

Gibberellic Acid for Table Grape Production

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History of Gibberellins

Although the gibberellins were well studied and isolated for agricultural uses by American and British scientists in the 1950's, they were first discovered by Japanese scientists investigating the phenomenon of abnormal elongation of rice. The scientists observed that affected plants grew taller than other plants in the field, but often became unhealthy and sterile. Japanese rice farmers called the disease, which seriously lowered the yield of rice crops throughout the Asian continent, *bakanae* or "foolish seedling" disease. In 1926, plant pathologists investigating the disease discovered that the causal agent was a fusarium-like fungus called *Gibberella fujikuroi*. However, it was later discovered that it was not the fungus itself, but a chemical secreted by the fungus that stimulated shoot elongation. The chemical was isolated and called gibberellin, after the fungus *G. fujikuroi*. In the 1930's

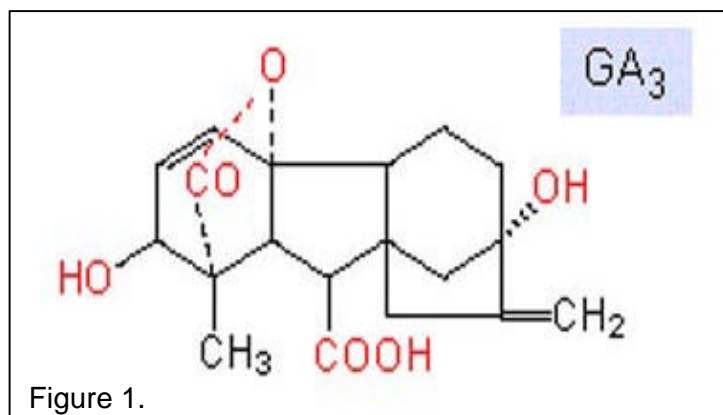


Figure 1.

Japanese scientists succeeded in obtaining impure crystals of two fungal growth-active compounds, which they named gibberellin A and gibberellin B. However, due to language barriers and the breakdown of communication during World War II, news of the discovery did not reach the west until the 1950's.

Today, we know that the gibberellins are a class of chemical (hormones) naturally occurring in all plants. There are more than 110 different gibberellins (GA₁, GA₂,....GA₃, GA₄,....GA₁₁₀) that differ relatively little chemically but greatly in their biological activities. Active gibberellins show many physiological effects depending on their structure as well as the species of plant (Table 1.). Gibberellins are primarily known for controlling cell division and elongation, an exciting discovery that would affect many agricultural commodities including grape.

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Uses of Gibberellin for Table Grape Production

The form of gibberellin commercially manufactured for grape production is GA₃, commonly called gibberellic acid (Figure 1.). The effects of gibberellic acid (GA) were first examined on grape by UC Davis viticulture professor Robert Weaver in the late 1950's. Weaver's research on Thompson Seedless led to a discovery that would revolutionize the table grape industry; GA applications at fruit set significantly increase the berry size of seedless grapes. Today we know that GA increases berry size by enhancing pericarp cell division and expansion (Table 4.).

By the mid 1960's, it was further discovered that applying GA during bloom could thin flower clusters and improve fruit set. Yet, how GA works as a thinning agent is not well understood. Over the last four decades, several hypotheses have been proposed to explain the mechanism of GA stimulated thinning (Table 3.). The first states that GA acts as a pollenicide, or that it interferes with pollen germination or pollen tube growth. This hypothesis developed early on when researchers reported that GA reduced pollen viability in both

seeded and seedless cultivars. However, recent work has suggested that pollen germination is not reduced by GA concentrations normally applied during bloom for thinning clusters.

The second hypothesis is based on relative concentrations of GA to other hormones such as cytokinins and auxins. Some researchers have proposed that GA applied at bloom alters the endogenous balance of hormones in the berry, causing flower abscission to occur. Proponents of this hypothesis state that elevated levels of GA promote thinning while cytokinins promote fruit set. Since very little is known about the hormone regulation within berries, evidence of this mechanism is not available.

