June 2020 Progress Report
California Grape Rootstock Improvement Commission
California Grapevine Rootstock Research Foundation
American Vineyard Foundation
California Table Grape Commission
CDFA Improvement Advisory Board

Project Title: Development of next generation rootstocks for California vineyards.

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Reporting Period: January 2020 to June 2020

Overall Summary: We continue to make strong rootstock breeding progress. Advanced selections have been planted in campus-based rootstock trials and others have been moved to FPS for later pre-release status. In the next year, I will push to make decisions on which 20-50 rootstock selections I will focus on to winnow down to 5 to 10 for release. We have excellent salt tolerance, deeply rooted drought adapted, broadly nematode resistant and salt tolerant, and advancing rootstocks with virus tolerance (both fanleaf and red leaf viruses). I am documenting my collections of wild *Vitis* for use by my replacement and future breeders so that this rich germplasm can address changing climates and pest/disease scenarios.

2019 Pollinations:
The 2019 crosses which were designed to use tetraploid and diploid *Vitis Muscadinia* hybrids from crosses of 101-14 x *M. rotundifolia* Trayshed (the 07107 population. We are advancing these as rootstocks but have thus far not been able to find fertile forms that we could introgress the strong resistance from *rotundifolia* into other backgrounds that root well. The few seeds we have produced were not viable. We made many crosses with tetraploid and diploid 101-14 x Trayshed progeny (some of which we had doubled their chromosome numbers. None of these crosses were successful. We made crosses with T6-42 (a fertile VR – *vinifera rotundifolia*) hybrid has repeatedly tested as resistant to phylloxera and ring nematodes. Very few seeds were produced, but T6-38 (also a fertile VR with good phylloxera resistance) was a more successful parent and produced 125 seeds in crosses to five standard rootstock parents.

2018 Pollinations and planting:
None of the 2018 crosses were germinated except 18-113 (GRN-3 x *acerifolia* 9018). The first 78 progeny have been planted in the field. Copies are being readied for salt and HarmAC testing. Thus far this group appears to segregate 1:1 for root-knot HarmAC, salt tolerance appears multigenic, and rooting is skewed towards hard to root.

Nina ran a trial with this set to see if the seedling root architecture could predict the architecture of green and hardwood cuttings. She completed the comparison with greens and there was poor correlation both in respect to root angle (R^2=0.49) and root thickness (R^2=0.15). In addition, she tried different containers, both 4" pots and Styrofoam cups as well as two media, perlite and our standard seedling mix which is the UC agronomy mix cut about ¼ with perlite. The correlations were not strong, but observations indicated that perlite gave better results especially for root diameter.

Search for fertile *Vitis* x *Muscadinia* progeny
We continue to attempt to obtain fertile progeny from crosses between *Vitis* and *Muscadinia*. We collected 29 OP (open pollinated where the pollen source is unknown) seeds from 5 different 07-107 (101-14Mgt x *M. rotundifolia*) progeny and three OP seeds from GRN-1 (*V. rupestris* x *M. rotundifolia*).

Single seeds from siblings 07107-204, -207 and -228 each produced a single seedling that initially displayed moderate vigor and seemed healthy while the single GRN-1 seedling was weak and died shortly after germination. Within 3 months all 07-107 progeny seedlings had died. The field grown parental plants are being closely monitored this season in hopes of finding more OP seed in these 101-14 x *rotundifolia* parents and perhaps this time they will produce healthy long-lived offspring. These crosses and plants have the great potential of incorporating the resistance of *rotundifolia* (all pests and fanleaf tolerance) into a more easily rooted background that may also be fertile.

18-113 (GRN-3 x *acerifolia* 9018)

160 additional seedlings were created for the 18-113 population (GRN-3 x *acerifolia* 9018). 149 are being multiplied for resistance screening and possible mapping for both salt and HarmAC (root-knot nematode strains collected from declining Harmony rootstock). At present 64 progeny are in testing against HarmAC (62 in testing for a second time and 2 for the first time) and 20 for *Xiphinema index* resistance.

Nematode resistance breeding:

Nina Romero and Yong Zhang are making excellent progress screening populations for nematode resistance. In the first half of 2020, we completed 3 different screens for HarmAC resistance and tested a total of 133 genotypes. The results of three main crosses are shown in Table 1. In the first generation 07-107 (*Vitis* x *Muscadinia* cross), the R:S ratio was nearly 3:1; the 16-063 cross made from a tetraploid *Vitis* x *Muscadinia* (VM) produced no resistant progeny; and in the 16-136 cross (a cross of the highly resistant 2011-175-15 x Dog Ridge) only 1 of 13 progeny were highly resistant, interesting segregation considering that the 2011-175-15 parent is highly resistant and Dog Ridge is susceptible. Table 2 reports the results of 20 accessions of 10 southwestern species tested with 80% determined to be highly resistant, much higher than the 31% in our previous testing of 93 wild species accessions.

We completed 2 ring nematode screens so far this year. Due to workflow conflicts, both ran longer than the standard 12 weeks. The trial involving non-VM resistance sources all tested susceptible while the VM resistance source test appeared to be less resistant than in a previous screen (Table 3). This observation suggested that screen duration may be an important factor in evaluating the severity of a ring screen. Ring resistance from *M. rotundifolia* (GRN-1, O39-16) is more stable and seems to cause a decline in ring counts relative to our blank pot with ring nematodes but without plants. This might explain why trials of non-*rotundifolia* lines can show some promise at 90 days but in trials that run longer, ring numbers can increase while remaining low in *rotundifolia* resistance backgrounds.

During this reporting period we completed our first two dagger nematode trials since late 2018, after having trouble expanding the inoculum. Table 4 summarizes the first trial which focused on a subset of the 18-113 (GRN-3 x *acerifolia* 9018) population. The R:S ratio is approximately 4:5 and the clearly susceptible to clearly resistant ratio is about 1:1. Interestingly, 50 of the genotypes had also been screened for resistance to HarmAC. The R-squared value is 0.417 with the ANOVA P-value indicating very high significance (<0.0001) for the correlation between the two resistances. In the second trial we see the same approximate 1:1 R:S ratio in a second group of 20 progeny in the 18-113 population. In a group of 20 progeny in the 07-107 VM cross, we saw and R:S ratio of 3:1 when placed into R and S categories.

Phylloxera:

Nothing to report and efforts continue to get Dr. Celeste Arancibia back from Argentina to finish our study of root phenolics and their relationship to phylloxera resistance / tolerance (see last report for background). Pandemic problems and visa issues have prevented her from returning but we expect her back later this summer.

Field Trials

There was significant activity over the period in establishing and expanding field trials and collaborations with other researchers. In 2019 we sent our first group of 18 advanced selections and 7 reference genotypes to Andreas Westphal at the Kearney Ag Center for nematode screening. Details and levels of resistance for the 9 additional advanced selections sent to Parlier this year for nematode testing are shown in Table 5.

This year we planted our fourth grafted rootstock trial at UCD. Details of resistances and horticultural evaluation are shown in Table 6 – note that all have better nematode resistance and some better rootability and higher horticultural scores than the 101-14Mgt and 1103P reference selections.

Table 7 provides parentage and greenhouse salt resistance results for the 12 selections planted at a salty vineyard site in Suisun. Although predominantly relying on salt resistance from *acerifolia* 9018, other promising selections based on the similar selection *acerifolia* 9035 and the unique selection *doaniana* 9028 are also included.

In addition, we established a GRN demo block with Freedom as the reference genotype to better assist industry in optimizing practices for and documenting early lifecycle performance of the UCD GRN rootstocks.

Salt Testing

Two salt trials were completed during this reporting period. Although we continue to improve the performance of our rapid greenhouse salt test, occasionally we experience a test which doesn't put enough pressure on the reference genotypes to reliably assess the test genotypes. This occurred in one test during this period. The failure resulted from a too cool greenhouse resulting from an ineffective steam heating system. The progeny of *acerifolia* 9018 once again displayed outstanding chloride exclusion; *doaniana* x 101-14Mgt progeny were intermediate and VM progeny were accumulators. None of the 7 wild *Vitis* species accessions tested displayed any noteworthy exclusion. A third trial has been sampled and awaits the completion of chloride analysis.

Three more salt trials are in various stages of testing. One tests genotypes from the failed test referred to above and a second is a large test of the new 18-113 (GRN-3 x *acerifolia* 9018) progeny. The third test is now receiving salt application and contains the genotypes detailed in Table 8. Importantly, it is set up to allow comparisons between greenhouse-based screening with an outdoor, multi-season, large pot trial shown in Figure 1. The outdoor trial will also evaluate chloride accumulation over time as well as shed light on sodium accumulation in fruit by the different chloride excluding sources.

Current testing and projections

There are currently 717 different genotypes in resistance testing: 293 for HarmAC, 90 for ring and 334 for salt. Of these, 95 and 90 genotypes have been inoculated for HarmAC and ring respectively. In the salt tolerance testing – 145 genotypes have completed testing and await chloride analysis. The rest are in various stages of preparation for testing.

