines at Tabor Hill vineyards in southwest Michigan. Cuttings were taken on December 15, 1980 and placed in plastic bags containing moist paper towels under 1.5° to 2°C refrigeration. The wood was prepared as two-node cuttings, cut just below the basal node and two to three centimeters above the upper node, in late January for Experiment I and early March for Experiments II and III. Cuttings were chosen from wood free of visible disease and injury.

Experiment I

These two-node cuttings were divided into three weight groups: light (2.0-3.4 grams), medium (3.5-5.4 grams) and heavy (5.5-15.8 grams). Immediately before planting the cuttings in sand, they were dipped into one of the treatment solutions to a depth of three cm. for five seconds. A total of 288 cuttings were used: one-third placed in each of the following conditions: under intermittent mist, covered with clear polyethylene tents or in the greenhouse with no other environmental treatment. Within each of these treatments, one-quarter (72) were dipped in 500 ppm

indolebutyric acid (IBA), one-quarter in 250 ppm naphthalene-acetic acid (NAA), one-quarter in 500 ppm iron chelate (Sequestrene 330 Fe, Ciba Geigy, 10% active ingredient) and the remainder in deionized water. Cuttings were placed 6.5 centimeters deep in flats of moist sterilized sand and placed on heating mats (25°C) in the greenhouse under their respective environmental treatments. All flats were placed in the same greenhouse at an air temperature of 22°C. Soil thermometers were used to monitor soil temperature in each flat. Misting occurred for six seconds every 15 minutes during daylight hours using deflection nozzles. All flats were watered as needed by drenching the soil with deionized water.

Each cutting was checked daily for root formation and then carefully replaced. Cuttings were recorded as "rooted" when one millimeter of root was visible. Days to various bud stages were also recorded. After 48 days, data on leaf and root number and surface area were collected. Roots were rinsed in a pail of tepid water before being run through a leaf area meter. Leaves were removed from the vine and measured; no stems or flower clusters were included in leaf surface area.

Experiment II

Cuttings were prepared as in Experiment I, although only those weighing between 5.0 and 10.0 grams were chosen. All cuttings were dipped in a powder formulation of 3000 ppm indole-3-butyric acid (Hormodin 2) and placed five cm. deep in moist vermiculite-sphagnum peat-perlite mix (VSP). Half of the cuttings (30) were placed in an 21 ± 2.5°C air temperature greenhouse with 26.5 ± 2.5°C bottom heat, while the remainder were placed in a 30 ± 3°C air temperature with 32 ± 2.5°C bottom heat.

All cuttings were misted (six seconds every 15 minutes).

All cuttings were checked daily for root initiation. After 40 days, roots on all were counted, the longest root measured, and all rooted cuttings were transplanted to six-inch clay pots containing the same vermiculite-peat-perlite medium and placed in a 24°C greenhouse. They were fertilized with 200 ppm liquid 20-20-20 N-P_2O_5-K_2O (Peter's General Purpose soluble fertilizer; with analysis of 5.61% nitrate nitrogen, 3.96% ammonium nitrogen and 10.43% urea, 20% phosphoric acid, 20% soluble potash) at every other watering and checked daily until the inflorescence reached post-bloom stage or abscised.

Experiment III

Cuttings were prepared as in Experiment I and only those weighing between 4.5 and 10.0 grams were used. Growth regulators were applied by spraying the entire cutting just prior to placing it in the flat. Treatments involved treating 15 cuttings (total of 105) with each of the following chemicals: 2500 ppm N-dimethylamino-succinamic acid (SADH), 150 ppm 2-chloroethyltrimethylammonium chloride (CCC), 100 ppm α-cyclopropyl-α-(p-methyoxyphenyl)-5-pyrimidinemethanol (A-Rest$^{(R)}$), 100 ppm gibberellic acid (GA_3), 250 ppm naphthaleneacetic acid (NAA), 100 ppm gibberellins A4/A7 ($GA_{4,7}$) and deionized water. Flats were filled with moist media containing a 1:1 ratio of peat and perlite; cuttings were inserted to a depth of approximately six centimeters. All flats were placed in a 30 $\pm$ 3°C greenhouse with bottom heat (32 $\pm$ 2.5°C), without mist. Data were collected each day by pulling up each cutting until roots had formed. Data were taken on days to root, days to callus formation and days to various bud stages.

Results

Experiment I

Number of Days to Root: Large cuttings (5.5^{+} grams) required significantly more days to root than the medium or small cuttings, regardless of environmental or chemical treatment, with no difference in days to root between small and medium weight cuttings (Table 1).

Cuttings placed under polyethylene tents also required significantly more days to root than those under mist or greenhouse conditions (Table 2).

Of the chemical treatments, control and NAA-treated cuttings rooted significantly earlier than Fe- or IBA-treated ones. IBA-treated cuttings took almost nine days longer than H_2O. There was no significant difference in days to root between NAA and control or between Fe- and IBA-treated cuttings (Table 3).

The interaction between environment and chemical was significant at the 5% level using Duncan's Multiple Range test. NAA-treated cuttings placed in the greenhouse (NAA/greenhouse) were earliest to root, though not significantly earlier than H_2O/greenhouse treatment. However, cuttings treated with Fe/greenhouse required over eight days longer than NAA/greenhouse cuttings. The IBA/polyethylene treatment required the greatest number of days to root, rooting 18 days after the NAA/greenhouse treatment. All three Fe treatments were among the slowest to root (Table 4).

Number of Days to 50 Percent Rooted: There was no significant difference in days to 50 percent rooted based on cutting size or environment. However, the small cuttings did require an extra seven days

Table 1. Influence of cutting weight on rooting of Vitis hybrid 'Seyval.'[z]

Cutting[x] Size	Number of[y] Days to Root	Percent[y] Rooted in 29 days	Total[y] Percent Rooted in 45 days
Small	24.2 a	93.9 c	95.9 b
Medium	24.7 a	77.3 b	91.8 b
Large	27.6 b	55.5 a	80.3 a

[z]Cuttings planted in the greenhouse, 22°C air temperature with 25°C bottom heat and misted six seconds every 15 minutes.

[y]Data is mean of 288 cuttings.

[x]Small cuttings weighed 2.0 to 3.45 g; medium 3.5 to 5.4 g; and large, 5.5 to 15.8 g.

Mean separation in columns by Duncan's Multiple Range test at the 5% level.

Table 2. Influence of propagation method on rooting, budbreak and inflorescence presence of dormant hardwood cuttings of Vitis 'Seyval.'

Propagation[z] Method	Days to[y] 50% Root	Number of[y] Days to Root	Percent[y,x] Rooted	Number[y,x] of Roots	Root[y,x] Surface Area	Days to[y] Budbreak
Greenhouse + Mist	24.5 a	24.0	97.9 b	8.1 b	5.7 a	8.3 a
Greenhouse	23.6 a	23.0	89.7 b	12.7 c	9.8 b	8.3 a
Greenhouse + Polyethylene Tents	28.4 b	29.9	80.3 a	5.6 a	4.3 a	12.8 b

[z]Cuttings were placed in moist, sterile sand under mist, polyethylene tents or with no covering, all with bottom heat (25°C) and air temperature of 22°C.