The final hypothesis suggests that GA induces nutrient or carbohydrate competition between flowers and shoots, or among individual flowers in a cluster. One version of this hypothesis is that GA stimulates shoot growth, thereby diverting nutrients away from developing berries. Another version states that GA stimulates nutrient competition between berries within a cluster by inducing rapid cell division and expansion at set. Thus, the larger berries become stronger sinks for nutrients and carbohydrates and the smaller, weaker berries abscise because they cannot effectively compete.

Varietal Response to GA Varies

Not all varieties respond similarly to GA applications. Some varieties, such as Perlette, are unresponsive to applications made at bloom. Because Perlette does not respond to chemical thinning, the clusters must be thinned manually. Workers comb each cluster separately by hand using small plastic scalp brushes until approximately 65-75% of the flowers are removed. Sometimes several passes through the vineyard are required in order to brush all of the clusters at the proper stage of development. Other varieties are extremely phytotoxic to GA. For instance, Fantasy Seedless vines treated with GA exhibit foliar toxicity, berry and cluster abscission, reduced cluster size and number the following year. Recently breeders have been focusing their efforts on production of new varieties that have naturally large seedless berries and require very small concentrations of GA to improve berry size and quality to reduce production inputs.

In contrast to seedless cultivars, GA does not significantly increase the berry size of seeded varieties. It has been shown repeatedly in field experiments that seeded cultivars such as Carignane, Tokay, Ribier and Red Malaga have failed to increase berry weight with applications of GA. In addition, research on Red Globe during the mid-1990's indicates that whole-vine GA applications (20 g/ac) at set have little to no effect on berry size and only a 10% increase in size could be obtained with a cluster dip application (40 g/ac). The lack of response is generally attributed to the presence of seeds, and their effects on endogenous GA levels (i.e. seeds produce GA which help size the fruit). It was reported in 1960 that the extent to which berry size increases in response to exogenous GA is dependent upon the number of seeds present. Generally, berries with fewer seeds respond positively to exogenous applications, and prior work has shown that no increase in berry weight is achieved in berries above 3 seeds. Since seeds are reported to be natural sources of endogenous gibberellin, it is likely that exogenous applications of GA compensates for the lack of seeds.

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Drawbacks of GA

While GA increases berry size, it has also been shown to retard color development.

Earlier work has shown that an increase in GA application rates during berry set from 16 g/ac to 64 g/ac resulted in a 40 % increase the berry weight of Flame Seedless, but reduced

harvestable fruit by 30 % due to inadequate color development

(Figure 2.). Although this phenomenon is not well understood, it is thought that the reduction in color development may be due to GA induced inhibition of key enzymes in anthocyanin (pigment) synthesis.

Gibberellin inhibition of these enzymes has been shown in cell suspension cultures of carrot, pea internodes and radish seedlings. However, further work is required to understand how GA effects color development in each variety, why some varieties are more sensitive than others and which pigments are involved.

Along with a reduction in color development, high rates of GA has further been associated with other vine and fruit quality problems such as poor budbreak, smaller cluster size and number the year following treatment, increased bunch rot, delayed maturity and post-harvest shatter.