Over the next year our focus is on verifying previous testing, checking anomalous results, and identifying additional selections to advance to FPS, especially those for salt resistance based on *acerifolia* 9018. Time permitting, we hope to map salt and nematode resistance in the18-113 GRN-3 x *acerifolia* 9018 population.

Drought tolerance/avoidance:

We are collaborating with MS student Idan Reingwirtz, from the McElrone lab, who is studying root anatomical and morphological differences between 110R and 101-14. Together, we are developing a

two-layered system where the lower half has been infused with PEG to modify the water potential of the medium. Plant apices plus one expanded leaf from *in vitro* plants were grown in 50 ml tubes containing 20 ml MS medium supplemented with 5 g/l gelzan (Phytotechnology labs). As soon as roots were visible, plantlets were transferred with original medium on top of 20 ml medium supplement with 0, 200 or 400 PEG 8000 (Sigma). Each treatment was replicated 5 times. Root growth was recorded for 2 months using digital images and noninvasive high-resolution x-ray computed microtomography imaging. Data is currently being analyzed by I.R. This work is now progressing as Idan recently sent us his data for further analysis.

Using *CRISPR* technology to study grape aquaporins:
PIP proteins (plasma membrane intrinsic proteins) are aquaporins that facilitate the transport of water and small neutral molecules across cell membranes. We have designed gRNAs targeting the *V. vinifera PIP2-1* gene to knock it out. Plasmid construction with DNA harboring CRISPR–Cas9 and guides has been performed by Dr. M. Ron at Britt lab. Transformations of embryogenic callus of Thompson Seedless, Chardonnay, and St George via *Agrobacterium* have been initiated, and we are currently acclimating the first group of Chardonnay and Thompson Seedless edited plants to greenhouse conditions. Sequencing of mutations has shown that high editing efficiency occurred with one the guides tested; with 9 TS lines and 10 CH lines, containing indels at the target site (1 CH and 2 TS had at least one wild type (WT) allele). Phenotyping of these plants will be performed in collaboration with the McElrone lab. The first group of lines in the greenhouse has been multiplied through green cuttings (Table 9) and will be tested for water relations and gas exchange in response to water stress treatments next month. We expect to complete phenotyping and molecular analysis in all lines by June 2021.

Chloride exclusion, germplasm and mapping population screening: We are using 75mM (12% sea water) salt concentrations to test germplasm previously identified as salt tolerant at 25-50 mM concentrations. We hope this more severe test will identify the most useful parents for crosses. There are currently 494 genotypes in testing; 162 for HarmAC, 157 for ring and 175 for salt. Of these, 71 and 101 genotypes have been inoculated for HarmAC and ring respectively. In salt tested, 149 genotypes have completed testing and await chloride analysis. All other remainders are in various stages of preparation.

Chloride tolerance research – Chris Chen
Several trials were conducted from June 2018 to May 2020 with the purpose of elucidating accessions which are tolerant to chloride toxicity, as well as to identify the ideal trial conditions for rapid identification of chlorine (Cl^-) tolerant accessions. From previous studies in the Walker lab regarding the use of different media in salt (NaCl) trials, we have determined that fritted-clay used in conjunctions with a semi-hydroponic irrigation regime allows for consistent soil-water infiltration rates and binding of cations which can be negatively-impacted by the addition of NaCl to the rooting substrate. All trials we have conducted have used this substrate as a rooting media. Testing the chloride resistance capacity of both cultivated, and wild, grapevines provided a range of possible levels of salt resistance in accessions which may be considered for rootstock development in the near future.

A cross of GRN3 by *V. acerifolia 9018* provided over 75 individual offspring for chloride testing using the methods developed from previous trials conducted over a one-year time period. GRN3 has excellent nematode resistance but is not salt tolerant. *Vitis acerifolia 9018* has been shown by this lab to be resistant to drought, certain pests, and highly resistant to salt-toxicity. Individuals of this cross were examined at 75mMol NaCl concentrations applied directly to the soil across a 28-day experimental time frame with the commercial rootstock, 140 Ruggeri, used as a tolerant biocontrol for comparisons.

The testing of this cross showed continuous variation in ability of offspring to exclude chlorine from leaf tissues (Fig. 2); this is the tissue that results in the most negative impacts in Cl^- damaged grapevines. Of the 77 individuals tested in this trial, only ten were significantly lower in leaf Cl^- accumulation than the

biocontrol, 140Ru; of these, one individual actually showed lower leaf Cl^- levels than the highly tolerant parent, *V. acerifolia 9018* (Table 10). This study implies the mechanism of chloride tolerance is related to a quantitative genetic control.

To further understanding optimal conditions for testing NaCl tolerance of grapevines, a trial to examine the potential for damage to the photosynthetic machinery in leaves was conducted using variable-concentrations of NaCl, applied to commercial rootstocks commonly available to growers in California. Sodium chloride was applied as in the previous trial, but at four concentration levels: 25mM, 75mM, 100mM, and a control of 0mM. With 140 Ruggeri again used as a biocontrol, we found that differences in these rootstocks' leaf-chloride accumulation were heavily skewed to occur only when intervals of 50mM NaCl or more separated the applied salt concentrations in treatment, for both higher and lower values (Fig. 2).

Furthermore, in all tested genotypes the applied NaCl concentration was a significant variable, but the varieties with the lowest leaf-chloride levels also had the lowest correlation coefficient between genotype and NaCl applied (Table 11). Most significant differences between genotypes at the same applied salt level occurred with one, or both, of two tested accessions: *V. acerifolia 9018* or 44-53Mgt; these represent the extremes of salt-tolerance we have found in the material available to us here at the University of California Davis, with the former being highly salt-tolerant and the latter being highly salt-susceptible. Although, other differences occur at the same salt concentration in other genotypes (Fig. 3)

Testing was also pursued for a wide range of wild grapevines collected by m and my predecessors. Continuous variation was also observed in the accessions tested from wild collections, as with the GRN3 x *V. acerifolia 9018* cross population (Fig. 4). However, unlike the above mentioned cross, when compared with 140 Ruggeri as a biocontrol no wild accession improved on the low values of leaf-chloride accumulation observed in *V. acerifolia 9018* while many accessions showed higher leaf-chloride accumulation levels following the study (Table 12). This suggests that *V. acerifolia 9018* is an ideal candidate for further study in NaCl tolerance in grapevine.

Developing a consensus DNA fingerprint database of the Walker lab southwestern US germplasm for diversity and population genetic studies:

I have amassed a very large collection of grape germplasm from the southern US – particularly the southwestern States (over 700 accessions). This collection is a very valuable resource for the rootstock breeding program. We are developing a consensus SSR fingerprint database to carry out population diversity studies that would help us to identify germplasm from different genetic groups. The collection also serves as the foundation for a NSF project to sequence many of these species and selections that is now underway. The sequencing and testing of these individuals for salt tolerance and PD resistance continues.

Genetic diversity of Mexican wild grapevines:

Previous research in the Walker Lab identified accessions native to Mexico to be resistant to biotic and abiotic stresses such as Pierce's Disease, nematodes and drought. An expansion of the evaluation of Mexico's *Vitis* germplasm could lay the foundation to preserving material for rootstock breeding purposes. Since 2016, PhD student Karla Huerta-Acosta has been working in collecting accessions across Northern and Central Mexico for a genetic diversity study. For this study, Mexican wild grapevines accessions were collected from private and public germplasms, as well as collection trips to regions where wild grapevines are endemic. The last collection trip to Mexico was in May 2019. In addition, Mexican *Vitis* spp. accessions from the USDA germplasm collection at Davis that were collected in the 1960s and 1990s were also included in this study.

A total of 317 accessions from Northern and Central Mexico were genotyped using simple sequence repeats (SSR) markers and phenotyped using anatomical features. A subset of 247 accessions were used to calculate genetic diversity parameters and population structure. Using STRUCTURE software to identify population structure, data showed K=6 was the most likely number of groups found from the collected samples. The STRUCTURE groups were named according to the geographic locations where most of the accessions came from (Eastern Mexico, Western Mexico, Northeastern Mexico, Central Mexico, Coahuila and Chihuahua).

The Eastern, Central and Western Mexico groups were distributed across the Trans-Mexican Volcanic province. It was identified the biogeographic province Trans-Mexican Volcanic Belt, located in Central Mexico that goes from Nayarit in the west coast to Veracruz in the east coast, was the most diverse province for wild grapevines. The Coahuila group was the least diverse and the most differentiated from the other groups. The most abundant species found were *Vitis arizonica*, *V. cinerea* and its hybrids. *Vitis bloodworthiana* was mostly found in the east, and *V. tiliifolia* was found in the west. *Vitis cinerea* was mostly present in Central Mexico and it hybridized with *V. arizonica*, *V. bloodworthiana* and *V. tiliifolia* in the to the north, east and west, respectively. This project helped elucidate the genetic diversity and species distribution in Mexico. The study was the first of its kind as no genetic diversity assessment has been performed for Mexican *Vitis* germplasm. The study has been finalized and the manuscript is nearing completion. The manuscript will be submitted to the American Journal of Botany in June-July 2020.