[y]Data is mean of 24 plants per four chemical treatments, NAA, IBA, Fe, H_2O.

[x]Data were taken after 45 days.

Mean separation in columns by Duncan's Multiple Range test at the 5% level.

Table 3. Influence of NAA, IBA and Fe on rooting and budbreak of dormant hardwood cuttings of Vitis hybrid 'Seyval.'

Chemical[z] Treatment	Days to[y] 50% Root	Number of[y] Days to Root	Percent[y,x] Rooted	Number[y,x] of Roots	Days to[y] Budbreak
NAA	21.9 a	21.2 a	93.1 b	8.3 a	9.2
IBA	29.1 b	31.7 b	75.1 a	8.8 ab	9.9
Fe	27.2 b	26.9 ab	95.9 b	7.8 a	10.0
H_2O	23.8 a	22.8 a	93.1 b	10.2 b	10.0

[z]Naphthaleneacetic acid, indolebutyric acid, iron chelate applied as five second dip in solution.

[y]Data is mean of 72 plants from three environments: greenhouse + mist, greenhouse, and greenhouse + polyethylene tents, all at 22°C air temperature (25°C bottom heat).

[x]Data was taken after 45 days.

Mean separation in columns by Duncan's multiple range test at the 5% level.

Table 4. Influence of propagation method in combination with NAA, IBA and Fe on rooting, budbreak and inflorescence presence of dormant hardwood cuttings of Vitis hybrid 'Seyval.'

Propagation[z]	Chemical[w]	Days to[y] 50% Root	Number[y] of Days to Root	Percent[y,x] Rooted	Number[y,x] of Roots	Root[y,x] Surface Area (sq cm)	Days to[y] Budbreak	Percent[y] Flower
Greenhouse + Mist	NAA	21.3 a	22.3 ab	100.0 b	7.6 bc	5.2	8.0	87.7
	IBA	25.0 a	25.2 ab	91.7 b	6.0 ab	4.6	8.0	75,0
	Fe	28.3 a	26.4 ab	100.0 b	7.5 bc	5.5	9.3	83.7
	H_2O	21.3 a	24.2 ab	100.0 b	11.2 de	7.3	8.0	75.0
Greenhouse	NAA	18.7 a	20.3 a	91.7 b	13.3 e	11.4	8.0	79.3
	IBA	22.7 a	23.1 ab	91.7 b	16.3 f	11.9	8.1	71.0
	Fe	29.3 a	28.9 b	87.7 b	10.0 cd	5.6	8.3	87.7
	H_2O	21.3 a	21.9 a	87.7 b	11.4 de	10.3	8.6	87.7
Greenhouse + Polyethylene Tents	NAA	23.7 a	23.2 ab	87.7 b	4.1 a	3.6	14.0	75.3
	IBA	47.3 b	38.8 c	42.0 a	4.0 a	3.1	13.5	79.3
	Fe	23.0 a	26.4 ab	100.0 b	6.0 ab	4.4	12.6	83.7
	H_2O	25.7 a	25.3 ab	91.7 b	8.1 bc	5.9	11.0	83.7
Method x chemical		*	**	**	**	--	--	--

[z]Cuttings placed in moist, sterile sand under mist, polyethylene tents or with no covering, with bottom heat.

[y]Data are mean of 24 plants (8 plants in 3 replications).

[x]Data were taken after 45 days.

[w]Naphthaleneacetic acid, indolebutyric acid, iron chelate applied as five-second dip in solution.

Mean separation in columns by Duncan's multiple range test at the 5% level.

compared to large cuttings. Fifty percent of all cuttings treated with NAA and H_2O rooted significantly earlier than those treated with IBA (Tables 1,2,3).

The IBA/polyethylene treated cuttings required significantly more days to reach the 50 percent rooted stage than all other treatments. NAA/greenhouse reached 50 percent in 18.7 days, but IBA/polyethylene needed 47.3 days. There was no significant difference between the remaining treatments (Table 4).

Percent Rooted by Day 45: The experiment terminated after 45 days when data were taken on total percent rooted. There was a significant difference in rooting percent based on cutting weight. Almost 95 percent of small cuttings rooted compared to 92 percent of medium and 80 percent of large. There was no significant difference between medium and small cuttings (Table 1).

Only 80 percent of cuttings placed under polyethylene rooted, compared to 90 percent of greenhouse and 98 percent of misted cuttings. There was no significant difference between greenhouse and misted cuttings (Table 2).

Likewise, chemical treatments provided significant differences at the 5% level using Duncan's Multiple Range test. A significantly smaller percentage of IBA-treated cuttings rooted than any other treatments; however, there was no significant difference between remaining treatments (Table 3).

The interaction between environment and chemical treatments was also highly significant. The IBA/polyethylene treatment gave the lowest percentage (42 percent), whereas IBA/greenhouse and IBA/mist each

resulted in almost 92 percent rooted. Four treatments showed 100 percent rooting: H_2O/mist, NAA/mist, Fe/mist and Fe/polyethylene (Table 4).

Number of Roots: Chemical treatments affected the number of roots present after 45 days. The H_2O (control) treatment had a significantly greater number of roots than Fe and NAA.

Cuttings under polyethylene produced less than half as many roots as greenhouse cuttings regardless of chemical treatment. Polyethylene cuttings bore significantly fewer roots than mist and greenhouse cuttings. Additionally, greenhouse-treated cuttings contained significantly more roots than either mist or polyethylene-treated cuttings (Table 2).

The environment and chemical interaction was highly significant. IBA/greenhouse cuttings resulted in almost four times as many roots as IBA/polyethylene or NAA/polyethylene. IBA/polyethylene and NAA/polyethylene treatments had significantly fewer roots than all treatment combinations except Fe/polyethylene and IBA/mist. NAA/greenhouse cuttings had more roots than all treatments except IBA/greenhouse, H_2O/mist and H_2O/greenhouse. IBA/greenhouse-treated cuttings produced significantly more roots than any other treatment (Table 4).

Root Surface Area: Only environment analysis resulted in any significant difference. The polyethylene and mist environment treatments had significantly less surface area than the greenhouse cuttings (Table 2).

Days to Budbreak: There was no difference in days to budbreak based on chemical treatment and no significant interaction between

environment and chemical treatment. However, buds under polyethylene took significantly longer to break than those under other treatments.

Percent Flower and Days to Flower: There was no significant difference in the percentage of cuttings which had floral buds, ranging from 71 to 88 percent, regardless of cutting size, chemical treatment or environment. Likewise, there was no difference in days to flower which ranged from 22.9 to 31.1 (Table 2, 3, 4).

Experiment II (Table 5)

The number of days required to 50 and 90 percent rooted was highly significant. Ninety percent rooted in less than 21 days at the higher temperature. At the lower temperature, 90 percent rooting was not achieved until 30 days. Less than 30 percent rooted by day 19 at the lower temperature. Almost 97 percent rooted in 40 days under both temperatures. Roots of the high temperature treatment were almost twice as long and numerous as those formed under lower temperatures. Budbreak occurred significantly earlier under high temperatures.

