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Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

Leaf sap brix and leafhoppers in vineyards

FINAL PROJECT REPORT

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Introduction

The advantages of practicing integrated pest management (IPM) with a "Plant Positive" rather than a "Pest Negative" perspective are becoming increasingly clear. As outlined by Eliot Coleman and many other capable deep agricultural thinkers, this Plant Positive perspective allows us to approach pest outbreaks with an emphasis on their basic causation, instead of simply treating the same old symptoms. On the other hand, we must be very cautious in presuming that simple cause and effect or predictive relationships can be delineated from single, although easily monitored, parameters in our complex agricultural ecosystems.

Recent research in the IPM Program at CSU Fresno on the effects of fertilizer type and amount on leafhopper population dynamics reflects a strong commitment to a "Plant Health" approach to IPM (Mayse et al. 1991). Results of a three-year field project showed that *Erythroneura* leafhopper densities were significantly greater on vines fertilized with synthetic ammonium nitrate compared with vines receiving compost fertilizer (Roy 1991, Garcia 1993). We further pursued the Plant Health line of research by investigating effects of irrigation practices on leafhopper populations. Higher leafhopper densities were found on vines receiving greater amounts of irrigation water (Trueta 1993). These results for cultural effects in IPM have been corroborated in similar research conducted recently by various University of California scientists (e.g., Drs. Kent Daane, Jeff Dlott, Larry Williams, Ted Wilson).

In 1991, around the time of developing plans for our irrigation studies, we learned that some organic agriculture consultants in California were promoting the use of Brix readings from leaf sap as a way of predicting potential leafhopper problems. According to the story being promoted, low Brix levels would indicate leafhopper danger, while high Brix levels mean the plant is well-protected against sucking insects. In fact, the 1993-94 issue of the Peaceful Valley Farm Supply Main Catalog (p. 54) stated that "a Brix reading above 12 indicates plant resistance to sucking insects." In the Natural Pest Management section of the Main Catalog (p. 68), the reader was further assured that "You can specifically discourage sucking insects in certain crops by building up plant Brix (sugar content) to the point that the plant sap is too thick for the insects to extract easily."

Additional enthusiasm for the Brix / leafhopper story came from an information sheet developed by Organic Ag Advisors (P.O. Box 1 622, Colfax, CA 9571 3) including tips for using the refractometer to measure plant Brix. In this how-to sheet, it was offered that "There is a definite and significant relationship between the plant Brix and it's [sic] attractiveness to sucking insects.... This phenomena [sic] has been personally verified for the following insects: aphids, spider mites, leafhoppers, [and five others]."

Naturally, this Brix / leafhopper story would be intriguing to anyone supporting the Plant Health perspective. Thus, as part of our irrigation study in 1992, M.S. graduate student Antonio Trias Trueta gathered preliminary data for both leaf sap Brix levels and leafhopper populations (Trueta 1993). He found that although leaf Brix readings stayed well below 12 throughout the season, leafhopper nymph densities nevertheless remained low < 5 per leaf) throughout the entire study. It seemed clear that it was possible to have relatively low Brix levels in leaf sap, and to also find low numbers of leafhoppers in the vineyard.

These preliminary findings began to discount the Brix / leafhopper story. There appeared to be virtually no empirical evidence to support this alleged Brix / leafhopper relationship. Thus, in 1994 we initiated a two-year field study of the potential for an inverse, predictive relationship between leaf sap Brix levels and *Erythroneura* leafhopper densities in San Joaquin Valley grape vineyards. Our primary objective was to rigorously evaluate the contention that high Brix levels in leaf sap (greater than 12) would lead to low leafhopper densities, while low Brix values would be associated with high leafhopper numbers in vineyards.

Study areas and methods

A total of eight vineyard field sites including four different grape cultivars were sampled for leaf sap Brix levels and leafhopper densities from mid-June to early October during 1994 and 1995. Vineyards studied in 1994 included the following (20+ acres each): 1) Barbera (organic) near Ripperdan in Madera County, 2) Grenache (organic) near Ripperdan in Madera County, 3) Carignane (Cal-York) in Madera County, and 4) Barbera (Cal-Jersey) in Fresno County. In 1995, vineyard field sites (all in Fresno County) included: 5) CSU Fresno Organic (6 acres), 6) CSU Fresno Conventional (6 acres), 7) Thompson seedless (organic, 20 acres) at Soghomonian Ranch 1, and 8) Thompson seedless (organic, 20 acres) at Soghomonian Ranch II. Thus, five of the eight vineyard sites in this study were farmed using organic production techniques.