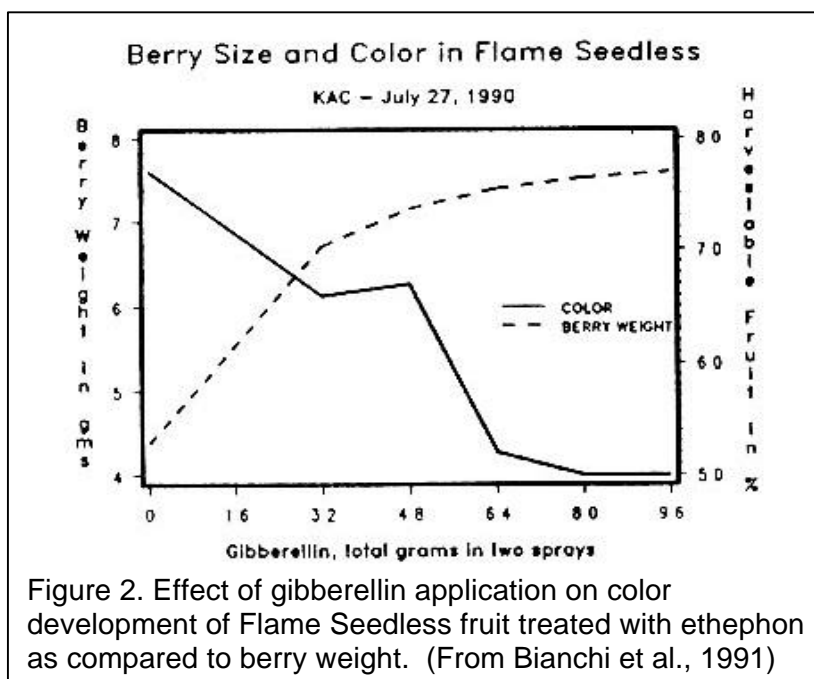
Conclusions

Research on GA for use on grapes revolutionized the table fruit industry by significantly increasing the size of seedless grapes. Since the introduction of GA for commercial use, domestic demand for table grapes shifted from seeded to seedless cultivars, and today 71% of American consumers prefer seedless grapes. Research continues on the physiological effects of GA as new table grape varieties are released and new developments are being discovered as other growth regulators are tested for use on table grapes. For example, CPPU (forchlorfenuron), a synthetic cytokinin, is currently being studied for use on grape when GA cannot be applied because varieties are either GA sensitive or unresponsive.

The typical vine response and a summary of common GA rates for thinning and sizing white, red and black seedless table grapes in California are presented in Tables 5, 6 and 7.

El CPPU, bajo las condiciones de California, será muy difícil usarlo en las var. de color. En Chile, ensayos en Crimson (grave daño al color), como también en Red Globe's de el Norte, donde el diferencial térmico es bajo ($T^{\circ} \text{Max} - T^{\circ} \text{min}$).

The expertise of Fred Jensen, Don Luvisi, Nick Dokoozlian, Bill Peacock and other farm advisors and specialists that contributed to the research on gibberellic acid for table grape production and agencies such as the California Table Grape Commission who have provided funding for research in this area are gratefully acknowledged.



Por esto el color en ensayos en Crimson, se afecta al usar altas concentraciones de citoquinina orgánica o CPPU + Gib.

Table 1. Effects of Gibberellins and Plant Development

- More than 110 GAs have been isolated and identified
- Stimulates cell division and cell elongation
- Increases cell wall extensibility
- May induce the import of carbohydrates to organs treated with gibberellins
- Can cause parthenocarpic (seedless) fruit development
- Promotes fruit set
- Can delay senescence in leaves and citrus fruits
- Breaks seed dormancy in some plants, which require cold or light to induce germination. This may occur in several ways:
 - Activates vegetative growth of embryo
 - Weakens the growth-constraining endosperm layer surrounding the embryo
 - Mobilizes stored food reserves for embryo growth
- Influences floral initiation and sex expression
 - In cucumber, hemp and spinach plants, exogenous applications of GA promote the formation of staminate (male) flowers and GA inhibitors promote the formation of pistillate (female) flowers

Table 2. Uses of GA₃ In the Production of Seedless Table Grapes

- Increases rachis and lateral lengths of cluster
- Stimulates flower abscission (thinning)
- Berry enlargement
- Enhances/delays fruit maturity

Table 3. Possible Modes of Action by GA₃ on Berry Thinning

- Induces nutrient competition between flowers and shoots or between flowers within a cluster
- Alters the hormone balance within the berries to promote thinning
- Increases rachis/lateral length, giving the cluster a looser appearance

Table 4. Mode of Action by GA₃ on Increasing Berry Size of Seedless Grapes

- An increase in berry size of GA treated fruit will occur within 48 hours of application
- Increases cell division
- Increases cell wall diameter and length
- May increase sink strength of clusters to carbohydrates

Table 5. Common GA Rates for Thinning and Increasing the Fruit Size of White Table Grapes in California