Fifty-two percent of the floral buds were retained at least to post-bloom stage under low temperatures; 58 percent were retained at high temperature, but the difference is not significant. Seventy-eight percent of all cuttings stuck broke with a primary floral bud; 43 percent of these developed to the post-bloom stage (fertilized ovaries begin to swell).

Experiment III (Table 6)

None of the chemicals tested showed a significant effect on days to budbreak; although, budbreak occurred three days earlier than

Table 5. Influence of temperatures on rooting, bud push and inflorescence retention of Vitis hybrid 'Seyval' hardwood cuttings in the greenhouse.

	Air/Soil Temperature	
	$21^{o}/27^{o}C^{z}$	$29^{o}/32^{o}C^{z}$
Days to 59% rooting	25.7	17.7**
Days to 90% rooting	30.0	21.0**
Total percent rooted (day 40)	96.7	96.7
Length of longest root (cm)	11.2	21.5**
Number of roots (day 40)	9.2	20.1**
Days to budbreak	19.9	16.6*
Percent fruitful[y]	52.0	58.0

[z]Figures are the means of 30 cuttings.

[y]Percent of all flowerheads which develop to post-bloom stage (when fertilized ovary begins to swell).

*,**Significant at the 5 and 1% level, respectively.

Table 6. Influence of various growth regulators on budbreak and rooting of hardwood cuttings of Vitis hybrid 'Seyval.'[z]

Treatment[w]	Days to[y] Root	Percent Rooted[y,x] by Day 14	Days to[y] Budbreak
SADH	14.1	53.0	17.9
CCC	12.9	73.3	17.5
A-Rest	13.1	66.7	15.7
GA_3	16.2	40.0	18.3
$GA_{4,7}$	17.3	06.7	17.8
NAA	13.3	53.3	16.1
H_2O	15.5	33.3	18.9
$lsd_{.05}$	2.4	--	--
$lsd_{.01}$	3.4	--	--

[z]Cuttings planted in peat-lite mix in $30\pm3^{o}C$ air temperature greenhouse with bottom heat ($32\pm2.5^{o}C$) without mist.

[y]Figures are the means of 15 observations.

[x]100% rooting occurred by day 36 in all treatments.

[w]Treatments were applied as a spray to runoff just prior to sticking.

control on A-Rest-treated cuttings. In fact, the control treatment required the greatest number of days to budbreak, but not significantly longer.

All cuttings rooted in an average of 18 days, with no significant chemical effect on days to root. CCC, A-Rest, SADH and NAA-treated cuttings rooted in fewer days than those treated with H_2O, but the difference was not significant.

Discussion

Experiment I

Cutting weight affected number of days to root, total percent rooted and percent rooted in 29 days. Smaller cuttings (2.0 to 3.45 g) rooted earlier and a greater total percent rooted. Initial cutting weight did not influence the number of roots present, root surface area, days to budbreak, percent flower or days to flower. This information is contradictory to that reported earlier (29, 65). Weaver et al. (65) found basal cuttings, generally heavier, rooted more rapidly than apical ones; however, a weight difference is not specified. Hosoi et al. (29) reported that heavier cuttings (7 g) had a greater number of roots than 3 gram cuttings. Perhaps a wider weight variation would have allowed these differences to appear.

Chemical treatments influenced the number of days to root, days to 50 percent rooted, total percent rooted and number of roots with no effect on days to budbreak, root surface area, percent flower or days to flower. Treatments with IBA hasten and improve rooting of various cultivars (4,28,41). In 1981, Ehrlinger and Howell (22) increased

rooting of 'Seyval' hardwood cuttings with 300 ppm IBA in talcum powder dip. The unexpected results in Experiment I are likely due to the concentration of IBA used (500 ppm). Earlier literature reported this concentration successful in enhancing rooting of various cultivars; Singh et al. (50) achieved a 10 percent increase in rooting of 'Perlette' cuttings using 500 ppm IBA; and later a five percent increase in rooting of 'Himrod' and 'Thompson Seedless' (51). Additionally, the IBA in this experiment was in solution and may have been washed away before it could affect root initiation, especially in the mist treatment.

However, IBA-treated cuttings placed under polyethylene tents took much longer to root than any other treatment with only 42 percent rooting. This one treatment combination adversely affected the data on IBA effectiveness, allowing no definitive conclusions to be drawn.

Treatments with Fe generally required more days to root and produced significantly fewer roots than control; however, a greater percentage of Fe-treated cuttings rooted than IBA. Therefore, only NAA did not adversely affect rooting, but the results were not significant. NAA has previously improved rooting in 'Delaware' cuttings at 25 and 100 ppm (24).

Cuttings under polyethylene took longer to root and reach budbreak, had fewer roots and a smaller percentage rooted. This is likely due to high soil temperatures reached under the covering. Even with ventilation, soil temperatures occasionally reached 37°C, although the temperature usually remained around 32.2°C. Soil temperatures never rose above 32.2°C under the other two treatments. It was thought that the polyethylene covering would prevent dehydration of the newly emerging leaves, but not lower the surrounding air temperature as a cool mist

does. However, it has been shown that soil temperatures over 30°C decrease rooting percentage and root number (29). Also, high temperatures (33°C) caused newly expanding buds to shrivel and abort (41). Therefore, it proved difficult to differentiate between the mist and greenhouse treatments when determining which method was superior. A larger percentage of cuttings under mist rooted, although the greenhouse treatment produced cuttings with a greater number of roots and root surface area.

Experiment II

Hardwood cuttings root best at higher temperatures (6,29), but the effect of rooting temperatures upon flower bud retention in 'Seyval' was unknown.

Mullins and Rajasekaran (41) "pre-rooted" hardwood cuttings by keeping buds dormant in a cold air temperature and warming the soil for root initiation. This technique greatly increased the percentage of inflorescences at anthesis (40 to 50 percent survived). They attributed this to the fact that developing inflorescences require cytokinins which are synthesized in the roots (54).

Therefore, it was not unexpected that at warmer temperatures, only 21 days were required to achieve 90 percent rooting, compared to 30 days at the lower temperature. However, there was no significant difference in the number of floral buds surviving to post-bloom stage at either temperature. Warm air and soil temperature treatment can reduce production time by 12 days and result in better, more uniform rooting, as well as produce more numerous and longer roots, since they had extra days in which root development was occurring. An equal number of cuttings had

rooted under both temperatures, indicating that if given sufficient time, the percentage of cuttings rooting will not vary with temperature.

Experiment III

The use of CCC, A-Rest and NAA hastened rooting by as many as 2.7 days compared to control and 4.4 days earlier than $GA_{4,7}$. There was no significant effect on days to root.

CCC, gibberellins and NAA (70) delay budbreak in some cases. However, Kliewer and Soleimani (36) concluded that GA_3 did not affect budbreak, although they applied GA_3 to two-year old potted vines rather than unrooted cuttings.

