The Effect of the Modified Munson Training System on Uneven Ripening, Soluble Solids and Yield of ‘Concord’ Grapes

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Abstract. ‘Concord’ grape vines trained to the Modified Munson and 4-arm Kniffin systems were sampled, at weekly intervals, beginning approximately one month before harvest and continuing to harvest. The fruit were categorized for evenness of ripening and analyzed for total pigment content and per cent soluble solids. Total yield, and components of yield were compared under the 2 training systems.

Fruit harvested from the Modified Munson trained vines ripened more evenly, contained more anthocyanin pigments, soluble solids, and produced greater yields than did vines trained to the 4-arm Kniffin system. The yield increase was due to increases in the percentage of fruiting shoots, clusters per shoot, and cluster weights on vines trained to the Modified Munson system. The increase in cluster weight was due to increases in berry weight and berries per cluster.

Low soluble solids like poor color development, is closely associated with reduced carbohydrate levels in the ‘Concord’ grape plant and is associated with mutual shading of leaves on vines of high foliage density (12, 16). This problem can be alleviated by cultural practices which provide greater exposure of leaves to sunlight (12).

This study was initiated to investigate the effect of the Modified Munson system (MM system), which is a double curtain training system for grapes, and the 4-arm Kniffin training system on uneven ripening, yield, and soluble solids content of ‘Concord’ grapes.

Materials and Methods

During the winters of 1966-67 and 1967-68, own-rooted ‘Concord’ vines planted on a 12 x 10 ft spacing were balanced pruned (30 + 10 and yielded 6 to 7 lb of pruning per vine) and trained to either the MM or the 4-arm Kniffin training systems. The MM system was a modification of the system advanced by Munson (7) and was constructed as described by Shoemaker (15) except the canes were trained on 2 wires rather than 4. It consisted of training the 4 canes of each plant on 2 parallel wires, 2 canes per wire with each of the 2 canes trained in opposite directions along the wire (Fig. 1). The 2 wires were positioned 5 to 5 1/2 ft above the vineyard soil surface and 4 ft apart. They were held in position by a fixed 2 x 4 inch piece of wood 48 inches long which was secured to a post 5 ft in height. As the grape shoots grew a curtain of foliage was formed along both sides of each wire and an open area was left between the wires which

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Fig. 1. Diagramatic sketch of a Concord vine trained to the MM system.

seemed to allow for excellent penetration of sunlight. The shoots were not positioned. This system differs from the Geneva Double Curtain (GDC) system (13), in that 4 canes were retained per plant and each trained along the 2 wires as previously described. This allowed for the establishment of the double curtain effect without the alteration of vines to the left and right wires as is the case with the GDC system (13). The 2 x 4 inch cross supports which carried the wires were fixed and could not be moved vertically as in the GDC system (13). The 4-arm Kniffin system was constructed as described by Larsen et al. (5).

Berry samples (200 berries per sample) were taken at random at weekly intervals beginning approximately one month before harvest. To minimize bias, each sample was collected without viewing the clusters. Following collection, the berries from each sample were weighed and visually graded into the following color categories: 1) purple, 2) red to reddish purple, or 3) green. The samples were then frozen at −20°C until ready for analysis.

Per cent soluble solids was determined for each sampling date by macerating the entire sample for 5 min. in a Waring Blender. Readings were obtained from 4 subsamples from each sample with a Bausch and Lomb low range hand refractometer and averaged.

Anthocyanin determinations were made by extracting 100 ml of the sample 3 times with 50 ml aliquots of methanol and then filtering over Whatman No. 1 filter paper. The filter paper was washed clear of anthocyanins and the methanol was combined with the 150 ml previously obtained. Each sample was cooled overnight, to allow for precipitation of colorless suspended material and refiltered. The filter paper was washed with additional methanol, which was combined with the sample extract, and the volume brought to 200 ml with methanol. Four 10 ml sub-samples from each sample were acidified to 1% with concentrated HCl. The optical densities were immediately read on a Bausch and Lomb Spectronic 20 spectrophotometer at 520 nm and averaged. The absorbance peak was predetermined by reading a sample on a recording spectrophotometer. The data were converted from absorbance to ppm delphinidin 3, 5-diglycoside equivalent using log S = 4.37 as described by Swain (17) and the quantitative value converted to ppm. Delphinidin 3, 5-diglycoside is one of the predominant pigment groups in 'Concord' grapes (14).