Brix data were collected using temperature compensating refractometers to evaluate soluble solids in plant tissues. The Organic Ag Advisors information sheet recommended that newly mature leaves or petioles should be sampled, further directing that many growers take samples between 10AM and noon. Among the numerous Brix-related variables we investigated in this study were the following: leaf blade vs. petiole; young, mid-cane, and older leaves; edge (outermost five vines) vs. interior of vineyard (20+ vines from edge); and time of day for Brix sampling (6-8AM, 1OA-12N, 2-4PM, 6-8PM).

For leafhopper data collection, standard direct observation leaf sampling for detecting nymphal numbers on twenty leaves per plot on each date was conducted along with the Brix data collection. In 1994, leafhoppers were collected from the same vines which were used to gather Brix data, but during 1995 Brix data were taken from the actual leaves which were used for leafhopper nymph sampling. Although leafhopper nymphs (small 2nd-3rd instar, large 4th-5th instar) were distinguished by species (i.e., variegated leafhopper *Erythroneura variabilis* and western grape leafhopper E *elegantula),* leafhopper data are combined here for simplicity of analytical comparison.

Results and discussion

Brix data for plant sap extracted from leaf blade tissue and from grapeleaf petioles showed that leaf blades yielded consistently higher (i.e., up to double) values for Brix. Also, the range of Brix levels for leaf blades was consistently about twice the range found in petiole sap. Based on these findings in 1994, plant sap samples were taken only from leaf blades in 1995. Data presented here for both years are for leaf blade sap Brix values only.

Although not so distinct a difference as found with leaves vs. petioles, Brix levels detected in sap from young leaf tissue were consistently higher than in more mature leaves. Results suggest that numerically higher Brix values, as well as a wider diversity of readings throughout the season are likely to be associated with younger leaf tissue.

Sampling location in the vineyard (i.e., edge vs. interior) appeared to be a relatively unimportant variable with respect to leafhopper and leaf Brix data. Although Brix values were slightly lower in edge vines for two of the four vineyards sampled in 1994, Brix and leafhopper samples were taken solely from interior vines in the 1995 vineyard field sites.

Time of day exerted relatively little impact on leaf sap Brix values in this study. In CSU Fresno vineyard plots, Brix levels were consistently lower during the 6-8AM sampling period than the 10A-12N interval, while at the Soghomonian field sites this pattern was not demonstrated. Thus, although actual Brix values varied minimally among time of day intervals during 1995, it should be noted that the physical chore of taking a refractometer reading in the hottest, driest part of the day was quite challenging. If adequate sap amounts could be extruded, Brix levels from even the 2-4PM interval were generally similar to other sampling periods.

Combining all leafhopper data from the CSU Fresno Barbera vineyard for 1995 revealed a statistically significant higher "mean leafhopper nymph per leaf" count in conventional plots (4.6) compared with the organic plots (2.5). However, the practical biological significance of this finding is probably limited, since both mean values are small compared to an economic threshold of around 20 nymphs per leaf, and also since these plots have been under differential treatment (i.e., organic vs. conventional) for only two years.

Data for leaf sap Brix and *Erythroneura* leafhopper densities collected during 1994 and 1995 were analyzed and evaluated using several different approaches selected to elucidate any consistent and predictable patterns of relationship. Two of the most promising of these evaluative methods are used here for presentation of the Brix / leafhopper data.

The first method simply involves constructing figures with seasonal dates along the X-axis and including Brix levels and leafhopper nymph densities as double Y-axes. Data compiled using this method comprise the "A." portions of the eight figures presented here, with each figure representing a different vineyard field site during a given year.

According to the Brix / leafhopper story, one would expect that the Brix and leafhopper lines would demonstrate a roughly inverse complementarity (i.e., lines in A. portions of the figures should approximate mirror images). One possible limitation to this technique of data presentation could involve leafhopper generation patterns, although charting data through several months in the various vineyards during this two-year study should minimize the visual challenges posed by such expected population peaks and valleys.

To enhance the likelihood of detecting any predictive relationship between Brix and leafhoppers, an additional method of evaluating the data was selected. This second method for data presentation involves plotting leafhopper nymph densities (Y-axis) against the associated numerically sorted Brix values (X-axis), a technique which factors out the seasonal dates on which the correlative leafhopper and Brix data were collected.
The "B." portions of the eight figures presented here illustrate this second method of data presentation.

Using the second method of data analysis and based upon the inverse relationship alleged in the Brix / leafhopper story, one would expect that the regression line formed in the B. portions of the figures would generally run from the upper left to the lower right of each figure (i.e., from low Brix / high leafhoppers to high Brix / low leafhoppers). The methodology used in computing the average sorted Brix values used in this second data array precludes exact comparison of data points between the A. and B. portions of each figure, although patterns are naturally quite comparable.