In Experiment III, there was no significant effect by any chemical on budbreak. In fact, budbreak occurred only one to five days prior to root initiation, although many inflorescences still abscised before flowerhead separation.

Summary

Based on these experiments the best method for rooting 'Seyval' cuttings is to use a soil-less medium and dip cuttings in talcum powder IBA (3000 ppm) before sticking. Air temperature should be between 26° and 32°C with bottom heat (21° to 34°C) and high humidity or intermittent mist for rapid, uniform rooting. Under these conditions, 50 percent rooting will occur in approximately 18 days and 90 percent in 21 days.

SECTION TWO:

THE EFFECT OF VARIOUS GROWTH REGULATORS ON FRUIT SET, SIZE AND YIELD OF *VITIS* HYBRID 'SEYVAL' UNDER GREENHOUSE CONDITIONS

THE EFFECT OF VARIOUS GROWTH REGULATORS ON FRUIT SET, SIZE AND YIELD OF VITIS HYBRID 'SEYVAL' UNDER GREENHOUSE CONDITIONS

Introduction

'Seyval' cuttings generally produce an inflorescence while in the rooting bench or shortly thereafter. These young inflorescences usually abscise either as an entire cluster prior to separation of the flowerhead or as individual florets shortly after bloom, resulting in many vines without fruit clusters or with poorly filled clusters containing only five or ten berries. In preliminary experiments, less than 50 percent of the first inflorescences reached the post-bloom stage. Fruit produced on greenhouse-grown vines is considerably smaller than fruit produced from the same cultivar grown in the vineyard.

Growth regulators can improve fruit set and size when applied either at full bloom or to immature fruit clusters: benzyladenine (BA) has been shown to increase the number of fruit per cluster (73). Succinamic acid dimethylhydrazide (SADH) increases fruit set and yield of field (21,58,59) and greenhouse-grown vines (42). Also, 2-chloroethyltrimethylammonium chloride (CCC) increases the number of berries per cluster (12, 43) although the berries are smaller than normal (21). Gibberellic acid (GA_3) at 100 ppm applied 11 days after bloom was shown to increase fruit set as well as the fresh weight of the clusters (13).

GA_3 also improves fruit size when applied either at bloom or to immature fruit (62). Applied at bloom, GA_3 increases berry size; but

reportedly reduces the number of berries set per cluster (19). However, others (31) found that GA_3 applied during bloom had no effect on the number of berries, but did increase fresh weight of the fruit. In some cases, BA has been shown to increase fruit size (73).

In a preliminary experiment, Malizewski et al. (38) experienced problems with the clusters of 'Seyval' containerized vines dropping berries. This was alleviated by spraying the very small clusters with BA. It has also been shown that dipping clusters in BA results in fewer dropped berries (47, 73).

The following experiment was designed to determine the effect of growth regulators on 'Seyval' hanging baskets.

Material and Methods

Dormant hardwood cuttings of one-year old canes were collected from mature 'Seyval' vines and prepared as two-node cuttings, cut just below the basal node and two to four cm above the upper node. Cuttings were taken in late March 1982 and immediately prepared for propagation. Only cuttings which weighed between five and ten grams and free of visible disease and injury were used.

All cuttings were dipped in a commercial powder mix of 3000 ppm indole-3-butyric acid (Hormodin 2) and placed five to six cm deep in a peat-perlite-vermiculite media (VSP) and placed in a warm, humid ($30\pm3^{o}C$) greenhouse with bottom heat ($32\pm2.5^{o}C$). A total of 320 cuttings were stuck in the propagating bench; 95 percent rooted sufficiently to transplant, and 85 percent had visible inflorescences. Cuttings with five or more roots and a visible floral bud were transplanted three

weeks after sticking, one cutting per six-inch clay pot containing VSP and placed under long day conditions (days equaled or exceeded 13 hours of light).

About half of the inflorescences abscised within one week of transplanting; 128 plants maintained an original inflorescence. These plants were placed in Block I, "first flower" (those at full bloom between 4/29 and 5/12). Block II, "second flower" consisted of vines whose original inflorescence abscised but that had a second inflorescence produced apical to the original on a primary shoot in full bloom between 5/20 and 6/4. From each block, 45 plants were chosen for uniformity of inflorescence size and stage of development; there were 10 replicates of each treatment in each block. Only one cluster was allowed per plant.

Treatments of deionized water, SADH (2500 ppm and 5000 ppm), BA (50 ppm), CCC (2500 ppm), GA_3 (100 ppm) were sprayed directly upon the inflorescence at full bloom. Two treatments were applied directly to immature fruit. These had SADH (2500 ppm) at full bloom, then BA (50 ppm) or GA_3 (100 ppm) sprayed onto immature fruit 21 days after full bloom.

The experiment was designed as a completely randomized block with pots set on 10-inch centers on greenhouse benches. After transplanting, plants were fertilized with 200 ppm 20-20-20 $N\text{-}P_2O_5\text{-}K_2O$ (Peter's General Purpose soluble fertilizer as described in section one) twice weekly. Plants were staked and pruned every two weeks after reaching four feet in height.

Data were collected at veraison (color change) about 90 days from full bloom; and included cluster weight, cluster volume, number of

fruit per cluster, individual berry diameter, length of cluster and days to sale. Volume was measured by water displacement in a graduated cylinder, while fruit diameter was measured using a plastic circle template.

Results

Number of Berries per Cluster: All treatments, except H_2O, resulted in significantly greater number of fruit than control clusters (Table 7). The clusters sprayed with SADH (5000 ppm) contained more berries than GA_3, control or H_2O-treated clusters with no difference between the two levels of SADH. CCC-treated clusters contained the largest number of fruit, more than all other treatments. In fact, CCC-treated clusters bore 12.6 times as many berries as control and 3.7 times as many as H_2O-treated clusters.

There was a significant difference in number of fruit between blocks. First flower vines contained fewer fruit per cluster than did second flower vines (Table 8).

Cluster Weight: All treatments, except H_2O, resulted in a highly significant increase in weight over control clusters (Table 7). The heaviest clusters occurred on vines treated with CCC at full bloom.

Clusters from first flower vines weighed significantly less than those from second flower vines due to the larger number of fruit present on second flower vines rather than an increase in weight per berry (Table 8).

Table 7. The influence of various growth regulators on fruit set and size of greenhouse-grown Vitis hybrid 'Seyval.'