Transcriptomic analysis of grapevine infected by red leaf viruses:
Prof. Nihal Buzkan was on a 1.5 yr-long sabbatical with me and returned to Turkey in September. She was working on this virus tolerance project and continues the analysis with colleagues in Italy with a manuscript expected by the end of this year. Experiments were carried out with Cabernet franc infected with red leaf viruses; leafroll (GLRaV-1) and rugose wood viruses (GVA) and two rootstocks Freedom (highly sensitive to red leaf viruses) and St. George (tolerant to red leaf virus disease) in field and *in vitro* conditions. Virus strains were LR131 for GLRaV-1 and LR132 for GVA. She also overlapped with Dr. Zhenhua Cui who is working on various aspects of the same project. Please see the June 2019 progress report of complete details on Nihal's research. Zhenhua has been more focused on the cause of graft union collapse due to Red Leaf and Vitiviruses.

Transcriptomatic analysis of GLRaV-1-infected grapevine on susceptible (Freedom) and tolerant (St.George) rootstocks was performed with RNAseq method. Virus infected-Cabernet franc (CF) on Freedom and St.George and mock inoculated ones as negative controls were used for total RNA isolation and cDNA library which were used for RNAseq. DE analysis of the libraries from virus-rootstock combination as well as the mock inoculated plants showed that qPCR would be useful to understand metabolic answer of the biological replicates. This part will be run in summer 2020 (July-September).

DeNovo analysis was also carried out with cDNA libraries and two novel viruses were discovered from contigs. The biological and molecular properties of two novel viruses must be studied in order to understand their pathological effect on grapevine.

Screening of rootstock population 08-180 (Freedom x St. George) for red leaf virus tolerance:
Dormant cuttings from the 08180 population and Cabernet franc with LR-1 and GVA were collected and stored at 36F for chilling requirement for about 6 weeks. These cuttings were bench grafted in mid-March 2018, then they were transferred into greenhouse conditions for virus replication and symptom observation. Seventeen progenies with LR131 and thirteen progenies with LR132 were grafted. Six replicates for each virus/rootstocks combination were prepared as well as negative (healthy) and positive (infected) controls, then they were periodically checked for virus presence with an ELISA test starting from 3-months post grafting (mpg) up to one year.

Two abstracts entitled 'Screening of rootstock population for *Grapevine leafroll associated virus-1'* and 'Tissue section and immunofluorescent staining in phloem tissue of red leaf infected susceptible and tolerant rootstocks' have been accepted to present at Plant Health 2020 APS Annual Meeting which will be held in Denver, CO, on August 10-14, 2020. This work is completed and a manuscript will be ready soon.

The first symptoms of leaf roll in the 80-180 population grafted with both virus strains were observed 7 mpg (months post grafting). Leaf reddening was hard to see because the plants were overgrown in the greenhouse. The virus titer was found be high in all 08-180 progenies with LR-1 until 6th and 7th mpg, when the titer remarkably dropped. They were still infected, but 50% of the grafted progenies had low virus titer compared to the positive controls. The highest virus titer was measured at 6 and 7 mpg when the first symptom appeared on the plants. GVA titer was always low in all 08-180 progenies and this might be due to an avirulence property of the virus strain. We need to biologically characterize LR132 for its level of virulence.

Dr. Zhenua Cui has taken over some of the work Dr. Buzkan initiated. In his previous stay in my lab we confirmed the severe graft incompatibility induced by GLRaV-1/GVA complex with 3 grafting methods. The paper detailing these results was judged to be the best of the year by the Austral. J. Grape and Wine Res. (Cui et al. 2019). This study found that St. George has the ability to cope with or eliminate this incompatibility, while GLRaV-1/GVA can easily kill vines when grafted on Freedom. Since GVA is always accompanied with GLRaV-1 in field infection, the role of GVA playing in GLRaV-1/GVA induced graft incompatibility remains unclear. Clarification of this red leaf virus tolerance in St. George is important for the breeding rootstocks with this tolerance. To answer these two questions, we continued to explore the mechanism of graft incompatibility induced by GLRaV-1/GVA.

In the last report (Jan 2020), the set-up and preparation of red leaf virus tolerance research was introduced, and some preliminary results were reported, which has been updated since then with more data. A total of 21 genotypes (including 11 *rupestris* accessions and 10 other commercial varieties) have been tested by grafting. Franc, LR131 (infected with GLRaV-1) and LR132 (infected with GLRaV-1 and GVA) were used as scions. In general, the survival rate of franc is higher than LR131 and LR132, but varied by 50%-80% upon different rootstocks (Figure 5). Rooting capacity is a very likely factor affecting the survival rate. In some cases, the healing of grafting union and bud elongation were nice, however, the bottom of rootstock rotted, making the graft failed. The virus-infection could affect grafting survival through changing both the grafting union healing and the rootstock rooting process. Freedom, LN33 and 101-14 had no more than 30% survival rate when grafted by LR132. St. George, Vru87, Vru110, AXR1, A. de. Serres, Schwarzmann, Paulsen 1103 and Richter 110 survived more than 50% when grafted by LR132, showing a relatively better virus tolerance. The analysis of the effect of virus and rootstock on the grafting survival (Table 13) showed that both rootstock genotypes and virus infection had significant effect on the grafting survival, and there is an interaction between virus and rootstock significantly affecting the grafting survival, indicating the varying virus tolerance. However, the grafting survival rate is the very first step to test the virus tolerance (other factors besides virus infection also affect the survival in our experimental system, like rootstock rooting capacity, conditions of the incubating bed).

The GVA cloning was accomplished with the assistance of Maher at FPS. We now have the full sequence of California GVA isolate (7404 bp, Figure 6), which is different with the other reported isolated (with 80%-90% identity). The California isolate will be used to build binary construct for further study.

The materials for study with grapevine red blotch virus are almost prepared and will be tested on different rootstock very soon (Figures 7 and 8). The surviving grafts have been transferred to greenhouse. Growth parameters will be measured to evaluate the virus' effect on the grafts. Their photosynthesis function will

be tested when the plants are fully established the biomass of the plants will be measured. The virus accumulation will be an important index to evaluate the plant virus tolerance. Rt-qPCR will be applied to test the virus accumulation of different grafts.

Based on above tests, some graft combinations (with lower and higher virus tolerance) will be selected to investigate the healing of the grafting union. The California GVA isolate will be used to build the expression vector, which will be inoculated to tobacco first and then on grapevine to create GVA single-infected plants. GVA-infected plants will be grafted on different rootstocks to determine GVA's pathogenicity, which will help elucidate the interaction between GVA and GLRaV-1.

Mechanism of GFLV Tolerance:
Please see the January 2020 report for additional background. Post-doc Dr. Erin Galarneau is working with Ph.D. student Andy Viet Nguyen to study the mechanism of rootstock-induced tolerance observed in O39-16. Buds were collected before bud break, along with inflorescences (2 collection times), flowers (pre-, 10% capfall, and 90-100% cap fall), and young berries (setting, peppercorn, and pea sized) were collected from GFLV-infected vines and healthy vines grafted on O39-16, GRN-1, and St. George from March-June 2020. Analyses of amino acids, phenolics, phytohormones, and RNA expression of hormone biosynthesis genes are ongoing. Further collections of seeds pre-veraison and at harvest will be conducted June-September 2020. An additional field site of Cabernet Sauvignon on O39-16 and GRN-1 has been added to investigate mechanisms further via RNA expression of hormone biosynthesis genes of vines affected by *X. index* and GFLV.

Inheritance of GFLV Tolerance Trait in a 101-14 x Trayshed Population:
Dr. Erin Galarneau is working with Andy Viet Nguyen to screen phytohormone biosynthesis genes and phytohormone concentrations of nine genotypes (plus controls) with different flower to fruit set ratios (**Tolerant:** 07107-005, 07107-043, 07107-008, **Moderate:** 07107-125, 07107-007, 07107-135, **Susceptible:** 07107-077, 07107-108, 07107-102, **Controls:** 101-14, St. George, O39-16, Cab Sauv), to determine the mechanism of the tolerance trait. Collections of buds were collected before bud break, along with inflorescences (2 collection times), flowers (pre-, 10% capfall, and 90-100% cap fall), and young berries (setting, peppercorn, and pea sized) have occurred March-June 2020. Further collections of seeds pre-veraison and at harvest will be conducted June-September 2020. Analyses of amino acids, phenolics, phytohormones, and RNA expression of hormone biosynthesis genes are ongoing. Andy Viet Nguyen will investigate the phytohormone genes, while Dr. Erin Galarneau will conduct the other analyses.