Variety	GA rates for thinning (grams/ac)	Number of bloom-time applications	Application Timing (% Bloom)	Comments	GA rates for sizing (grams/ac)	Number of applications for sizing fruit	Timing of 1 st application (mm in berry diameter)	Comments
White								
Perlette	Not Recommended	0	Not Recommended	<ul style="list-style-type: none"> Perlette does not respond to GA at bloom time. Thinning occurs by physical rather than chemical means. Clusters are brushed by hand to remove approximately 65-75% of the flowers. 	40 - 60	2 - 3	5	<ul style="list-style-type: none"> High rates may delay fruit maturity and reduce fruitfulness the following year.
Princess	0.5 - 1	1	85 - 90%	<ul style="list-style-type: none"> Rates >1g/ac may result in excessive thinning and reductions in yield. GA at bloom increase berry weight 20%. GA at bloom + size girdle increase berry weight 40%. 	Not Recommended	0	Not Recommended	<ul style="list-style-type: none"> Berry sizing sprays reduce cluster number and cluster size the following year. The recommended program for an increase in berry size is GA at bloom + size girdle.
Thompson Seedless	8 - 16	2 - 3	50 – 85%	<ul style="list-style-type: none"> The period during 30 to 80% bloom may pass in as little as two days during hot weather or may last for several days during cooler weather. Two applications of GA may be applied to decrease flower set. The first is applied at 50-60% bloom and the second made at 80-90% bloom. 	40 - 60	2 - 3	4 - 5	<ul style="list-style-type: none"> High rates increase shatter and reduce fruitfulness the following year.

Table 6. Common GA Rates for Thinning and Increasing the Fruit Size of Red Table Grapes in California

Variety	GA rates for thinning (grams/ac)	Number of bloom-time applications	Application Timing (% Bloom)	Comments	GA rates for sizing (grams/ac)	Number of applications for sizing fruit	Timing of 1 st application (mm in berry diameter)	Comments
Crimson Seedless	1	1	85 - 90%	<ul style="list-style-type: none"> Rates >1g/ac may result in excessive thinning, shot berry and reduced fruitfulness the following year. 	Not Recommended	0	Not Recommended	<ul style="list-style-type: none"> GA Rates >20 g/ac cause foliar toxicity and reduce bud break and fruitfulness the following year. High rates of GA at fruit set reduce berry color and increase post-harvest shatter. GA rates below 20 g/ac do not consistently increase berry size.
Flame Seedless	4 - 12	2	50 - 85%	<ul style="list-style-type: none"> Two applications of GA may be applied to decrease flower set and improve uniformity. 	40	2 - 3	5 - 9	<ul style="list-style-type: none"> High rates reduce color development and delay maturity.
Ruby Seedless	1		85 – 90%	<ul style="list-style-type: none"> Rates >1g/ac may result in excessive thinning and shot berry. 	16	1	10	<ul style="list-style-type: none"> Color development, increased bunch rot, delayed maturity, increased shatter, and reduced vine fruitfulness varies widely from year to year and is aggravated by GA sizing applications. Timing = berry set + 10 days.
Red Globe (seeded variety)	Not Recommended	0	Not Recommended		40 – 50 ppm	1	15 - 16	<ul style="list-style-type: none"> Cluster dip applications are effective for increasing berry size. Whole vines sprays < or = 16 g/ac have little to no effect on berry size. Response to GA depends on number of seeds in berries. GA applications retard color development.

Comentarios sobre situación en Chile.

Sí, así se evita el exceso de raleo y el escobajo rígido.

Si se recomienda, pero dirigido.

- 1 o 2 de 20 ppm.
- 1° 6-7 mm (Así se evita escobajo rígido y desgrane).
- 2° 9-12 mm

La inmersión en Chile también es mas efectiva.