Treatment[w]	Number[z] of Fruit	Indiv.[z] Berry Weight(g)	Cluster[z] Weight (g)	Indiv.[z,y] Berry Diam.(mm)	Indiv.[z,x] Berry Vol.(ml)	Cluster[z,x] Volume (ml)	Rachis[z] Length (cm)
Control (no trt)	4.0	1.36	5.26	12.4	1.24	4.20	2.6
Deionized H_2O	13.6	0.99	14.39	10.8	0.82	11.65	5.0
SADH (2500 ppm)	34.2	1.11	40.22	11.8	1.00	30.72	6.9
SADH (5000 ppm)	40.0	1.20	46.56	11.7	1.03	38.50	10.5
BA	33.8	1.47	49.68	12.2	1.42	43.45	7.5
CCC	50.2	1.12	55.34	11.5	1.00	44.15	8.9
GA_3	18.9	1.92	34.81	13.9	1.80	33.00	7.4
SADH + GA_3[v]	37.2	1.43	49.45	13.1	1.29	42.70	9.0
SADH + BA[v]	34.1	1.62	49.54	12.8	1.50	45.25	7.4
$LSD_{.05}$	14.1	0.33	17.99	1.0	0.30	16.33	3.1
$LSD_{.01}$	18.6	0.43	23.86	1.3	0.39	21.65	4.5

[z]Data were average of 10 vines, collected at veraison.

[y]Berry diameter measured using a plastic circle template.

[x]Berry volume measured by water displacement in a graduated cylinder.

[w]Chemicals were combined with deionized water and sprayed to runoff at full bloom.

[v]SADH (2500 ppm) applied as spray to runoff at full bloom, second treatment applied 21 days later to immature fruit.

Table 8. Influence of flowering time on fruit size and yield of Vitis hybrid 'Seyval' grown in the greenhouse.

Flowering[z] Period	No.[y**] Fruit	Individual[y] Berry Weight (g)	Individual[y,x] Berry Volume (ml)	Individual[y,w] Berry Diameter (mm)
First	22.4	1.30	1.1	5.0
Second	36.8	1.43	1.2	5.2

[z]First flower period, 4/29/82 through 5/12/82; second, 5/20/82 through 6/4/82. Original inflorescence abscised on second flower vines and a second inflorescence was produced apical to the original on a primary shoot.
[y]Data are the mean of 45 vines each with one cluster.
[x]Berry volume was measured by water displacement in a graduated cylinder.
[w]Berry diameter was measured using a plastic circle template.
[**]Significant at the 1% level.

Table 9. Influence of flowering time on number of days to sale and days from full bloom to sale of greenhouse-grown Vitis hybrid 'Seyval.'

Flowering[z] Period	Days to[y,x] Sale	No. of Days from[x] Full Bloom to Sale
First	70.8	34.7
Second	86.5	32.5
$LSD_{.05}$	--	--

[z]First flower period, 4/29/82 through 5/12/82; second, 5/20/82 through 6/4/82. Original inflorescence abscised on second flower vines and a second inflorescence was produced apical to the original on a primary shoot.
[y]Number of days from stick to "pea-sized" fruit (8-10 mm diameter).
[x]Data are the mean of 45 vines each with one cluster.

Individual Berry Weight: The GA_3 treatment produced the heaviest berries of all treatments and was the only treatment that was significantly greater than control (Table 7). However, the control clusters bore berries significantly heavier than the H_2O treatment which resulted in the smallest individual berries. SADH plus GA_3-treated berries were not heavier than control and weighed less than berries sprayed with GA_3 at full bloom. No difference existed between individual berry weight of first and second flower vines (Table 8).

Cluster Volume: The difference between the control clusters' volume and all treatments, except H_2O, was highly significant (Table 7). Similarly, all treatments, except control, had larger cluster volumes than H_2O. There was no difference between remaining treatments.

Clusters from first flower vines displaced less volume than those from second flower vines due to a greater number of fruit present on second flower vines rather than an increase in berry size (Table 8).

Individual Berry Volume: Only the clusters treated with GA_3 at full bloom resulted in berries of greater volume than control (Table 7) or any other treatment. There was no difference between the remaining treatments or between first and second flower vines (Table 8).

Individual Berry Diameter: Only GA_3 sprayed at full bloom produced highly significant differences over control (Table 7). However treatments using GA_3, SADH plus GA_3, and SADH plus BA gave larger berries than CCC, SADH (2500) and SADH (5000) as well as H_2O. No difference in berry diameter existed between blocks (Table 8).

Length of Cluster: All treatments, except H_2O, resulted in significantly longer clusters than control (Table 7). SADH (5000), CCC and SADH plus GA_3 treatments produced clusters longer than H_2O-treated ones. Applications of 5000 ppm SADH produced clusters longer than all treatments except BA, CCC and SADH plus GA_3. Clusters treated with 5000 ppm SADH at full bloom were four times longer than control.

Days to Sale: The mean number of days from stick to sale for first flower vines was 70.8; 86.5 days for second flower; however, this was not significant. Marketable size fruit was defined as having a diameter between eight and 10 millimeters (Tables 9, 10). There also was no difference in days from full bloom to sale.

Although the difference was not statistically significant, the second flower vines spent an average of 15.7 days longer in the greenhouse because their original inflorescence abscised. Those extra days were spent developing a second inflorescence.

Discussion

The successful production of greenhouse-grown fruited grapevines will involve the use of growth regulators to improve market appearance.

The use of any spray at full bloom improves fruit set from three times (deionized water) to 12.5 times (CCC). Therefore, any spray increases cluster weight, volume and length. The goal of this experiment is to produce clusters that are aesthetically pleasing on grapevines in a hanging basket, not just clusters containing more or larger berries.

Table 10. Influence of various growth regulators on days to sale and the number of days from full bloom to sale of greenhouse-grown Vitis hybrid 'Seyval.'

Treatment[x]	Days to[z,y] Sale	No. of Days from[z] Full Bloom to Sale
Control (no treatment)	75.4	33.3
Deionized H_2O	79.4	33.4
SADH (2500 ppm)	79.8	33.7
SADH (5000 ppm)	81.0	34.2
BA	78.2	33.0
CCC	78.6	33.6
GA_3	79.8	33.5
SADH + GA_3[w]	79.0	34.7
SADH + BA[w]	76.6	33.0
$LSD_{.05}$	--	--

[z]Data taken were the average of five vines per two replications.
[y]Number of days from stick to "pea-sized" fruit (8-10 mm diameter).
[x]Chemicals were combined with deionized water and sprayed to runoff at full bloom.
[w]SADH (2500 ppm) was applied as spray to runoff at full bloom, second treatment was applied 21 days later to immature fruit.

Deionized Water and Control: Control vines had very poor fruit set and consequently the clusters were unsaleable. Clusters sprayed with deionized H_2O contained more fruit, but each individual berry was smaller than the control and were considered unsaleable.

Cycocel: Clusters treated with CCC produced by far the greatest number of fruit and the longest clusters. However, the fruit were quite small and many were hard, tiny green berries.

That CCC increased the number of berries per cluster was not unexpected (12, 43) nor was the observation that the berries were small (21). However, an undesirable result of the use of CCC was the production of uneven, unattractive clusters, with an unbalanced mix of very tiny and average-size berries.

SADH: No difference was apparent between 2500 and 5000 ppm SADH with regard to any of the measurements except cluster length; 5000 ppm produced longer clusters which resulted in more attractive appearance. Generally, the 5000 ppm SADH clusters were the most attractive of all treatments. The clusters sprayed with 2500 ppm SADH were tight and clubby, often developing mold prior to harvest.