GFLV Resistance in the 101-14 x Trayshed Population and Fertile VR Hybrids:
In addition to finishing up the field evaluations for rootstock-induced GFLV tolerance, Andy Viet Nguyen is also concluding his study on evaluating GFLV resistance in the 101-14 x Trayshed populations and fertile VR hybrids. This study focuses on the ability of each rootstock genotype to resist the virus by suppressing virus multiplication. Results from this study are shown in Figures 9 and 10. Most of the evaluated rootstock genotypes harbor more virus compared to O39-16, the resistant control. However, most notably, 07107-065 (from the 101-14 x Trayshed population) and T6-42 and NC6-15 (both are fertile VR hybrids) harbor less virus than O39-16. Also, the VR hybrids b59-50 and 06725-01 appear to harbor similar levels of virus as O39-16. We will compare these results to the field evaluation data (i.e. the fruit set ratio data) to determine if there is a possible correlation between the rootstock's ability to suppress virus multiplication and the rootstock's ability to induce GFLV tolerance to scions.

Propagation of hard to root rootstocks:
James Shoulders (MS student and current Production Manager at FPS) has been working on detailing propagation for hard to root materials such as O39-16, GRN1, and 420A. Needed rootstocks in the future will come from non-traditional species and will be harder to root. That said, I do not have trouble rooting

or grafting O39-16, GRN1 or GRN5. Some key points: The mothervines need to be mature (young vines do not propagate as easily as older vines); don't over grow (excess water and N fertilizer) later in the season. The cuttings root and graft more easily when mature (lignified not green). This can be problematic because there are southern species in their parentage that grow longer into the Fall and shed leaves later. For potted plants, pre-callusing for extended periods works well as does callusing after grafting and longer growth periods in the greenhouse.

GRN-1 Rooting and Propagation**:** 300 cuttings each of GRN-1, 101-14, O39-16, and 420A supplied by nurseries in the Sacramento and San Joaquin valleys were used for a rooting experiment. They were grafted to Cabernet Sauvignon and Chardonnay. There were two controlled variables in the experiment: (1) time spent in the warm callus room prior to grafting, ranging from 1 – 5 weeks; and (2) time allowed to grow in greenhouse after grafting, ranging from 4 to 10 weeks. Conditions other than that were typical: cuttings were omega bench-grafted and given 2 weeks in the callus chamber to heal after grafting. No hormones were used, and all cuttings were hot water dipped.

Caution: keep moist not wet; prepare callusing /greenhouse areas where you can treat these pre- and post- grafted plants separately from standard rootstocks – more shade, less watering, high humidity, good air circulation, active fungicide program. Ensure that your production crews don't treat these plants in the same way as they treat standard rootstocks.

Table 1. Nematode resistance to the combined Harmony A and C strains for 3 populations tested in the reporting period. Resistance is measured on a 1 to 4 scale with 1 highly susceptible and 4 resistant with no nematode damage.

		HarmAC Resistance				
Cross ID	Cross	1	2	3	4	Cross ID Total
07-107	101-14Mgt x Trayshed	1	8	1	27	37
16-063	5BB x b55-1	11	7			18
16-136	Dog Ridge x 2011-175-15	2	8	2	1	13

Table 2. Numbers of recently tested southwestern *Vitis* accessions with strong resistance to HarmAC nematodes. Resistance is measured on a 1 to 4 scale with 1 = highly susceptible and 4 = resistant with no nematode damage.

	HarmAC Resistance		
Vitis Species	1	2	4
acerifolia		1	2
arizonica	1		2
candicans			3
champinii			2
cinerea			2
doaniana		1	
riparia	1		2
rupestris			1
shuttleworthii			1
treleasei			1

Table 3. Comparison of the same genotypes tested for ring nematode resistance using two different intervals: 2019N-06 Ring for 8 weeks and 2019N-10Ring 22 weeks. Resistance is measured on a 1 to 4 scale with 1 = highly susceptible and 4 = resistant with no nematode damage.

Genotype	2019N-06Ring	2019N-10Ring	Genotype Average
07107-002	4	2	3.0
07107-005	4	3	3.5
07107-007	4	3	3.5
07107-012	4	3	3.5
07107-018	4	1	2.5
07107-062	4	2	3.0
07107-112	4	2	3.0
07107-120	4	4	4.0
07107-191	4	3	3.5
07107-196	4	3	3.5
07107-198	4	2	3.0
07107-202	4	2	3.0
07107-208	4	2	3.0
07107-229	4	3	3.5

07107-241	4	4	4.0
07107-244	4	3	3.5
Trial Average	4	2.6	3.1

Table 4. Resistance to dagger nematode (*Xiphinema index* – Xi) for progeny and reference genotypes. Resistance is measured on a 1 to 4 scale with 1 = highly susceptible and 4 = resistant with no nematode damage.

Cross or Reference	Xi Resistance Rating				Cross or Ref Total
	1	2	3	4	
18-113 (GRN-3 x *acerifolia* 9018)	20	9	6	18	53
French Colombard	1				1
O39-16 (Almeria x *rotundifolia* 'Male')			1		1
St. George	1				1
Rating Total	22	9	7	18	56

Table 5. Own-rooted selections sent to Parlier 5/5/2020 for nematode testing. Only selection 2012-185-8 has been salt tested scoring of 3.0 in the single time it was tested.

Genotype	Parentage	Avg Harm AC Resist	Times Harm AC Tested	Ave Ring Resist	Times Ring Tested	Avg HW Root-ability	Times Root-ability tested
2012-110-2	101-14Mgt x GRN-5	3.4	5	3.0	3	1.6	6
2012-112-10	101-14Mgt x GRN-2	3.8	4	3.0	1	2.8	3
2012-112-7	101-14Mgt x GRN-2	3.9	3	3.0	1	1.8	4
2012-113-11	101-14Mgt x GRN-4	4.0	2	3.0	1	2.0	5
2012-113-16	101-14Mgt x GRN-4	3.5	4	2.4	5	2.5	2
2012-113-43	101-14Mgt x GRN-4	3.5	3	3.0	1	1.8	5
2012-126-37	OKC-1 S01 x GRN-4	4.0	2	3.0	1	2.0	2
2012-153-27	Ramsey x *doaniana* 9028	3.7	3	3.0	1	1.5	2
2012-185-8	GRN-3 x *berlandieri* 9031	3.7	3	2.7	3	1.5	4

Table 6. Advanced rootstock selections planted 4/29/2020 in the UCD rootstock trial grafted with Cabernet Sauvignon FPS31. Nematode resistance is measured on a 1 to 4 scale with 1 highly susceptible and 4 resistant with no nematode damage. Rootability is reported from typical duration (17 days) for hardwood cuttings coming out of callus. Scale is 0 with no usable plants and 4 excellent shoots and roots. The Horticultural (Hort) Field scores range from 1- brushy short internodes small caliper; 2- average quality; 3- very good, long canes, long internodes, good caliper, no brushiness.

Genotype	Female_parent	Male_parent	Avg HarmAC resistance	Avg Ring Resistance	Avg Root-ability	Hort Field Score
101-14Mgt			2.8	1.3	1.8	2.9
1103P			1.0	1.5	2.5	2.8
2011-143-20	Ramsey	08314-15	3.4	3.0	2.7	3.0
2011-143-5	Ramsey	08314-15	3.9	3.0	3.0	2.1
2012-110-2	101-14Mgt	GRN-5	3.4	3.0	1.6	3.0
2012-110-33	101-14Mgt	GRN-5	4.0	2.7	1.5	2.4
2012-110-8	101-14Mgt	GRN-5	4.0	3.3	1.6	2.4
2012-112-10	101-14Mgt	GRN-2	3.8	3.0	2.8	2.9

2012-112-7	101-14Mgt	GRN-2	3.9	3.0	1.8	2.8
2012-113-11	101-14Mgt	GRN-4	4.0	3.0	2.0	2.1
2012-113-43	101-14Mgt	GRN-4	3.5	3.0	1.8	2.5
2012-113-8	101-14Mgt	GRN-4	4.0	3.0	1.5	1.8
2012-118-17	161-49C	GRN-4	3.5	2.3	2.0	3.0
2012-126-37	*acerifolia* *O*KC-1 S01	GRN-4	4.0	3.0	2.0	2.0
2012-153-27	Ramsey	*doaniana* 9028	3.7	3.0	1.5	2.5

Table 7. Salt tolerant selections grafted to Chardonnay cl. 4 and planted in a salty vineyard site in Tidal flats of Suisun, Solano County, CA. Salt tolerance scores: 1= accumulating high levels of leaf chloride while 4 = very low levels of chloride.