Leafhopper and Brix data collected during 1994 are summarized in Figures 1-4. The pattern most consistent with the Brix / leafhopper story for 1994 is found in Figure 2 (Ripperdan Grenache vineyard). Although the general slope of the line illustrated in Figure 2B appears to support the alleged relationship, data in Figure 2A indicate that both low Brix / low leafhopper and high Brix / high leafhopper situations were recorded, in direct contrast to the story. Data for the other three vineyards sampled during 1994 (Figures 1, 3, 4) reveal essentially the opposite patterns from those predicted by the Brix / leafhopper story (i.e., slopes in B. portions of these figures run generally from lower left to upper right).

Data collected from four vineyard field sites during 1995 are summarized in Figures 5-8. Patterns at the CSU Fresno Barbera organic plots (Fig. 5A) appear to generally fit the Brix / leafhopper story, although the sorted Brix data (Fig. 5B) reveal that the trend from upper left to lower right is broken at both low- and mid-range Brix levels. These inconsistencies may be additionally explained by the upward trend in leafhopper densities during September 1995 which coincided with the highest Brix values of the season (Fig. 5A).

In the CSU Fresno Barbera conventional plots (Fig. 6), virtually all possible combinations of low and high Brix and leafhopper values were demonstrated. Thus the sorted Brix pattern in the conventional plots (Fig. 6B) revealed no clear support for the alleged relationship. As mentioned earlier, the fact that the differential production system treatments (organic vs. conventional plots) at CSUF had only been implemented for two years underscores the apparently high level of variability in expected patterns of Brix and leafhopper data in vineyards.

Data for the two organic Thompson seedless vineyards sampled during 1995 showed very similar patterns (Figs. 7, 8). Leafhopper counts generally declined from June to early July, while Brix values peaked in late June but then dropped sharply in early July (Figs. 7A, 8A). Sorted Brix data for the Soghomonian vineyards (Figs. 7B, 8B) provided no support for the Brix / leafhopper story; in fact, these data are essentially the opposite of the alleged predictive relationship.

Conclusions

Results compiled during this rigorous two-year empirical study of eight San Joaquin Valley vineyards (including five organic operations) provide no consistent support for the alleged predictive Brix / leafhopper relationship as it has been widely promoted in recent years. In only two of the eight vineyard field sites (Figs. 2, 5) were data patterns even moderately similar to those expected from the story. More importantly, data patterns for the other six vineyard sites were either in direct opposition (Figs. 1, 3, 4, 8) or essentially neutral (Figs. 6, 7) with respect to the alleged Brix / leafhopper relationship.

Although most farmers, agricultural consultants, and even academic researchers are beginning to recognize that grapevine nutritional status can certainly affect the population dynamics of leafhoppers and other pests, available evidence that leaf sap Brix levels alone can be used to reliably predict herbivore population changes is clearly less than compelling. Perhaps noteworthy is the fact that the 1996-97 Peaceful Valley Farm Supply Main Catalog (p. 53) suggested simply that "Plants with high (a Brix reading above 12) sugar content also have good 'immune systems.'" This statement is appropriately more cautious than the 199394 Main Catalog's (p. 54) broad assurance that "a Brix reading above 12 indicates plant resistance to sucking insects."

Acknowledgments

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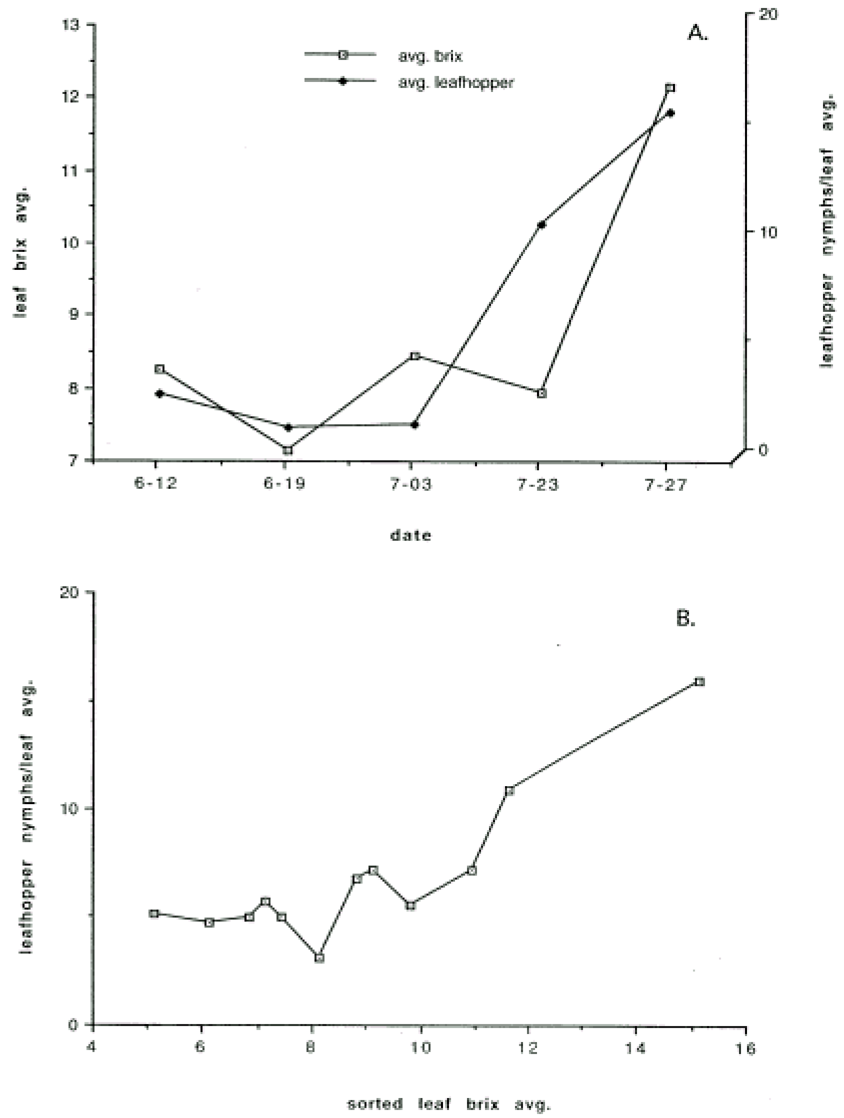