Benzyladenine: BA treatments at full bloom resulted in good-sized berries in fair numbers on attractive clusters. They contained more fruit than control, H_2O and GA_3-treated clusters; and the fruit were larger than many treatments.

GA was also sprayed on the immature fruit to increase size (73) and prevent fruit drop (38,47,73). These clusters were sprayed at full bloom with 2500 ppm SADH to reduce floral abscission. Therefore, the number of fruit does not vary from that produced using 2500 or 5000 ppm SADH only at full bloom. No fruit drop was experienced

after 14 days from full bloom, so this effect of BA could not be evaluated. However, BA-treated fruit were heavier and larger than those treated with H_2O, CCC or SADH alone and were slightly larger and heavier than fruit sprayed with BA at full bloom.

Gibberellic Acid: GA_3 sprayed at full bloom resulted in the largest berries. As was expected, this treatment produced fewer berries than any treatment except H_2O and control. Each individual berry was larger, but the cluster weighed less than all but control. These clusters were generally too loose and much shorter than other treatments.

GA_3 was also applied to fruit 21 days after full bloom to increase fruit size (13, 62) without reducing the number of fruit. SADH (2500 ppm) was sprayed at full bloom prior to the GA_3 treatment. This combination gave more fruit and resulted in berries which weighed less than the GA-treated at full bloom. The reduced weight was unexpected; perhaps the treatment should have been made earlier or at higher concentrations.

Further, there was no difference between the diameter of berries treated with GA_3 at fruit or at bloom, although the latter were slightly larger. The SADH + GA_3-treated berries had larger diameters than many and were about the same size as those treated with BA and control.

The only difference between first and second flower vines was in the number of fruit per cluster. Second flower vines contained larger numbers of fruit which resulted in larger cluster weights and volumes. However, there was no difference between blocks in regard to individual berry weight, volume, diameter and total cluster length.

Summary

The objective of this experiment was to produce good-sized, attractive clusters in a short period of time. Three treatments stand as superior to the others. SADH sprayed at 5000 ppm at full bloom resulted in clusters that were aesthetically full, well-tapered and composed of numerous fair-sized berries. An advantage of this treatment was that only one application was required. SADH (2500 ppm) at full bloom plus BA 21 days later, produced attractive clusters containing slightly fewer fruit which were larger; therefore, an improved, although tighter, cluster was produced. However, two applications and chemicals are required and BA is not generally used by bedding plant producers. The third possibility is SADH (2500 ppm) plus GA_3 21 days later. These clusters were attractive and the fruit were slightly larger than those formed using one spray of SADH at full bloom.

Using any of these three treatments produces attractive, full clusters from hardwood 'Seyval' cuttings in 9½ to 11 weeks for the early flowering vines and 11 to 14 weeks for the later ones. The late flowering vines bear larger clusters. This fact, combined with the low percentage of vines which retain their initial clusters, makes two-stage marketing and production desirable.

THE EFFECTS OF THREE LEVELS OF NITROGEN AND SOIL PH ON GREENHOUSE CONTAINER-GROWN *VITIS* HYBRID 'SEYVAL'

Introduction

In preliminary experiments, many of the container-grown grapevines developed circular necrotic lesions on the foliage, perhaps due to a combination of high soluble salts and low pH. Little is documented on pH and nitrogen preferences of grapevines grown in soilless media in the greenhouse, although general field recommendations are available; so this experiment was conducted in order to make recommendations regarding fertilizing procedures.

Material and Methods

Dormant hardwood cuttings (eight to 10 nodes) of one-year old canes were collected at Tabor Hill vineyards in southwest Michigan. Cuttings were taken in late March and immediately prepared as two-node cuttings, cut just below the basal node and two to three cm above the upper node. Cuttings were selected from wood free of visible disease and injury and placed in six cm deep 1:1 ratio of peat and perlite at 30± 3°C under intermittent mist (six seconds every 15 minutes) with bottom heat (32±2.5°C).

Cuttings rooted in three weeks; at that time, they were selected for uniformity of root area, shoot growth and inflorescence

SECTION THREE:

THE EFFECTS OF THREE LEVELS OF NITROGEN AND SOIL PH ON GREENHOUSE CONTAINER-GROWN *VITIS* HYBRID 'SEYVAL'

size, then transplanted into six-inch clay pots. Only cuttings with a visible inflorescence were chosen.

Three batches of soil were mixed prior to transplanting: high pH (6.1 to 7.0), medium (5.1 to 6.0) and low (4.0 to 5.0). All mixes were based on a 1:1 ratio of peat to vermiculate and included:

1362 g/cu yd	magnesium sulfate
120 g/cu yd	treble super phosphate
1589 g/cu yd	trace elements (Esmigram)
3 oz/cu yd	wetting agent

Additionally, the high pH mix contained calcium carbonate (2270 g/cu yd), the medium pH mix contained calcium carbonate (1135 g/cu yd) and calcium sulfate (1135 g/cu yd); while the low pH contained calcium sulfate (2270 g/cu yd).

Twenty-seven cuttings were planted in the proper medium, divided into three groups, and fertilized with 0, 100 or 300 ppm nitrogen (N). All three nitrogen levels contained 90 ppm potassium from K_2SO_4. Phosphoric acid was added to correct the solution pH to 6.0. Fertilizer solutions contained:

0 ppm N	100 ppm N	300 ppm N
0.23 g/l K_2SO_4	0.2 g/l NH_4NO_3	0.79 g/l $CaNO_3$
	0.23 g/l KNO_3	0.4 g/l NH_4NO_3
		0.23 g/l KNO_3

All cuttings were watered as needed with the solution and leached with deionized water (pH 6.0) once every two weeks. Soil pH was recorded weekly. Flower clusters were sprayed with 5000 ppm SADH at full bloom.

After 10 weeks, all plants were pruned back to seven nodes (no flower clusters were removed). Measurements were made after 17 weeks including, the number of nodes below the inflorescence, total

vine length, new vine growth since pruning, number of fruit, fruit weight, number of tendrils, number of branches, length of longest branch, total number of nodes and the number of woody nodes. Plants were also rated for foliage chlorosis (1 = deep green, no chlorosis; 2 = entire leaf slightly chlorotic; 3 = entire leaf severly chlorotic, primarily yellow or white) and presence of necrotic spots (1 = no spots, 2 = less than five spots per leaf, and 3 = more than five spots or spots larger than 1.25 cm in diameter).

Results

Fruiting: The level of nitrogen significantly affected the number of fruit clusters, the number of fruit per cluster and total number of fruit. Vines fertilized with 300 ppm N had significantly more clusters as well as a greater number of total fruit, using Duncan's multiple range test at 5% level. Vines treated with 300 ppm N had over 2.5 times more fruit than 100 ppm N and over 14 times more than 0 ppm. There was no difference between the number of fruit per cluster of vines treated with 100 or 300 ppm N. Both treatments had significantly more fruit per cluster than vines receiving 0 ppm N. The 300 ppm N treatment averaged almost 44 berries per cluster; the 100 ppm treatment had over 30, compared to less than six berries per cluster for 0 ppm N (Table 11).