Genotype	Female parent or species	Male parent or source	Avg Chloride exclusion rating	Min Chloride exclusion rating	Times Chloride exclusion tested
140Ru			2.8	1.0	21
16162-005	Ramsey	*acerifolia* 9035	3.7	3.0	3
16162-009	Ramsey	*acerifolia* 9035	3.7	3.0	3
2012-153-29	Ramsey	*doaniana* 9028	4.0	4.0	1
2014-160-001	Ramsey	*acerifolia* 9018	4.0	4.0	3
2014-160-003	Ramsey	*acerifolia* 9018	4.0	4.0	2
2014-160-013	Ramsey	*acerifolia* 9018	4.0	4.0	1
2014-160-016	Ramsey	*acerifolia* 9018	4.0	4.0	3
2014-160-019	Ramsey	*acerifolia* 9018	3.7	3.0	3
2014-160-027	Ramsey	*acerifolia* 9018	4.0	4.0	2
44-53M			1.1	1.0	14
doaniana 9026			4.0	4.0	2
acerifolia 9018			4.0	4.0	13
acerifolia 9035			3.4	2.0	5
Ramsey			1.8	1.0	9

Table 8. Selections being tested in an outdoor, multi-season, large pot trial at UCD. Salt tolerance scale: 1 = accumulating high levels of leaf chloride, 4 = very low levels of chloride.

Genotype	Reason included	Avg Cl exclusion rating	Min. Cl exclusion rating	# times tested
1103P	standard rootstock	2.0	2	1
140Ru	tolerant reference	2.8	1	21
44-53M	susceptible reference	1.1	1	14
doaniana 9026	promising excluder	4.0	4	2
girdiana -8	promising excluder	3.0	3	1
acerifolia 9018	best excluder	4.0	4	13
Ramsey	historic reputation	1.8	1	9
St. George	intermediate reference	2.1	2	10

Table 9. Number of lines regenerated from embryogenic callus of TS and CH inoculated with A. tumefaciens carrying a CRISPR-Cas9 construct to knock out the *PIP2*-1 gene. Preliminary indel identification was conducted using the online tool "TIDE" (https://tide.nki.nl). WT: wild type, chim: chimera, NT: not tested.

Thompson Seedless			Chardonnay		
Line	TIDE result	Mother plant ( ) and reps in gh	Line	TIDE result	Mother plant ( ) and reps in gh
- **Untransformed TS**	WT	(1) 6	- **Untransformed CH**	WT	(1) 6
- **4**	Δ1/Δ1	(1) 6	- **1**	Δ1/Δ2	(1) 4
- **5**	WT	(1) 6	- **2**	Δ1/Δ1	(1) 5
- **6**	Δ1/Δ1	(1) 3	- **3**	Δ1/Δ1	(1) 4
- **7**	did not	-	- **15**	Δ1/Δ4	(1) 5
- **8**	grow	(1) 0	- **16**	chim	(1) 0
- **9**	Δ1/Δ1	(1) 0	- **17**	chim	(1) 0
- **10**	NT	(1) 0	- **19**	chim	(1) 5
- **11**	Δ1/Δ1	(1) 4	- **20**	WT	(1) 3
- **12**	WT/Δ1	(1) 3	- **21**	chim	*in vitro*
- **13**	chim	(1) 5	- **22**	NT	*in vitro*
- **14**	chim	(1) 3	- **23**	NT	(1) 5
- **18**	chim	*in vitro*	- **24**	NT	*in vitro*
- **26**	Δ1/Δ1 chim	*in vitro*	- **25**	Δ1/Δ6	(1) 4
			- **27**	NT	*in vitro*
			- **28**	chim	(1) 6

Table 10: Individuals with leaf-chloride levels significantly different from biocontrol 140Ru at $\propto = 0.05$

Genotype	Difference	p-value
18113-030	4.997	0.0252*
18113-042	2.582	0.0360*
18113-031	2.997	0.0341*
18113-047	3.165	0.0333*
18113-073	8.085	0.0170*
18113-006	10.33	0.0123*
18113-068	5.069	0.0272*
18113-057	5.739	0.0250*
V. acerifolia 9018	13	0.0083*
18113-039	16.17	0.0051*

Table 11: Honest significant differences ($\propto = 0.05$) in groupings of NaCl concentrations within individual genotypes by color.

Summary of fit (Genotype ~ NaCl Concentration applied)			**Tukey honest-significant-difference groupings by NaCl concentration within single genotypes**			
Genotype	R^2	p-value	*Group-Control*	*Group-25mM NaCl*	*Group-75mM NaCl*	*Group-100mM NaCl*
101-14 Mgt	0.96	<0.0001	a	a	b	b
110 R	0.76	0.0075	a	a	b	b
140 Ru	0.88	0.0005	a	a	b	b
44-53 Mgt	0.90	0.0002	a	a	b	b
99R	0.82	0.022	a	a	b	b
Dog Ridge	0.85	0.0012	a	b	c	c
V. acerifolia 9018	0.61	0.0481	a	a	ab	b
Ramsey	0.90	0.0002	a	b	c	c
Riparia 'Gloire'	0.81	0.0028	a	b	b	c

Table 12: Pairwise-Comparison of tested genotypes at the same [NaCl] with significant differences in leaf-chloride levels

*140Ru used as control			
Level	**Abs(Dif)-LSD**	**p-Value**	
16136-003	161	<.0001*	High leaf-chloride levels (Poor chloride excluders)
NM12-105.31	93.7	<.0001*	
44-53	155.1	<.0001*	
C16-94	134.9	<.0001*	
16131-002	87.88	<.0001*	
16190-020	55.62	<.0001*	
16158-001	50.18	<.0001*	
2011-115-13	45.95	<.0001*	
16158-004	29.53	<.0001*	
16131-032	29.28	<.0001*	
UT12-095	26.95	<.0001*	
16131-023	24.6	<.0001*	
16131-039	24.28	<.0001*	
16131-004	21.28	0.0001*	
UT12-085	31.38	<.0001*	
UT12-087	20.2	0.0002*	
16131-040	18.98	0.0002*	
AZ11-016	14.95	0.0008*	
16190-012	13.78	0.0012*	
NM11-055	12.95	0.0015*	
NV12-057.09	10.8	0.0029*	
16158-012	10.55	0.0031*	
NM11-068	10.45	0.0032*	
UT12-098	10.38	0.0033*	
UT12-093	10.13	0.0035*	
16131-035	7.601	0.0071*	
NM11-073	7.284	0.0078*	
16110-001	4.116	0.0181*	
AZ11-012a	3.701	0.0201*	
UT11-002-01	2.201	0.0294*	
AZ11-015	0.784	0.0415*	
NM12-105.18	4.979	0.0127*	
NM11-040	-29.9	1	No difference from control; 140Ru
2012-108-6	-37.9	1	
NM11-026	-31.7	1	
2014-160-046	-32.2	1	
NM11-033	-39.8	1	
longii 9018	6.904	0.0020*	Low leaf-chloride

Table 13: Significant differences from control, 140Ru, in leaf-chloride concentrations (mg * L)