Table 7. Common GA Rates for Thinning and Increasing the Fruit Size of Black Seedless Table Grapes in California

Variety	GA rates for thinning (grams/ac)	Number of bloom-time applications	Application Timing (% Bloom)	Comments	GA rates for sizing (grams/ac)	Number of applications for sizing fruit	Timing of 1 st application (mm in berry diameter)	Comments
Black								
Autumn Royal	1 - 2	1	85 - 90%	<ul style="list-style-type: none"> GA at bloom increases berry weight and length. May reduce the number and size of seed traces. 	Not Recommended	0	Not Recommended	<ul style="list-style-type: none"> GA has little effect on berry size and may reduce cluster size the following year.
Black Emerald	2 - 3	1 - 2	85 - 100%	<ul style="list-style-type: none"> Rates >3g/ac result in excessive shot berry and reduced fruitfulness the following year. Correct use and timing of GA can reduce set up to 30%. Overthinning and shot berry will occur if GA is applied prior to 50% bloom. 	20	1	4 - 5	<ul style="list-style-type: none"> Applications increase shatter at harvest as well as fruitfulness the following year. GA sizing spray may increase berry size up to 20%. GA sizing spray + girdle may increase berry size up to 40%.
Beauty Seedless	8-16	1 - 2	50 – 85%	<ul style="list-style-type: none"> Two applications of GA may be applied to decrease flower set. 	48	2	4 - 5	<ul style="list-style-type: none"> High rates of GA reduce color and delay maturity. Tends to have tight bunches.
Fantasy Seedless	Not Recommended	0	Not Recommended	<ul style="list-style-type: none"> GA is extremely phytotoxic to Fantasy Seedless. Vines treated with GA exhibit foliar toxicity, berry and cluster abscission. 	Not Recommended		Not Recommended	<ul style="list-style-type: none"> GA applications significantly reduce cluster number in the following season. GA should not be applied to Fantasy Seedless.
Summer Royal (cultural practices work in progress)	Not Recommended	0	Not Recommended	<ul style="list-style-type: none"> GA thinning sprays not required due to loose cluster architecture. 	10-20	1	Berry set	<ul style="list-style-type: none"> Based on preliminary results, GA + girdle at berry set increases berry weight by 13%. Unclear how GA size sprays will affect return fruitfulness.

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Influence of Crop Load on the Berry growth and Quality of Autumn Royal Table Grapes

Nick Dokoozlian, Steve Vasquez and Nona Ebisuda

Introduction

Autumn Royal is a late-maturing black seedless table grape developed by David Ramming and Ron Tarailo of the USDA-ARS in Fresno, CA. The cultivar, formerly known and tested as USDA selection #A97-68, was released in 1996 and resulted from the cross of Autumn Black x C74-1. In addition to several USDA numbered selections, its parentage includes Blackrose, Calmeria, Flame Seedless and Ribier. The cultivar produces large, dark purple to black berries that ripen in late-September to mid-October. The commercial appeal of Autumn Royal rests on its large berry size and late maturity, as well as the fact that relatively few inputs are required for the production of high quality fruit.

Variable production among seasons has been reported as a potential problem with Autumn Royal, with cluster counts on the same vine often alternating dramatically between seasons. At present it is unclear whether or not large crops impact the return fruitfulness of this cultivar. Early work also suggested that crop load had a major impact on the vine performance and fruit quality. This work indicated that, compared to most table grape cultivars, the berry growth and anthocyanin or color accumulation of this cultivar were highly sensitive to crop load. The purpose of this three-year study was to determine the long-term effects of crop load on the yield, fruit quality and return fruitfulness of this cultivar.

Procedures

The experiment was established in 1999 on mature, own-rooted vines at the Kearney Agricultural Center in Parlier. The vines were quadrilateral-cordon trained and spur pruned, and trellised to the standard "T" system. Immediately following fruit set, vines were adjusted to crop loads ranging from 5 to 30 clusters per vine in all three seasons. All clusters were tipped to a length of approximately 8" at this same time. All other cultural practices were performed as normal for the cultivar and region.

At harvest, one-hundred randomly selected berries were collected from each. A 25-berry subsample of each replicate was frozen (-20 C) for subsequent anthocyanin analyses. The remaining berries were counted and weighted, and their length and diameter recorded. The berries were then macerated in an electric blender, filtered through a paper towel, and the resultant juice allowed to settle for 30 minutes. An aliquot of each sample was then used for juice soluble solids and titratable acidity determinations.