Fresh Weight of Vines and Foliage: Vines fertilized with increasing levels of nitrogen had increasing fresh weight. Also, plants grown in low pH had significantly greater fresh weight than those with high pH (Table 12).

Table 11. The influence of three levels of nitrogen on flower and fruiting of greenhouse container-grown Vitis hybrid 'Seyval.'

Nitrogen Level	No. of Fruit Clusters[z]	Total No. of Fruit[z]	No. Fruit per Cluster[z]
0 ppm	0.7 a	6.7 a	6.7 a
100 ppm	1.2 a	37.4 a	30.3 a
300 ppm	2.1 b	94.0 b	44.0 b

[z]Data based on means of 27 vines.
Mean separation in columns by Duncan's multiple range at the 5% level.

Table 12. The influence of three levels of nitrogen on foliage fresh weight and vine growth of greenhouse container-grown Vitis hybrid 'Seyval.'

Nitrogen Level	Foliage Fresh Weight (g)[z]	Initial Vine Length (cm)[z,y]	New Growth (cm)[z,x]	No. of Branches[z]	Foliar Chlorosis[z,w]	Foliar Necrosis[z,v]
0 ppm	31.20 a	30.7 a	16.9 a	0.3 a	2.5 b	1.8 b
100 ppm	122.28 b	94.7 b	84.9 b	4.1 b	1.0 a	1.1 a
300 ppm	138.73 c	88.4 b	78.7 b	4.9 c	1.0 a	1.8 b

[z]Data based on means of 27 vines.
[y]Vine length on 6/10/82 prior to pruning, cuttings were stuck on 4/2/82.
[x]Measurement of new growth which occurred between 6/10/82 and 7/22/82.
[w]Rated on a scale from 1 to 3; 1 = no chlorosis; 2 = entire leaf slightly chlorotic; 3 = entire leaf severely chlorotic, primarily yellow or white.
[v]Rated on a scale from 1 to 3; 1 = no spots, 2 = less than five spots per leaf, 3 = more than five spots or spots larger than 1.25 cm in diameter.
Mean separation in columns by Duncan's multiple range test at the 5% level.

The interaction between nitrogen and pH also affected foliage fresh weight (Table 13). The combination of 100 ppm N/low pH and 300 ppm N/medium pH produced vines of highest fresh weight. The 100 ppm N/high pH combination had significantly less foliage than 100 ppm N/low pH.

Vine Length: Nitrogen also affected initial vine length and new growth after pruning (Table 12). Plants grown with 0 ppm N were significantly shorter than those fertilized with 100 and 300 ppm N. pH had no effect on initial vine length, but did affect new growth (Table 14). The low pH vines were 1½ times longer than the high pH vines.

Foliar Chlorosis and Necrosis: Low levels of nitrogen (0 ppm) resulted in leaves that were severely chlorotic and contained numerous necrotic lesions. High levels of nitrogen (300 ppm) also resulted in significnatly more necrosis than was present on 100 ppm N-treated foliage (Tables 12, 13).

Number of Branches: With increasing levels of nitrogen, there were increasing number of branches per plant. Those treated with 0 ppm N grew very few side branches (only one out of three plants had even a single side branch). The 300 ppm N treatment averaged five branches per plant, significantly more than the other two treatments.

Table 13. The influence of three levels of nitrogen and three levels of soil pH on foliar growth and appearance and fruit number of greenhouse container-grown Vitis hybrid 'Seyval.'

Nitrogen Level	Soil[w] pH	Foliage[z] Fresh Wt. (g)	Initial[z,y] Vine Length (cm)	New[z,x] Growth (cm)	No. of[z] Branches	Foliar[z,v] Chlorosis	Foliar[z,u] Necrosis	No.[z] of Fruit	Fruit[z] per Cluster
	low	36.1 a	31.9	28.4	0.45	2.3	1.7	10.0	10.0
0 ppm	medium	28.7 a	33.9	13.7	0.10	2.4	1.8	5.0	5.0
	high	28.8 a	26.4	8.7	0.32	2.7	1.9	5.0	5.0
	low	146.6 d	105.7	95.8	4.34	1.0	1.0	34.7	34.7
100 ppm	medium	119.6 bc	90.8	87.0	4.11	1.0	1.0	21.7	17.7
	high	100.7 b	87.6	71.8	3.78	1.0	1.2	56.0	38.5
	low	138.4 cd	90.0	97.4	4.89	1.0	1.8	99.3	49.7
300 ppm	medium	146.5 d	90.2	77.3	5.34	1.0	1.8	103.0	42.1
	high	131.3 cd	85.1	61.4	4.55	1.0	1.8	79.7	40.2
Interaction		*							

[z]Data based on means of three vines in three replications.
[y]Vine length on 6/10/82 prior to pruning, cuttings were stuck on 4/2/82.
[x]Measurements of new growth which occurred between 6/10/82 and 7/22/82.
[w]Low pH = 4.0-5.0; medium = 5.1-6.0; high = 6.1-7.0.
[v]Rated on a scale from 1 to 3: 1 = no chlorosis; 2 = entire leaf slightly chlorotic; 3 = entire leaf severely chlorotic, primarily yellow or white.
[u]Rated on a scale from 1 to 3: 1 = no necrotic spots, 2 = less than five spots per leaf, 3 = more than five spots per leaf or spots larger than 1.25 cm in diameter.
*Interaction significant at the 5% level using Duncan's multiple range test.

Table 14. The influence of three levels of soil pH on foliage fresh weight and vine growth of greenhouse container-grown Vitis hybrid 'Seyval.'

Soil[z] pH	Foliage[y] Fresh Weight	New[y,x] Growth
Low	107.0 b	73.9 b
Medium	98.3 ab	59.4 ab
High	86.9 a	47.3 a

[z]Low pH = 4.0-5.0, medium = 5.1-6.0, high = 6.1-7.0.

[y]Data based on means of 27 vines.

[x]Measurement of new growth which occurred after pruning on 6/10/82 and before 7/22/82.

Mean separation in columns by Duncan's multiple range test at the 5% level.

Discussion

It appears that of the three levels of nitrogen tested, a nitrogen concentration between 100 and 300 ppm is preferable. At 300 ppm (during late spring) the plants bore more clusters and more fruit per cluster; and the vines were more extensively branched, which is important for attractive hanging baskets. Plants grown using 100 ppm were well-branched and bore an acceptable number of fruit clusters.

It was not known whether or not levels of nitrogen as high as 300 ppm would reduce fruit formation. An excess of nitrogen has been shown to reduce crop yield (75). In experiments in perlite-vermiculite media, one to four millimoles of NO_3 produced superior vine growth and fruitfulness than 0.5 millimoles. The researchers concluded that a nitrogen supply that promotes good foliar color and growth will also enhance fruit production (34). In this experiment, the levels of nitrogen were 0.0 mM (low), 7.1 mM (medium), and 21.4 mM (high), considerably higher than that reported by Kliewer and Cook (34).

However, the 300 ppm N treatment produced more fruit than other levels, however, it also resulted in a greater number of necrotic lesions. Therefore, a concentration between 100 and 300 ppm is recommended. Further, pH had no effect upon plant growth.