Figure 1. 1994 data from a Barbera vineyard (organic) near Ripperdan in Madera County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.

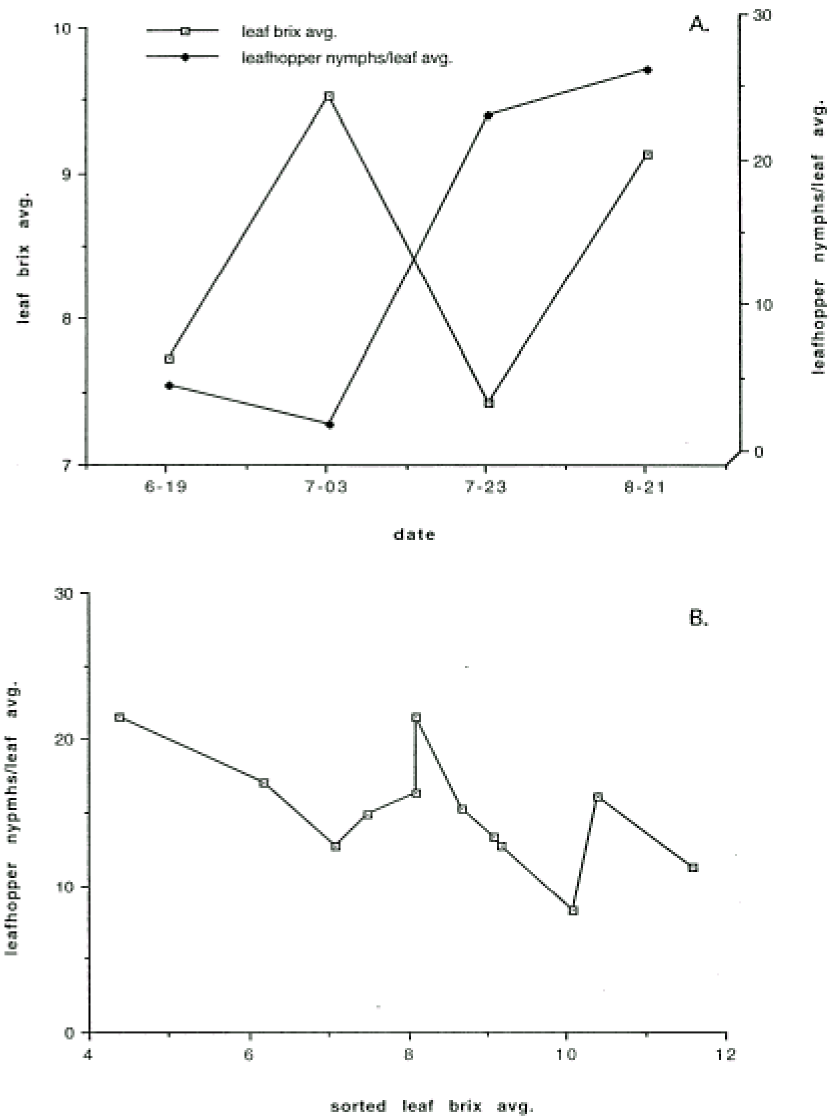


Figure 2. 1994 data from a Grenache vineyard (organic) near Ripperdan in Madera County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.