Comparison	First Genotype	Second Genotype	Salt Concentration (mMol NaCl)	Difference	p-Value
101-14Mgt - Riparia 'Gloire'	101-14Mgt	Riparia 'Gloire'	100	48.78	0.0394
110R - 101-14Mgt	110R	101-14Mgt	100	78.33	0.0012
110R - Dog Ridge	110R	110R	100	82.45	0.007
110R - 140Ru	110R	140Ru	100	68.33	0.0044
110R - Ramsey	110R	Ramsey	100	78.33	0.0012
44-53 - 101-14Mgt	44-53	101-14Mgt	25	83.55	0.006
44-53 - 101-14Mgt	44-53	101-14Mgt	75	219.22	<0.001
44-53 - 101-14Mgt	44-53	101-14Mgt	100	210.67	<0.001
44-53 - 110R	44-53	110R	25	93.33	0.001
44-53 - 110R	44-53	110R	75	234.56	<0.001
44-53 - 110R	44-53	110R	100	289	<0.001
44-53 - 140Ru	44-53	140Ru	25	100.22	<0.001
44-53 - 140Ru	44-53	140Ru	75	234.56	<0.001
44-53 - 140Ru	44-53	140Ru	100	220.67	<0.001
44-53 - 99R	44-53	99R	25	95.55	0.001
44-53 - 99R	44-53	99R	75	242.56	<0.001
44-53 - 99R	44-53	99R	100	254.78	<0.001
44-53 - Dog Ridge	44-53	Dog Ridge	25	56.33	0.0179
44-53 - Dog Ridge	44-53	Dog Ridge	75	193.89	<0.001
44-53 - Dog Ridge	44-53	Dog Ridge	100	206.56	<0.001
44-54 - V. acerifolia 9018	44-53	*V. acerifolia 9018*	25	110.45	<0.001
44-54 - V. acerifolia 9018	44-53	*V. acerifolia 9018*	75	306	<0.001
44-54 - V. acerifolia 9018	44-53	*V. acerifolia 9018*	100	344.44	<0.001
44-53 - Ramsey	44-53	Ramsey	25	62.22	0.0092
44-53 - Ramsey	44-53	Ramsey	75	194.22	<0.001
44-53 - Ramsey	44-53	Ramsey	100	210.67	<0.001
44-53 - Riparia 'Gloire'	44-53	Riparia 'Gloire'	25	72.55	0.0026
44-53 - Riparia 'Gloire'	44-53	Riparia 'Gloire'	75	264.11	<0.001
44-53 - Riparia 'Gloire'	44-53	Riparia 'Gloire'	100	259.45	<0.001
Dog Ridge - 99R	Dog Ridge	99R	75	48.66	0.0398
Dog Ridge - 99R	Dog Ridge	99R	100	48.22	0.0416
Dog Ridge - Riparia 'Gloire'	Dog Ridge	Riparia 'Gloire'	75	70.22	0.035
Dog Ridge - Riparia 'Gloire'	Dog Ridge	Riparia 'Gloire'	100	52.89	0.0258
V. acerifolia 9018 - 101-14Mgt	*V. acerifolia 9018*	101-14Mgt	75	86.78	0.004
V. acerifolia 9018 - 101-14Mgt	*V. acerifolia 9018*	101-14Mgt	100	133.77	<0.001
V. acerifolia 9018 - 110R	*V. acerifolia 9018*	110R	75	71.44	0.003
V. acerifolia 9018 - 110R	*V. acerifolia 9018*	110R	100	55.44	0.0197
V. acerifolia 9018 - 140Ru	*V. acerifolia 9018*	140Ru	75	83.22	0.006
V. acerifolia 9018 - 140Ru	*V. acerifolia 9018*	140Ru	100	123.78	<0.001
V. acerifolia 9018 - 99R	*V. acerifolia 9018*	99R	75	63.44	0.008
V. acerifolia 9018 - 99R	*V. acerifolia 9018*	99R	100	89.67	0.002
V. acerifolia 9018 - Dog Ridge	*V. acerifolia 9018*	Dog Ridge	25	54.11	0.0227
V. acerifolia 9018 - Dog Ridge	*V. acerifolia 9018*	Dog Ridge	75	112.1	<0.001
V. acerifolia 9018 - Dog Ridge	*V. acerifolia 9018*	Dog Ridge	100	137.89	<0.001
V. acerifolia 9018 - Ramsey	*V. acerifolia 9018*	Ramsey	25	48.23	0.0416
V. acerifolia 9018 - Ramsey	*V. acerifolia 9018*	Ramsey	75	111.78	<0.001
V. acerifolia 9018 - Ramsey	*V. acerifolia 9018*	Ramsey	100	133.7	<0.001
V. acerifolia 9018 - Riparia 'Gloire'	*V. acerifolia 9018*	Riparia 'Gloire'	100	85	0.005
Ramsey - 99R	Ramsey	99R	75	48.33	0.0411
Ramsey - Riparia 'Gloire'	Ramsey	Riparia 'Gloire'	75	69.89	0.036
Ramsey - Riparia 'Gloire'	Ramsey	Riparia 'Gloire'	100	48.78	0.0394

Table 14 Analysis of variance of the effect of virus, rootstock and their interaction on grafting survival rate.

Parameters	df	F	P
Virus	2	122.1	**
Rootstock	20	8.9	*
Virus × Rootstock	40	32.4	**

*means significant difference at $P < 0.05$ level, **means significant difference at $P < 0.01$ level.

Figure 1. Outdoors, large pot trial at UCD shown May 26, 2020.

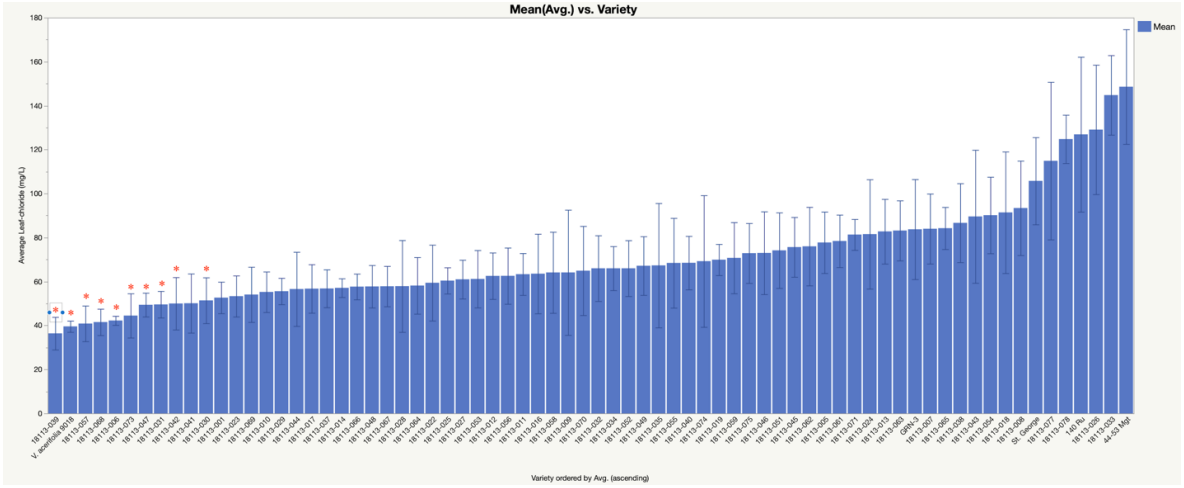

Figure 2: Continuous variation in NaCl tolerance in offspring of GRN3 x *V. acerifolia* 9018 measuring accumulated leaf-chloride levels (mg/L); * = significantly lower leaf chloride accumulation than biocontrol, 140Ru, at 75mMol [NaCl]

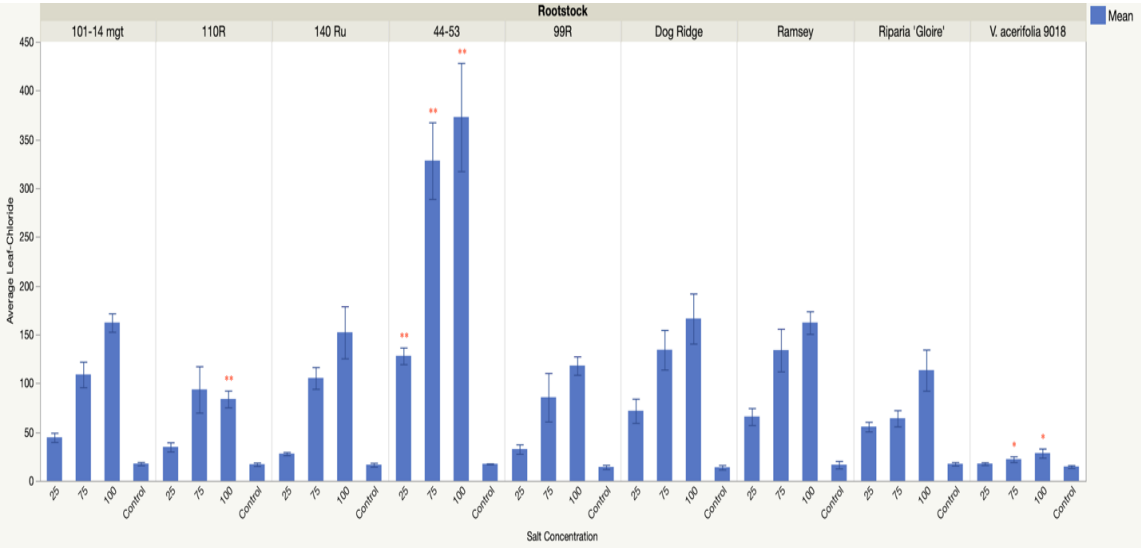

Figure 3: Treatment comparisons using 140Ru as median biocontrol; * = significantly lower at $\propto = 0.05$; ** = significantly higher at $\propto = 0.05$

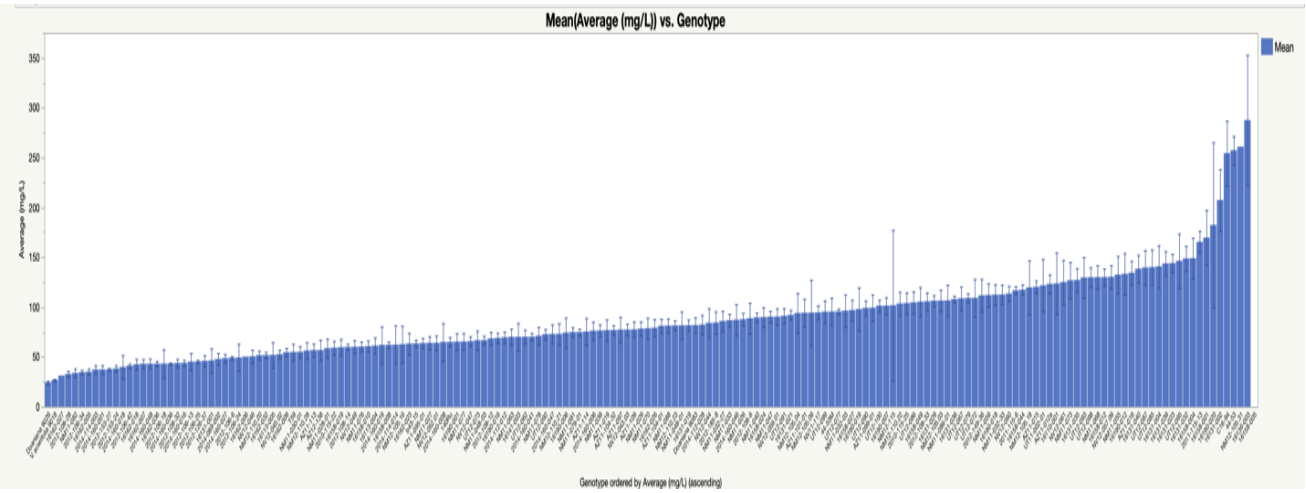

Figure 4: Continuous variation observed in leaf-chloride levels (mg/L) in unrelated SW *Vitis*.

