EXAMINATION OF GLASSY-WINGED SHARPSHOOTER ENTRY POINTS OF A HIGH-RISK VINEYARD IN THE TEMECULA VALLEY

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ABSTRACT
During the 1997-1990 Pierce's disease (PD) epidemic in Temecula, the Weaver vineyard had relatively modest losses in Chardonnay grapevines, while neighbors lost 100%. The Weaver vineyard is near citrus and therefore supposedly vulnerable. The owners thought an area in the vineyard opposite a driveway across from the vineyard that opened into a citrus orchard was a likely site of entry of glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis* from the neighboring citrus orchard. Patterns of replacement grapevines were documented in the Weaver vineyard and tested statistically for any underlying patterns. The data gathered showed both parallel and perpendicular runs of replaced grapevines in concentrated PD replacement sectors of the vineyard. While there was an area of grapevine replacement opposite the driveway mentioned, there were other groupings of grapevine replacement on the opposite side of the Weaver vineyard. Thus the area in question opposite the driveway remains a curiosity and not the only area affected. What remains unknown is why the Weaver vineyard escaped the serious losses suffered by adjacent vineyards with the same variety of grapevine. The cause of this apparent resistance to PD is being studied further.

INTRODUCTION
The GWSS is a xylem feeder and transmits various strains of the bacterium *Xylella fastidiosa* to a number of economically important plants such as citrus, almond, and grapevine causing diseases [1-4]. In the late 1990's, a surge of GWSS swept through Southern California's Temecula Valley causing significant plant loses due to PD. One vineyard, the Weaver vineyard, remained largely unaffected during this event, suffering only an 11% loss of vines, though it features classic high-risk properties. Characteristics of the Weaver vineyard that place it in a high-risk category include its proximity to two citrus groves [5] located directly across the street, and a susceptible grapevine variety, Chardonnay [6]. The effects of the citrus groves opposite the Weaver vineyard were of interest as the vine replacements in the vineyard showed signs of a possible GWSS entry point due to a driveway (Figure 1) that runs between the groves. Figure one was taken from the Weaver vineyard looking directly across the street into the neighboring citrus orchard. The Weaver vineyard anomaly of apparent resistance to PD could be due to such factors as endophyte concentration, plant morphology, genotype, or soil composition.

Figure 1. Driveway into neighboring citrus grove

METHOD
The pattern of rabbit guards indicating new replacement grapevines was recorded and analyzed with respected to proximity to each other and the vineyard's perimeter. There were 420 replaced vines, 38 of which were replaced due to rodent damage. Data of replaced vines were tested with the logistic regression equation. The rabbit guards were present in sectors in the vineyard.

RESULTS
An analysis of row and column effects was performed using logistic regression to determine the direction of entry in all significantly concentrated sectors. Sector A had only a row effect. Sector B had no significant column or row effect. Sector C is a combination of two sectors, which shared the same column data on the perimeter of the vineyard, and they had only a column effect.

Model I: The driveway entry point was located across from vineyard rows 47 and 48. Replacement grapevine data was tested using the logistic regression equation: $p = \text{logit}(\alpha + \beta_i \times Distance_i)$. Where α is the intercept, $ß_i$ is the correlation, and the distance *i* is the distance from the entry point to the replaced vine *i*. The *p-value* of the result was 0.0067 and the distance from the entry point to each replaced grapevine was found to be statistically significant (*p-value* less than 0.05).

Model II: The vineyard was evenly divided into 16 sectors. The concentration of replacement grapevines in each sector was tested against the average concentration using the logistic regression equation: $p = \text{logit}(\alpha + \beta_i \times Section_i)$. Where α is the intercept, $ß_i$ is the correlation and sector *i* is the concentration of replacements per sector. There were four sectors (sector *C* is a grouping of two separate but adjacent areas) with a significantly higher concentration (with *p-value* less than 0.05) of lost grapevines than average (figure 2.). All four sectors were near either a neighboring vineyard or a citrus grove. Sector A: *p-value* = 0.0026, concentration = 0.1857; Sector B: *p-value* = 0.0002, concentration = 0.2051; Sector C consists of two adjacent sectors: first *p-value* < 0.0001, concentration = 0.2308, second *p-value* = 0.0055, concentration = 0.1786.

Figure 2. The map of Weaver's vineyard. According to Model II, sector A-C are the highly significant areas of PD loss.