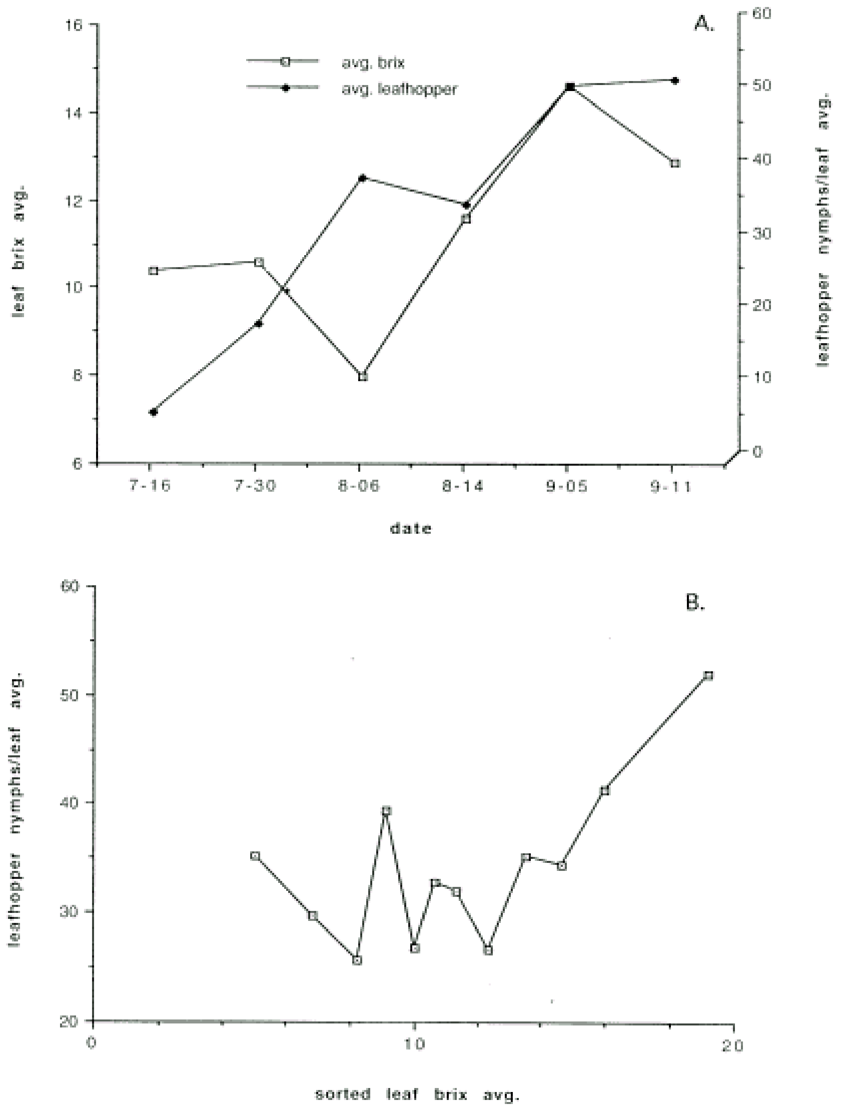


Figure 3. 1994 data from a Carignane vineyard (conventional) in Madera County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.