At harvest all clusters were removed from the vine and visually assigned a quality grade (packable or cull). Clusters were assigned to the cull grade if quality defects could not be easily removed by thinning at harvest. Cull clusters were assigned to one of the following defect categories: poor color, bunch rot, or unacceptable appearance (excessive shot berries, poor berry set, or straggly rachis clusters). The weight of packable fruit and the fruit assigned to each cull category was recorded separately.

Results

The influence cluster number per vine on the total packable yield, mean cluster weight and number of boxes produced per acre over the three-year study are presented in Figure 1. Positive, linear relationships were found for cluster number per vine, total yield and the number

of boxes produced per acre. Few significant correlations between cluster number per vine and mean cluster weight were found.

Little correlation between total boxes per acre, berry weight and fruit soluble solids were found (Figure 2). A negative, linear relationship between color development and total boxes per acre was observed. Color development was the fruit quality parameter most affected by crop load, with the portion of clusters with acceptable color for harvest dropping below 70% of total yield when crop load exceeded 20 clusters per vine, approximately 40 pounds per vine or 800 22-lb boxes per acre.

Conclusions

Few correlations between crop load (either clusters per vine or total pounds of fruit per vine) and fruit quality parameters (berry weight, soluble solids) were found, with the exception of color development. Color development, measured by the number of clusters with acceptable color at harvest, showed a negative, linear correlation with crop load. The portion of clusters with acceptable color dropped below 75% of total yield when crop load exceeded 20 clusters per vine, approximately 40 pounds of fruit per vine (800 22-lb boxes per acre). Crop load had no effect on return fruitfulness over the three-year study.