APPENDICES

APPENDIX A

A Study of *Vitis* Cultivars Suitable for Hanging Basket Greenhouse Culture

Malizewski *et al.* (38) conducted a preliminary experiment on three grape cultivars: 'Seyval,' 'Vignoles,' and 'Concord' to determine their suitability for hanging basket culture. 'Seyval' showed the best potential while 'Vignoles' failed to flower and was discarded. 'Concord' flowered and set fruit, but was considered "too leggy" and awkward-looking in a 10-inch basket due to its large leaves and long internodes. 'Seyval' produced five to eight-inch pea-sized clusters in 13 to 14 233ks.

Material and Methods

Dormant hardwood cuttings were collected in January and February from various sources in Michigan, California and New York and placed in cold storage (2^{o}C). Cuttings were prepared as two-node cuttings, cut just below the basal node and two to three cm above the upper node. Cuttings were chosen which weighed between 5.0 and 10.0 grams and were free of visible disease and injury. All cuttings were dipped in a powder formulation of 3000 ppm indole-3-butyric acid (IBA) and bases placed in moist 1:1 ratio of peat and perlite medium. The flats were placed under intermittent mist (6 seconds every 15 minutes) in a

30°C greenhouse and supplied with bottom heat (32°C). There were three replications of eight cuttings each.

All cuttings were checked for root formation every other day and data were taken on days to root, days to flower, percent rooted and percent fruited. Cultivars are shown in Table 15. All cultivar performance was compared to 'Seyval.' Any flower clusters which developed were sprayed with 2500 ppm SADH at 50 percent bloom.

Results

Four of the tested cultivars produced fruit within sixteen weeks (Table 15). 'Seyval' had fruit clusters on 91.7 percent of the vines; almost 96 percent rooted in 35 days. 'Chelois' had clusters on 87.5 percent and 91.7 percent rooted. 'Alden' and 'Viblanc' bore clusters on 20.8 percent and 12.5 percent respectively. None of the others bore clusters.

Almost 100 percent of 'Ventura' and !Steuben' (Michigan) cuttings rooted in 35 days. These cultivars leafed out nicely, but no flowers were ever formed. 'Queen,' however, had almost 92 percent of its primary buds develop an inflorescence, but no roots ever formed and the inflorescence dehydrated and senesced. Of the four cultivars sent from California, only 'Alden' rooted on 50 percent of the cuttings.

Discussion

Only 'Seyval' and 'Chelois' produced fruit clusters on a great enough percentage of vines to merit growing them. Both cultivars have attractive foliage and short internodes so they produce full baskets.

Both are wine grapes which are grown in Michigan. 'Seyval' is a white-fruited cultivar and produces long, tapered clusters. 'Chelois' has purple fruit; the fruit is fair-sized but the clusters are rounder than 'Seyval.' Both cultivars can be produced on the same time schedule, using the same techniques.

Table 15. Rooting and fruiting percentages of twelve Vitis cultivars grown in the greenhouse.

Cultivar	% Rooted[z] 21 Days	Total %[z,y] Rooted	%[z] Flower	%[z,x] Fruit
Michigan[w]				
Seyval	91.7	95.8	87.5	91.7
Chelois	83.3	91.7	83.3	87.5
Ventura	83.3	100.0	0.0	0.0
Alden	79.2	87.5	62.5	20.8
Viblanc	83.3	95.8	75.0	12.5
Steuben	87.5	100.0	0.0	0.0
Interlaken	50.0	70.8	0.0	0.0
California[w]				
Alden	25.0	50.0	0.0	0.0
Ruby Seedless	0.0	0.0	0.0	0.0
Ribier	0.0	0.0	0.0	0.0
Queen	0.0	0.0	91.7	0.0
New York[w]				
Himrod	25.0	50.0	10.7	0.0
Steuben	50.0	70.8	0.0	0.0
Suffolk Red	62.5	70.8	0.0	0.0

[z]Data based on mean of 24 cuttings.
[y]In 35 days.
[x]Cuttings with fruit clusters present in 16 weeks.
[w]Source of wood.

APPENDIX B

A Grower's Guide to the Production of Hanging Baskets of Fruited Grapevines

Production time: Crop flowers in two stages. Vines retaining their initial clusters will be ready for sale and have "pea-sized" (8-10 mm) fruit in 9½ to 11 weeks. The second half of the crop will be ready in 11½ to 14 weeks.

Rooting: Root hardwood cuttings in sterilized sand or soil-less media, burying only the lower node. Air temperature should be around 30°C with bottom heat (32°C) and high humidity or mist for fastest, most uniform rooting. At this temperature, 50 percent will be rooted in 18 days and 90 percent in 21 days. Use a talcum powder dip of 3000 ppm indole-3-butyric acid (IBA) before sticking.

Cultivars: 'Seyval' is a popular wine grape which produces white clusters that are five to eight inches long. 'Chelois' is also a wine grape which bears purple fruit in the same time period as 'Seyval,' although the fruit clusters are smaller.

Transplanting: Transplant before the roots become too long. Grape roots are thick and brittle, easily broken during potting. Vines with broken roots experience greater transplant shock.

Growing On Temperature: 25-30°C is recommended. Temperatures above 35°C and those below 20°C result in tendril formation rather than inflorescence formation.

Media: Any well-drained mix.

Spacing: Four two-node cuttings per 10-inch basket are recommended. One cutting occasionally will not survive transplanting and three cuttings make a full, attractive basket.

Fertilization: Apply between 100 and 300 ppm N at every other watering along with potassium and phosphorus. A suitable pH is between 5.0 and 6.0; at higher pH, iron deficiency and necrotic lesions are more likely to occur. A foliar spray or soil application of iron may be necessary after transplanting.

Photoperiod: Vines produce greater numbers of berries when placed under 16-hour days. Continuous lighting greatly reduces the number of fruit.

Growth Regulators and Fruit Production: For improved fruit set apply one of the following to flower clusters when at least 50 percent of the inflorescences have opened:

1) SADH (5000 ppm) at 50 percent bloom.
2) SADH (2500 ppm) at 50 percent bloom plus GA_3 (100 ppm) 21 days later to immature fruit.
3) SADH (2500 ppm) at 50 percent bloom plus BA (50 ppm) 21 days later to immature fruit.

Pests: Spider mite is the main pest in the greenhouse.

Sample Schedule:

February 6	Stick cuttings
February 27	Cuttings rooted; transplant
March 8 - 20	First full bloom - apply SADH to inflorescence
March 28 - Apr 12	Second full bloom - apply SADH to inflorescence
March 20 - Apr 10	Spray first fruit (optional) with GA_3 or BA
Apr 18 - May 3	Spray second fruit (optional) with GA_3 or BA
Apr 14 - 22	First flowering baskets ready for sale
Apr 26 - May 12	Second flowering baskets ready for sale

Total Time:	9½ - 11 weeks for first flowering
	11½ - 14 weeks for second flowering

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BIBLIOGRAPHY

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