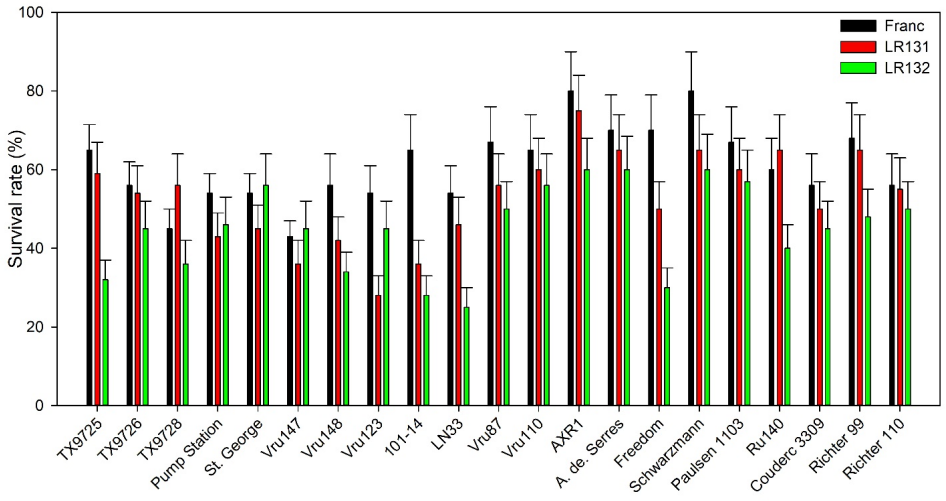

Figure 5. The survival rate of different graft combinations

>Maher

AAATCTGACGAACTTGATAAACCGAATATTTAACTTGATTCCCATTGATTATAAGTGAACAGACGTTACCAGCACCT
ACGCTCTGCGAAGTACCTGTGAATTCACTACCATGTCGATATCAGTGTCCTCCCAACGTGTAGCAGCCTCCAACCTC
TACACAAACGGACATGAAGAATCAGTTAAAGCAATTAAAGAATTGAAGAGCAAGCGGTTATTGGAGACCGAAACT
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CCTGGACGAGAGCTATGATCACTGCTTGATCCAGAGATACAAGGCGGGTGGGGCAATAGGTTTCCATGCTGATGA
CGAGCCATGCTACTTACCGGGGGGCTCCGTGGTCACCGTGAACTTGAAAGGTGATGCAACATTCGAGGTCAAAGA
GAACAGCTCTGGAAAGATAGAGAAGATCATGCTGCACGACGGAGATGTATACACAATGGGGCCAGGCATGCAAC

Figure 6. Part of the California GVA sequence

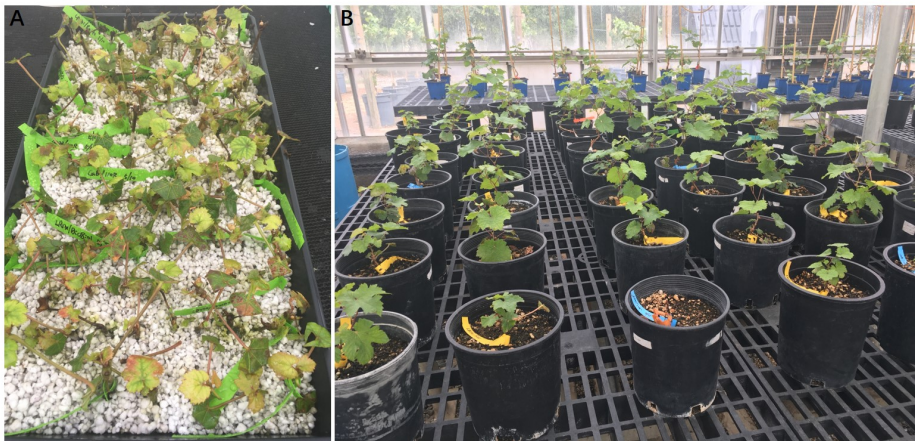

Figure 7 and 8. Surviving grafts on the propagation bed; and grafted plants transferred to the greenhouse.

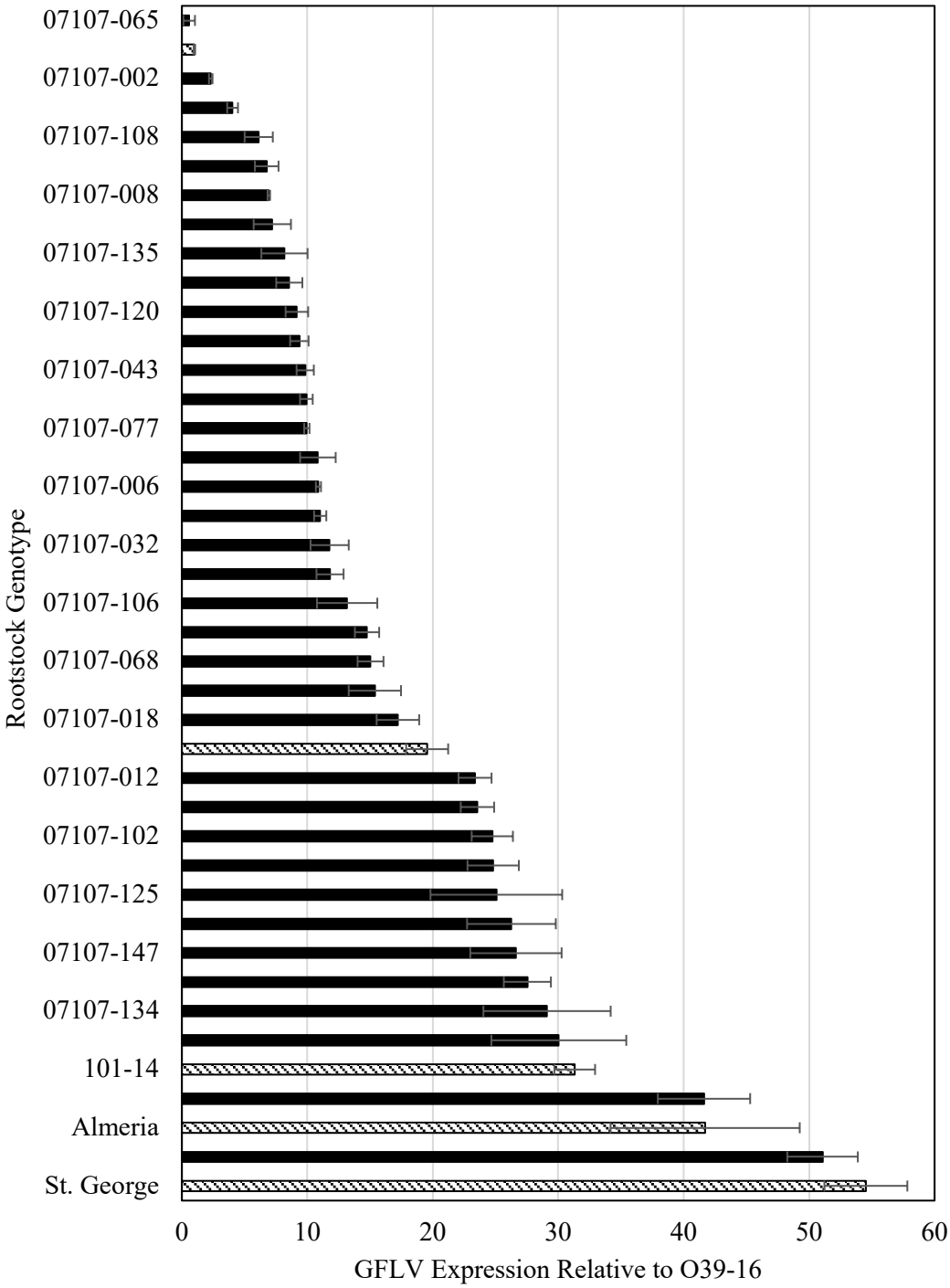

Figure 9. Quantity of GFLV in inoculated rootstocks from the 07107 population, expressed relative to the resistant control of O39-16. Positive controls Cabernet Sauvignon, 101-14, Almeria, and St. George are included.