Model III: Data within significantly concentrated sectors (sector A-C) was tested for both horizontal (row) and vertical (column) effects and against the concentration within each row or column using the equation: $p = \text{logit}(\alpha + \beta_i \times Row_i + \beta_i \times Column_i)$ Sector A (rows 41-54 and columns 1-15) only showed a row effect in rows 45, 47, and 48 (R_i-R=1.3923, 1.9313, 1.1204 respectively, and *p-values* are less than 0.05). Sector B (rows 1-13 and columns 16-30) had no significant row or column effect (*p-values* are more than 0.05). Sector C (rows 14-26 and columns 46-61) showed a column effect only in columns 53, 54, 55, 57 and 58 (R_i-R=1.1357, 1.4427, 1.1357, 1.4427, 1.1357, and *p-values* are less than 0.05).

Model IV: This model was necessary since the replaced grapevine data included grapevines that were replaced due to rodent damage as well as vines replaced to PD-related loss. In this model, the probability of rodent damage was evenly subtracted from each grapevine (*P = C+(1-C)),* where *P* = the probability of PD-related loss, and *C* = the probability of rodent damage = 38/420 = 0.0905). Then the probability of PD-related loss for each grapevine was calculated using the modified logistic regression equation: $p = c + (1-c)\text{logit}(\alpha_i + \beta_i x_i)$. The color map of the probability was plotted (figure 3.).

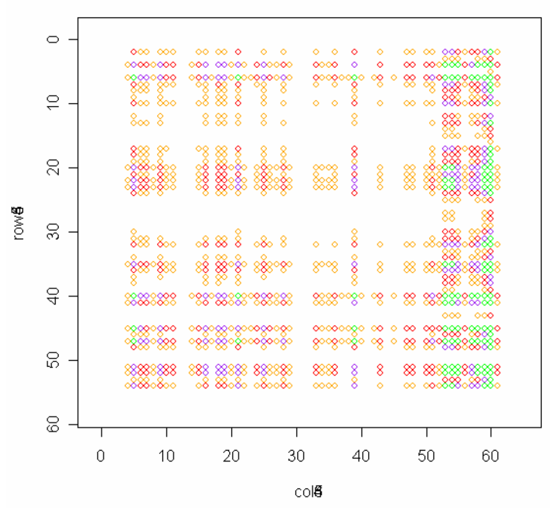

Figure 3. A color map of the probability of individual grapevine replacement due to PD according to Model VI. The range of probability is represented by: no color <0.2, red 0.2-0.25, purple 0.25-0.3, and green >0.3.

DISCUSSION

The concentrated sectors of the Weaver vineyard yield insight to GWSS behavior with respect to PD appearances. A theorized entrance point is supported by a perpendicular statistical pattern within a concentrated sector at the perimeter of the vineyard. Sector A of the Weaver vineyard shows this row effect, which is directly across from a road located between two citrus groves, a common GWSS harbor. GWSS tend to disperse intermittently while foraging [8], possibly to avoid predation or competition. The presence of a "corridor" absent of foliage may further aid the migration and dispersion of GWSS into a field. While the exact times of individual GWSS feeding and transmission are unavailable, regular and repeated contact with specific plants can be visualized, as these plants will be less likely to recover from PD symptoms and have to be replaced. Since the perimeter of a vineyard is necessarily more exposed to GWSS activity (the GWSS must cross the perimeter to enter the vineyard), one would expect to see more symptomatic vines where the GWSS enter.

Thirty-eight grapevines were removed due to rodent damage from possibly California ground squirrel, the jackrabbit, and/or the pocket gopher [9-11]. The vertical and horizontal logistic regression statistical analysis was performed to find a correlation between runs of data within concentrated areas. Only runs perpendicular to the perimeter could give rise to GWSS entrance points while parallel runs could be attributed to rodent damage. The runs of data in Sector C reflect the feeding behavior of rodents in that they are localized, parallel runs in close proximity to the rodent habitat. The habitat was identified by burrows, droppings, and activity.

Another possible cause of localized vine replacement could be due to GWSS nymph feeding behavior supporting vine-to-vine transmission locally. This behavior may explain the pattern observed in Sector B.

Future Works. It is important to recognize other environmental factors that may affect the introduction and spread of PD infection. Possible effects include parasitic wasps, endophytic bacteria antagonistic to the pathogen, plant morphology, and soil composition. Also, the soil may contain micronutrients capable of disrupting biofilm formation by the pathogen in the xylem of the grapevine. It is likely that the apparent resistance of Chardonnay grapevines in the Weaver vineyard to PD has several contributing causes. If some of these factors are discrete, such as endophytes protecting grapevines against PD, it may be possible to convert them into treatments to protect other vineyards. There is some precedent for this non-recombinant symbiotic control approach.

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