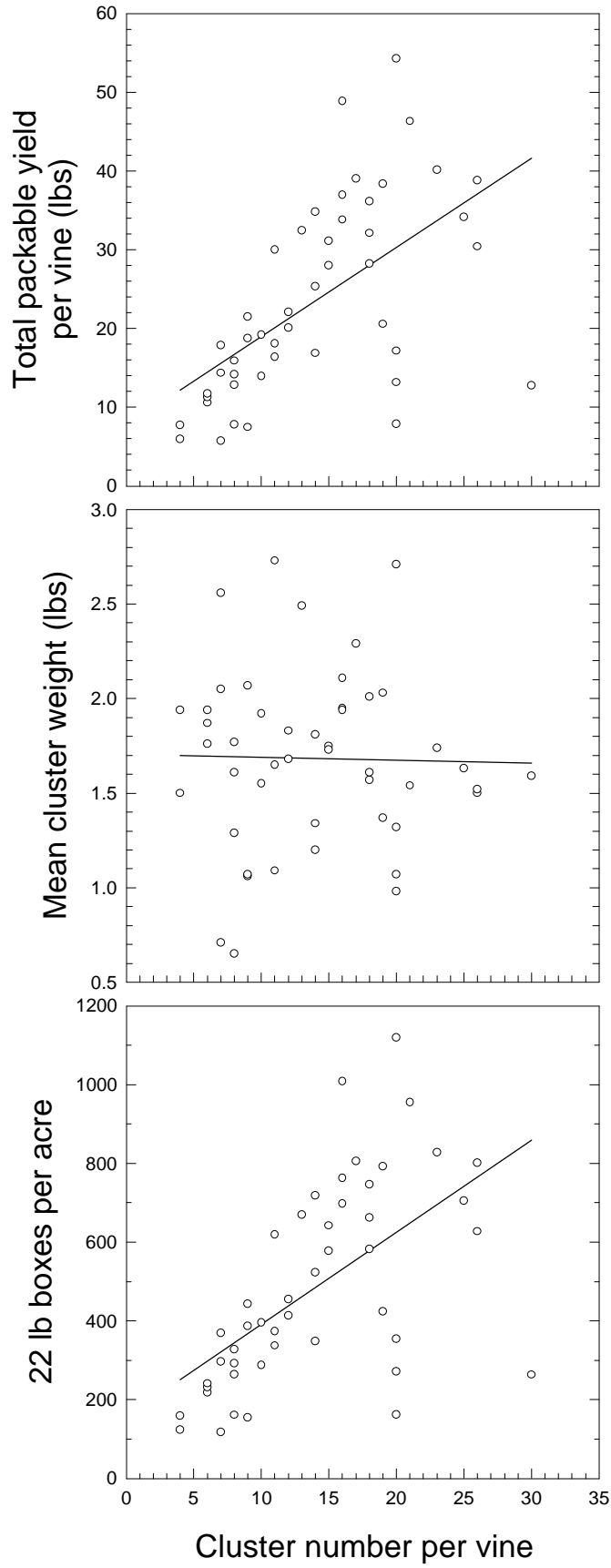


Figure 1

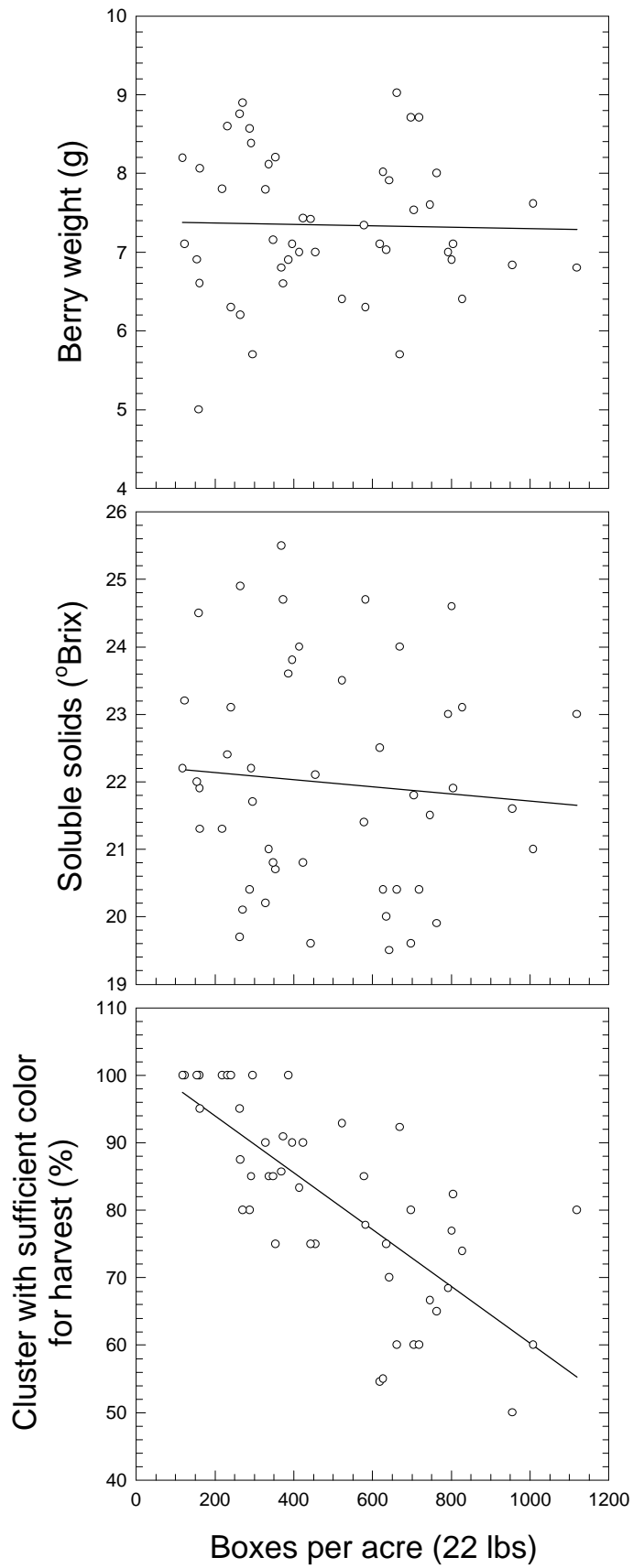


Figure 2

Disclaimer: Discussion of research findings necessitates using trade names. This does not constitute product endorsement, nor does it suggest products not listed would not be suitable for use. Some research results included involve use of chemicals which are currently registered for use, or may involve use which would be considered out of label. These results are reported but are not a recommendation from the University of California for use. Consult the label and use it as the basis of all recommendations.

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