At harvest the average number of berries per cluster was determined by randomly selecting 100 clusters from each vine and counting the number of berries per cluster. Per cent fruiting shoots per vine was obtained by count-
ing the number of shoots with clusters and dividing this figure by the total number of shoots. The number of clusters per shoot was determined by counting the total number of clusters per vine and dividing by the total number of shoots on that vine.

Leaf area per kilogram of fruit was determined by the method of Sparks and Larsen (16).

The experimental design was a randomized block design with 7 replications. A single plant constituted the experimental unit. The experimental plots were encompassed by border plantings to eliminate any extraneous variation due to border effect. All data were subjected to analysis of variance.

RESULTS AND DISCUSSION

Leaf area per kilogram of fruit. The MM and 4-arm Kniffin systems produced comparable leaf area per kilogram of fruit during both years of this study (Table 1). These ratios were lower for both systems in 1968 than in 1967 (Table 1).

Uneven ripening. During the 2 years of this study, vines trained to the MM system produced fruit that ripened more evenly than did fruit harvested from vines trained to the 4-arm Kniffin system (Table 2). In 1967, about 95% of all fruit obtained from vines trained to the MM system were purple in color, the remaining fruit were either green or red to reddish purple (Table 2). A lower percentage of purple fruit were harvested from vines trained to the 4-arm Kniffin system in comparison to the MM system of training while a significantly higher percentage of red and green fruit were obtained. In 1968, the same trends were evident.

There were no differences, between years, in either color category of fruit harvested from the 4-arm Kniffin system nor were there differences between years in the percentage of purple berries produced on vines trained to the MM system (Table 2). There was a significant increase in the percentage of green fruit in samples harvested from the MM system in 1968, over that obtained for the same system in 1967, indicating a greater degree of evenness of ripening in 1967 than in 1968. This increase in green fruit in 1968 occurred at the expense of the red to reddish purple berries since there was a significant reduction in the latter in 1968 as compared to 1967.

The advantage of the MM system in increasing uniformity of ripening is also reflected in the pigment content of fruit sampled from the two training systems (Fig. 2). During both years of this study, fruit harvested from vines trained to the MM system had a significantly greater pigment content than fruit from vines trained to the 4-arm Kniffin system. This difference increased with time. In 1968, the same trends were evident as in 1967 except that initial color development occurred approximately one week later than in 1967. There was considerable variation in pigment content between years in fruit harvested from both training systems.

A possible explanation for the increased uniformity of ripening which occurred in fruit grown on vines trained to the MM training system is that the development of anthocyanin compounds is dependent upon the total carbohydrate pool from which precursors are derived (1, 4). Since anthocyanins are secondary compounds, they will form when the precursor needs of the more primary biosynthetic processes are met (4). The total quantity of these precursors is proportional to the total quantity of carbohydrates produced; the larger the carbohydrate pool, the greater are the chances of maintaining a precursor pool large enough to supply both the primary and secondary biosynthetic needs adequately.

GDC trained vines are reported to be superior to umbrella Kniffin trained vines due to a reduction in the mutual shading of leaves thus affording better leaf ex-

Table 1. Leaf area (M²)/kg fruit on Concord grape vines trained to the MM and 4-arm Kniffin systems for the 1967 and 1968 growing seasons.

<table>
<thead>
<tr>
<th>Year</th>
<th>Leaf area (M²)/kg of fruit *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Modified Munson</td>
</tr>
<tr>
<td>1967</td>
<td>1.20a</td>
</tr>
<tr>
<td>1968</td>
<td>.90b</td>
</tr>
</tbody>
</table>

\*Means followed by the same letter in rows or columns are not statistically different at the 5\% level of probability.

Table 2. Per cent green, red to reddish purple, and purple berries per sample at harvest as affected by the MM and 4-arm Kniffin training systems.

<table>
<thead>
<tr>
<th>Training system</th>
<th>Purple berries (% )</th>
<th>Red to reddish purple berries (%)</th>
<th>Green berries (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Munson</td>
<td>95.3a</td>
<td>97.0a</td>
<td>4.6c</td>
</tr>
<tr>
<td>4-arm Kniffin</td>
<td>85.2b</td>
<td>86.7b</td>
<td>8.2e</td>
</tr>
</tbody>
</table>

\*Means followed by the same letter (in rows or columns) are not statistically different at the 5\% level.