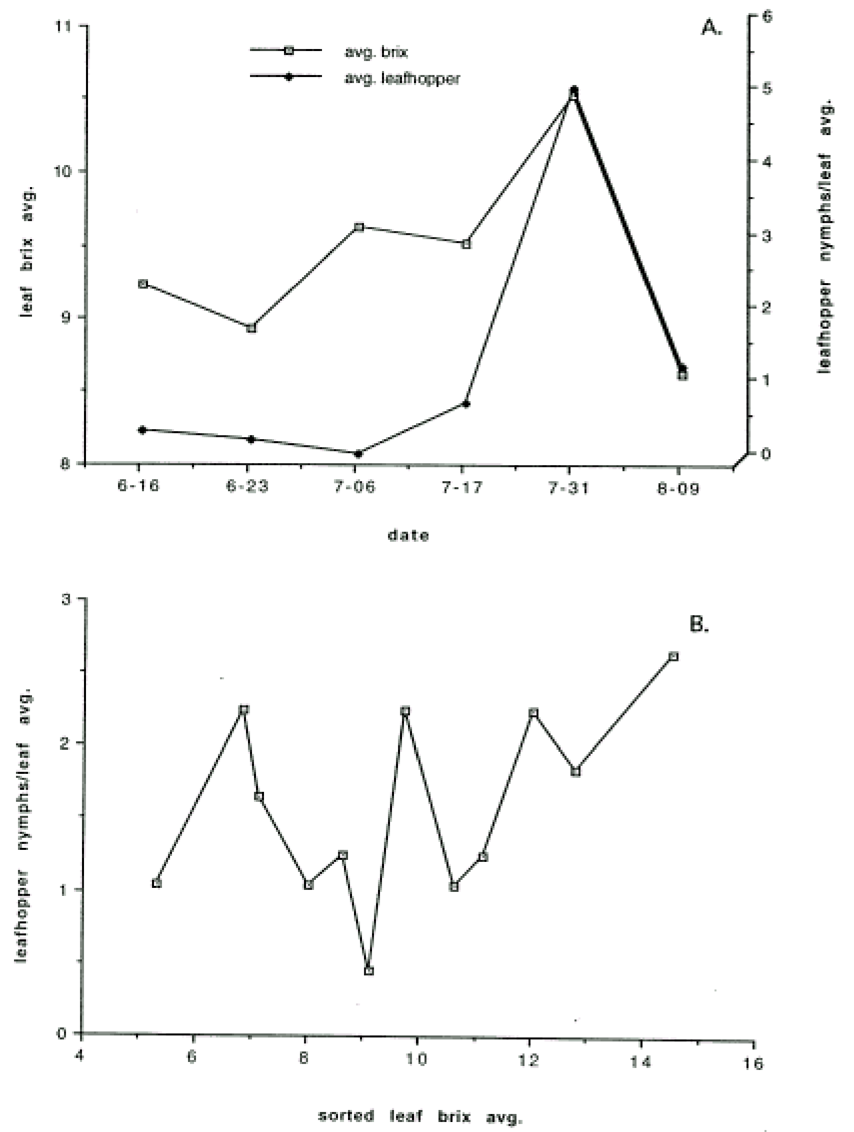


Figure 4. 1994 data from a Barbera vineyard (conventional) in Fresno County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.

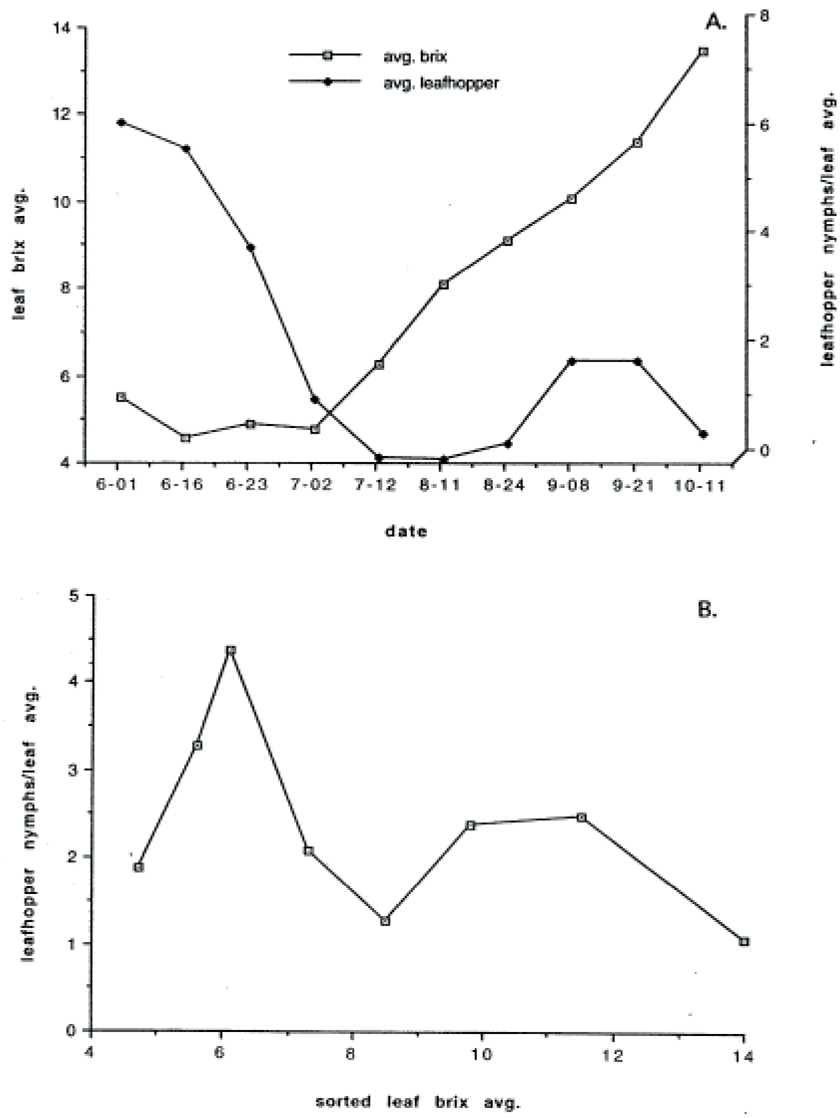


Figure 5. 1995 data from a Barbera vineyard (organic) at CSU Fresno in Fresno County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.