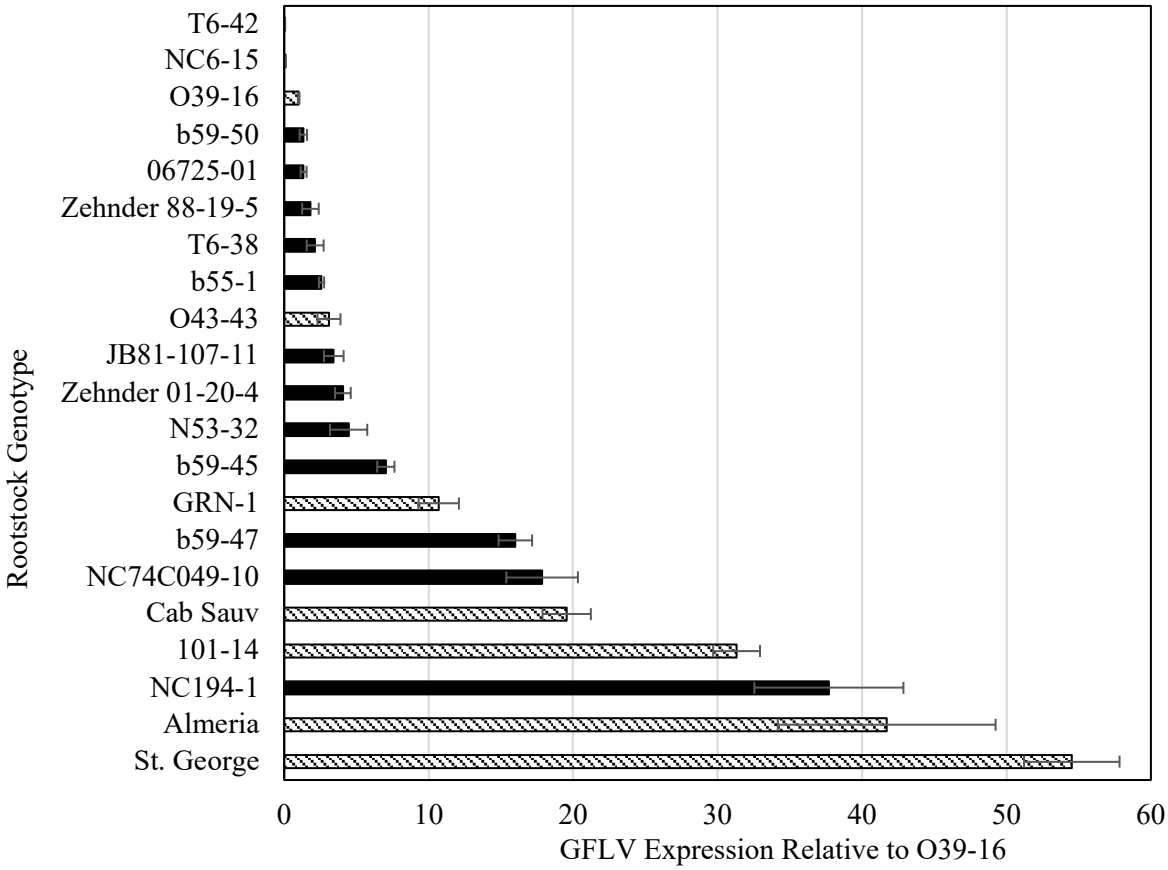

Figure 10. Quantity of GFLV in inoculated fertile VR hybrids, expressed relative to the resistant control of O39-16. Positive controls Cabernet Sauvignon, 101-14, Almeria, and St. George are included. O43-43 (sibling of O39-16) and GRN-1 (another *rotundifolia*-based rootstock) are included for comparison.

Presentations to Industry Groups

Walker, M.A. 2019. An update on the performance of the GRN rootstocks. Daniel Roberts Client Meeting, Jan 18

Walker, M.A. 2019. How to select rootstocks. Viticulture Short Course, Napa, Feb 13.

Walker, M.A. 2019. Grape vine pruning demo and instruction, UC Davis for Folsom Lake College, Feb 23.

Walker, M.A. 2019. Stacking PD resistance genes for durable resistance. Current Advances in Wine and Grape Research, UC Davis, Feb. 27

Walker, M.A. 2019. Current and future objectives of the grape breeding program at UC Davis, Salinas Farm Advisor Office, On the Road Presentation, March 8

Walker, M.A. 2019. Grape rootstock breeding update. California Grape Rootstock Improvement Commission, Coalinga, CA March 11.

Walker, M.A. 2019. The grape breeding program at UC Davis: where it's been and where it's going. CSU Fresno, March 20.

Walker, M.A. 2019. An update on the performance of the GRN rootstocks, Lakeport, On the Road Presentation, March 28.

Walker, M.A. 2019. Rootstock breeding update for the IAB. UC Davis, April 9, 2019.

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Walker, M.A. 2019. Performance of the GRN rootstocks in a fanleaf site. Lodi Winegrape Growers Association/ Gallo Winery, Lodi, CA, July 11, 2019.

Walker, M.A. 2019. UCD vineyards and grape breeding program. Lake County Winegrowers, UC Davis, July 17, 2019.

Walker, M.A. 2019. UCD PD resistance breeding program. David Ramey Winery and Growers and staff, Healdsburg, CA Aug 2, 2019.

Walker, M.A. 2019. UCD grape breeding program. SNFL/Murcia staff and directors, Murcia Spain, Aug 6, 2019.

Nguyen, A.V. 2019. Characterizing grapevine fanleaf virus resistance and tolerance in a 101-14 Mgt. x *rotundifolia* population. North American Grape Breeders Conference, Missouri State University, Aug. 16.

Walker, M.A. 2019. Breeding PD resistant wine grapes and the UCD grape breeding program. Alabama Winemakers Annual Conference. Auburn Ag Extension, Jemison, AL, Sept. 13, 2019.

Walker, M.A. 2019. Viticulture and Enology Program Overview. Presentation at visit by SupAgro – Montpellier, France. Held at UC Davis, Sept 20, 2019.

Walker, M.A. 2019. Constellation winery tour of Foundation Plant Services Vineyards and Clones. For Constellation winemakers and research directors, UC Davis, Oct. 1, 2019.

Walker, M.A. 2019. UCD Grape breeding program and department tour for Wonderful Nursery management staff. UC Davis, Oct. 17, 2019.

Walker, M.A. 2019. UCD Grape breeding program. Presentation for UCD visit by Congressman Jim Costa and staff. UC Davis, Oct. 25, 2019.

Walker, M.A. 2019. Viticulture and grape breeding at UC Davis. Presentation to Paul Schmitt and students from Wabash College. UC Davis, Nov. 22, 2019.

Walker, M.A. 2019. Progress in the UCD grape breeding program. Current Issues in Vineyard Health, FPS, UC Davis, Dec. 3, 2019.

Walker, M.A. 2019. New PD resistant winegrapes and the UCD grape breeding program, UCD Brian German Ag Press. UC Davis, Dec. 18, 2019.

Walker, M.A. 2019. New PD resistant winegrapes and the UCD grape breeding program, UCD interview with Sarah Klearman, UC Davis, Dec. 20, 2019.

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Walker, M.A. 2020. Breeding drought resistant rootstocks and update on the GRN rootstocks. Daniel Roberts Client, Martinelli Winery, Santa Rosa, CA, Jan. 10, 2010.

Walker, M.A. Grapevines on Freedom rootstock: sudden vine decline associated with graft incompatibility. Grape Day UC Davis, Jan. 21, 2020.

Walker, M.A. Grape breeding at UCD, Mendosa growers visiting UCD. Jan 29, 2020

Walker, M.A. PD resistant winegrapes released. National Grape Research Alliance, Sacramento. D=Feb. 2020.

Walker, M.A. Grape rootstocks and viruses, Crop Care Associates, Napa, CA Feb. 21, 2020.

Walker, M.A. Pruning grapevines from spurs to canes and from head to cordons. Folsom Lake College Vit course. Feb . 22, 2020.

Posters/Abstracts at Scientific Meetings

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Riaz, S., R. Hu, C. Agüero, a. Tenscher and A. Walker. 2018. Molecular breeding support for the development of Pierce's disease resistant winegrapes: new sources of resistance and markers. CDFA PD/GWSS Board Symposium Poster, San Diego, CA Dec. 12

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