Fig. 2. Influence of the MM and 4-arm Kniffin training systems on pigment content of Concord grapes.

posing more efficient photosynthesis per unit leaf area (12). The same would be expected to be true for the MM system which produces a comparable curtain effect. This phenomenon is supported by the leaf area/fruit ratio data which shows that the MM system produced a leaf area/fruit ratio comparable to the 4-arm Kniffin system during both years of this study, but produced berries with higher soluble solids, a greater pigment content, and more evenness of ripening than the latter system (Table 1, Fig. 2, Fig. 3). This would suggest that the leaves were better exposed on vines trained to the MM system, thereby increasing photosynthetic efficiency per unit leaf area. The resultant increase in the carbohydrate pool should enhance anthocyanin synthesis and greater uniformity of ripening. The data for anthocyanin accumulation for each system over the 2 years supports this hypothesis (Fig. 2).

**Soluble solids.** Grapes produced by the MM system had a significantly higher soluble solids content than did those produced by the 4-arm Kniffin system (Fig. 3). These data are in agreement with those of Shaulis et al. (12).

In 1967, the difference in soluble solids content of fruit harvested from the 2 training systems remained the same on all sampling dates, thus this difference occurred prior to the first sampling date (Fig. 3). Soluble solids content of fruit from both training systems were still increasing at harvest. This would suggest that fruit were harvested too early; however, it is doubtful if fruit harvested from the 4-arm Kniffin system would have attained the same level of soluble solids as those harvested from the MM system since they showed no indications of increasing at a greater rate than fruit harvested from the MM system.

In order to determine the point in time at which soluble solids began to differ in fruit from vines trained to the 2 systems, sampling was begun one month earlier in 1968, and the 1968 harvest was made when the curves for soluble solids accumulation began to approach a maximum.

Earlier in the season soluble solids did not differ in grapes sampled from the 2 training systems, but a statistically significant difference did occur by the 4th sampling date, about 22 days before harvest (Fig. 3). However, a difference, not statistically significant, occurred one week earlier. This period roughly coincides with the period described by Shaulis, et al. (12), where the competition for light in a vigorous ‘Concord’ vineyard with umbrella training becomes intense and remains so until leaf fall due to a doubling of leaf area and the shoots becoming more pendant resulting in the formation of a dense canopy. This influence would be reflected more in the soluble solids content of fruit harvested from the 4-arm Kniffin system since there are fewer exterior shoots than would be found on curtain systems.

In 1968, soluble solids began to accumulate at a reduced rate in fruit collected approximately 8 days before harvest from both systems. There was no difference in soluble solids content between the last 2 sampling dates of fruit from vines trained to the 4-arm Kniffin system. However, soluble solids in fruit from vines trained to the MM system were still increasing on the date of harvest but at a reduced rate than in previous weeks (Fig. 3). Possibly if harvest had been delayed another week greater differences would have been obtained between the 2 systems, but due to the initiation of bird damage harvest was necessary on this date.

The percentage soluble solids differed between years in fruit trained to both systems (Fig. 3). Soluble solids were 1% higher in 1967 than in 1968. A possible partial explanation for this difference would be the lower leaf to fruit ratio that existed in 1968 when compared to 1967 (Table 1). The lower leaf to fruit ratio would be expected to cause a reduction in soluble solids.

**Yield.** The effect of training system on total yield per plant as well as per shoot was statistically significant for both years of this study. The MM system was superior to the 4-arm Kniffin system (Table 3).

The components of yield for the 2 years revealed that increases in the per cent fruiting shoots per vine and clusters per shoot were responsible for the differences in yield between training systems during 1967. The yield difference between trellis systems in 1968 was due to the 2 previously mentioned factors plus an increase in cluster weight, resulting from an increase in the number of berries per cluster and berry weights (Table 3).