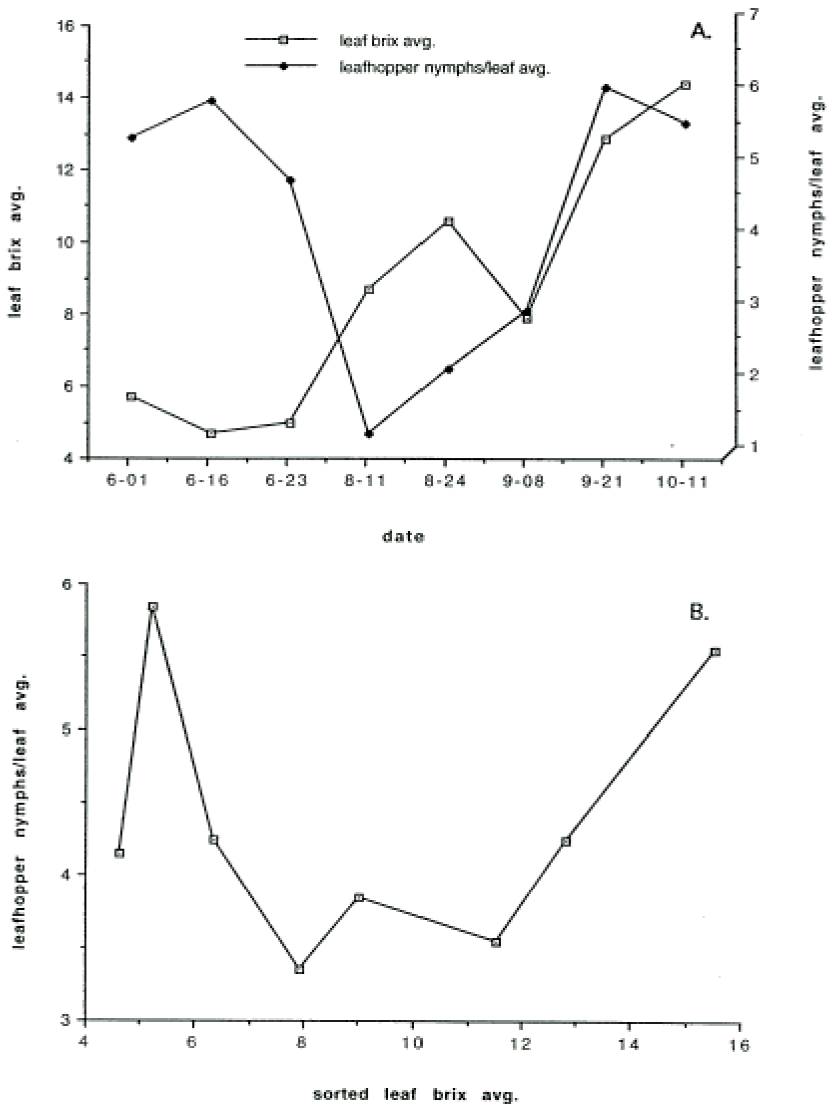


Figure 6. 1995 data from a Barbera vineyard (conventional) at CSU Fresno in Fresno County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.