These data differ from those reported by Shaulis et al. (13) that gains in fruit maturation could be expected the first year of trellis conversion and increased yields could be expected thereafter. In this study increased yields were obtained the first year of trellis conversion and even larger yield differences the following year. A possible explanation for this phenomena would be that Shaulis et al. (13) compared the GDC system to the umbrella Kniffin system whereas in this study the MM system was compared to the 4-arm Kniffin system. The umbrella Kniffin system produced higher yields than the 4-arm Kniffin (11) thus the chances of increasing yields the first year of trellis conversion when a curtain system is compared to the 4-arm Kniffin are greater than if it were compared to the more efficient umbrella Kniffin system.

The 1968 increase in yield over the 1967 season in vines trained to the MM system agree with that reported by Shaulis, et al. (13). A possible explanation for this increase in yield would be that those vines trained to the MM system entered the 1968 season in a better carbohydrate nutritional condition than in 1967. This could have been due to the greater total carbohydrate production which resulted in these curtain trained vines during 1967, since the curtain training system reduces the shading effect within vines resulting in more efficient photosynthesis per unit leaf area (12). Partridge (9) suggested that the carbohydrate content of the cane in the spring of the year influences the number and size of clusters formed; thus one might explain the increase in berries per cluster in 1968 on this basis. Possibly the increase in the number of clusters per shoot which was responsible for the increased yields obtained between training systems in 1967, was due to the same phenomena. It would seem from

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**Table 3.** The components of total yield of Concord grapes, as affected by the Modified Munson and 4-arm Kniffin systems.

<table>
<thead>
<tr>
<th>Category</th>
<th>1967</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Components of yield</strong></td>
<td>1967</td>
<td>1968</td>
</tr>
<tr>
<td>(a) Fruiting shoots (%)</td>
<td>99.5</td>
<td>99.8</td>
</tr>
<tr>
<td>(b) Clusters/shoot (no.)</td>
<td>2.5</td>
<td>2.4</td>
</tr>
<tr>
<td>(c) Cluster weight (g)</td>
<td>114.6k</td>
<td>146.7l</td>
</tr>
<tr>
<td>(1) Berries/cluster (no.)</td>
<td>36.5n</td>
<td>47.3o</td>
</tr>
<tr>
<td>(2) Berry weight (g)</td>
<td>3.2p</td>
<td>3.1p</td>
</tr>
</tbody>
</table>

*Means followed by the same letter in rows are not statistically different at the 5% level of probability.
these data that carbohydrate content in the canes must be higher to obtain an increase in berries per cluster than an increase in clusters per shoot.

**Literature Cited**


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**Noninfectious Bud-failure in Almond, a Nontransmissible Inherited Disorder. III. Variability in BF Potential Within Plants**

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*Abstract.* Source of buds within individual trees was studied in relation to development of noninfectious bud-failure (BF) in almond. Buds were collected from upper and lower portions of phenotypically normal seedling trees of populations where BF potentiality existed. Comparison of propagated trees over a period of 7 years showed that differences existed in BF potential between upper and lower parts of the tree but not among buds from the same budstick. The differences between location suggested random changes in BF potential occurred within the bud source trees.

Noninfectious bud-failure (BF) in almond is a bud-perpetuated, hereditary disorder that produces a distinctive phenotype characterized by lack of viable buds and production of roughened bark. Variability exists in severity of expression within single trees and within clones (10). Different levels of BF are not only bud-perpetuated but are also genetically transmitted (5). In addition, buds from phenotypically normal trees can produce BF trees. This indicates that BF potentiality can exist within trees that do not exhibit identifiable symptoms. Wilson (10) has shown that the percentage of BF trees within a clone can increase with consecutive vegetative propagations, indicating a progressive phenotypic shift from normal to BF within the clone.

Kester (4) found that the numbers of BF affected individuals in particular seedling (S generation) populations arising from BF parents increased each year continuing into the S + 1 generations (i.e., first scion generation). This result suggested that many of the phenotypically normal plants had BF potentiality and would eventually express the BF phenotype. BF potential can be expressed by the age at which BF appears in a tree, the severity when it does appear and the percentage of trees producing BF originating from the same bud source. Continuous change in BF potential, perhaps beginning with the zygote, was indicated. The critical level at which BF symptoms were manifested was not attained in many plants until trees were grown into the S + 1 generation. It was postulated that more trees would develop BF in further scion generations.

This pattern of change is similar to those which have been described as juvenile to mature changes (3). Different parts of a seedling plant can vary in ontogenetic age and different growth forms can be perpetuated by selecting propagating material from different parts of the same