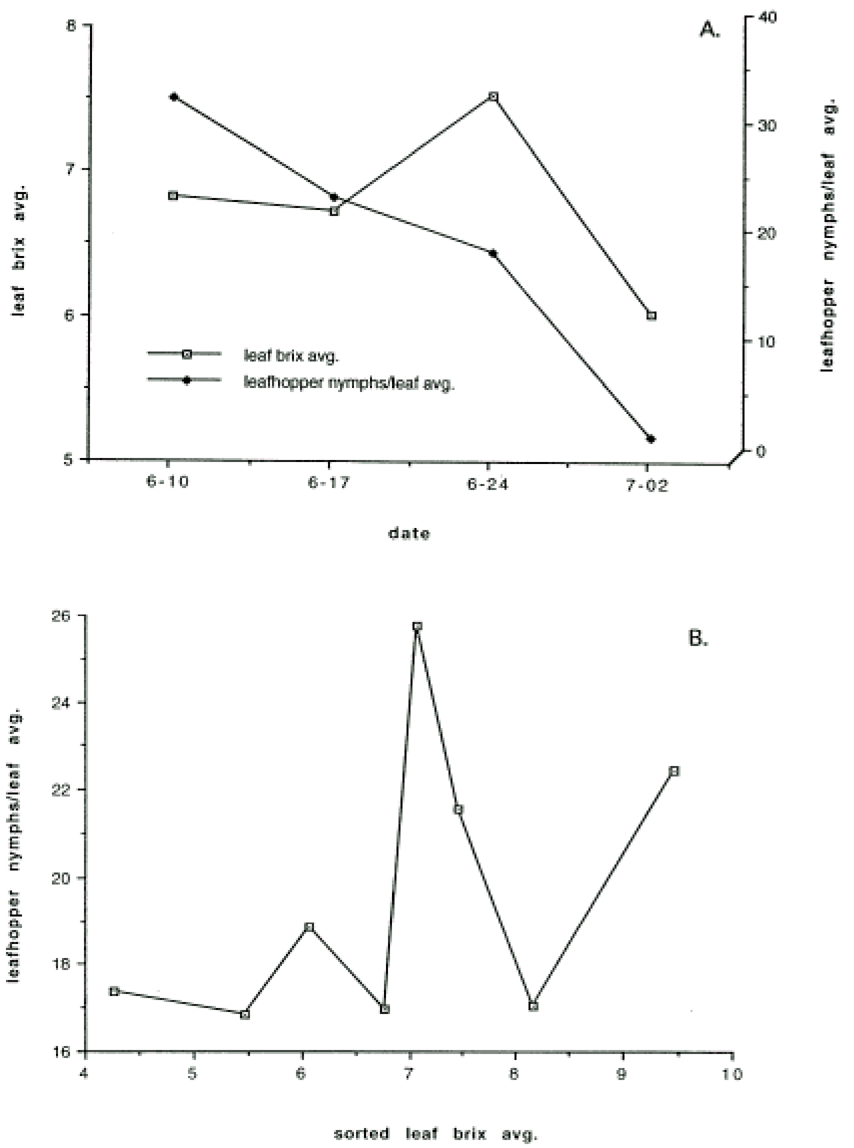
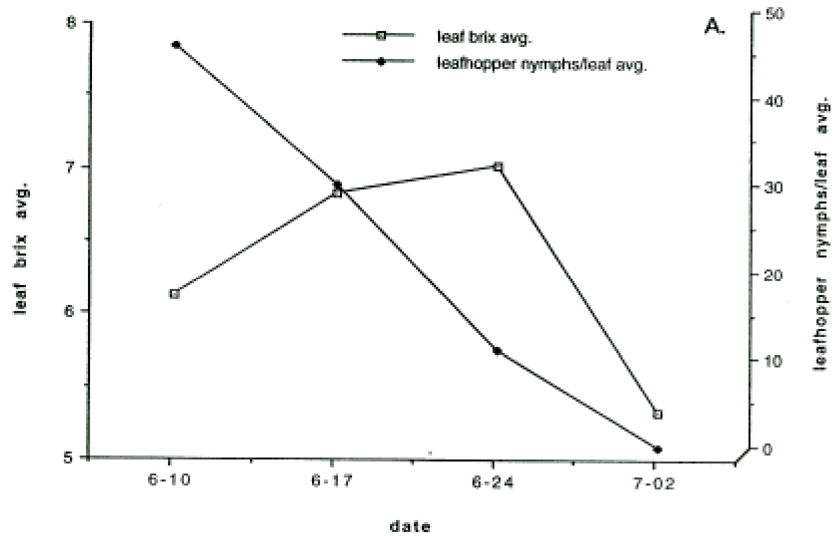


Figure 7. 1995 data from a Thompson seedless vineyard (organic, Soghomonian I) in Fresno County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.



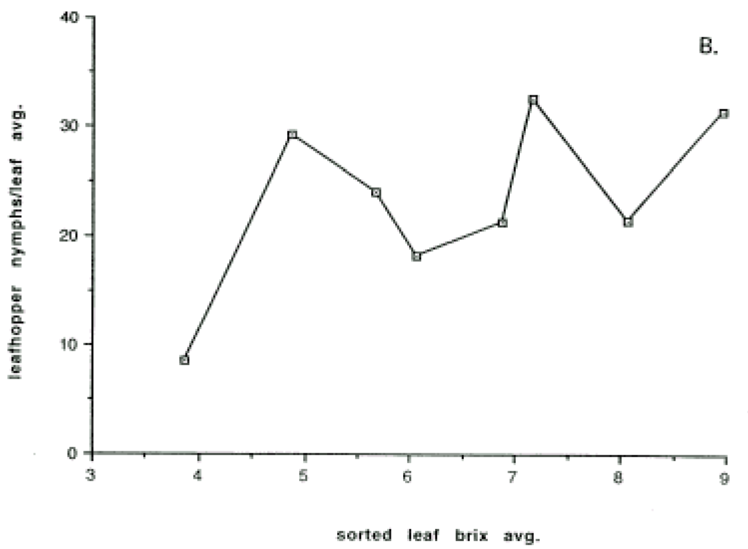


Figure 8. 1995 data from a Thompson seedless vineyard (organic, Soghomonian II) in Fresno County: A. Leaf sap Brix levels compared with *Erythroneura* leafhopper nymph densities. B. Brix readings sorted numerically (independent of date) and regressed against leafhopper counts.