WALNUT IMPROVEMENT PROGRAM 2013

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ABSTRACT

The Walnut Improvement Program works to develop improved scion cultivars for the California walnut industry and new rootstocks with pathogen and abiotic stress resistance while simultaneously increasing knowledge about the genetics of the crop and maintaining breeding resources. The primary objective of scion breeding is generation of new cultivars with early harvest dates, yield, and good kernel color. This year we continued to assist nurseries in obtaining wood for increase and production of the recently released 'Solano', an early to mid-season harvesting variety with excellent kernel color and timing similar to Vina but with better color and tree structure. Several additional advanced selections with Payne-time to mid-season harvest dates and excellent color continue to show promise and are under serious consideration for release. Wood of these was distributed to interested nurseries and growers for increase and further evaluation. This year we also continued evaluation and propagation of 86 scion selections on campus and in state-wide grower trials and completed early evaluations on over 4300 seedling trees. We continue to evaluate 121 backcross seedlings, mostly 4th generation crosses tested as virus resistant by DNA marker analysis, for their yield, bearing habit, and nut traits. The most promising of these were grafted into a patch testing block for confirmation of virus resistance and several were used as parents for next generation crossing. We collected another year of phenotyping data from a block of Chandler x Idaho crosses in order to generate further information for the walnut genomics effort and development of DNA markers, and we collected DNA samples from all breeding program seedlings for use in implementing a lateral bearing marker. A current field trial of transgenic crown gall resistant rootstock selections continues to be observed and used for graft union studies, a new trial of these was established at a site suitable for pathogen resistance testing in the field, and additional trees were grown in a nursery for potential use in orchard trials. We significantly improved the process used to introduce field material of rootstock candidates into tissue culture propagation, continued to develop use of gibberellic acid for clonal plantlet elongation in the greenhouse, evaluated the use of new types of pots for use with small plants, and improved the culture medium used for tissue culture plant production. Field and tissue culture germplasm collections continue to be maintained as a breeding resource and for use by other research projects requiring diverse genetic material.

OBJECTIVES

The objectives of the Walnut Improvement Program are:

- To provide the California walnut industry with improved walnut cultivars and rootstocks
- To develop knowledge that will increase the efficiency of walnut breeding
- To develop and maintain an array of traits available for breeding in the future

The program consists of several projects with specific objectives:

- The classical cultivar breeding project uses traditional methods to develop and release new cultivars that combine precocity (high early yield) and early harvest date with kernel quality, in-shell traits, and disease resistance.
- The backcross breeding project for blackline is designed to move the resistance to cherry leafroll virus found in black walnut and Paradox into commercial quality English walnut varieties.
- The rootstock improvement program seeks genetic solutions to rootstock related problems including *Phytophthora*, nematodes, crown gall and *Armillaria* and works to improve rooting and clonal propagation methods. Both rootstock breeding and gene insertion methods are used to develop new genotypes which are multiplied and grown for pathogen resistance testing.
- New technologies that increase the efficiency of breeding and the range of genetic material available for walnut improvement continue to be evaluated and adapted to walnut breeding as opportunities arise.
- Germplasm collections are maintained and augmented when possible for future breeding use and are available for other researchers.

PROCEDURES

Scion cultivar breeding.

Seedlings for evaluation are generated through controlled crosses. This involves bagging female flowers prior to anthesis to exclude unwanted pollen, collection and storage of pollen from chosen parents for up to a year, and careful timing in application of the appropriate pollen to receptive flowers. The crossing designs used during the 2007-2013 seasons place priority on crossing the best kernel quality, nut trait and yield selections with the earliest harvesting selections as shown in the Tables 1-7.

Seed from these crosses is collected in the fall before nut drop, air dried before storing and chilled until the end of harvest season. To ensure the highest possible germination, nuts are chipped open at the blossom end using a “Texas Nut Cracker” which opens a hole in the shell without damaging the embryo. Nuts are then immersed in cold, slowly running, water for 2 days before planting in the greenhouse. The resulting seedlings are chilled for 2 months in a cold room or outdoors to give them their first year of dormancy. In the spring the dormant seedlings are planted in a nursery for a year prior to replanting in seedling blocks at UC Davis. For many years Burchell Nursery has generously donated this service.

Seedlings to be evaluated are planted on relatively close spacing (6’) and any that appear to be terminal bearing or have signs of inbreeding (dwarfs, extra-lates etc.) are culled at age 3 to 4. By age 5, trees with continued appearance of low yield or other problems are also cut down. Full evaluations are undertaken only on precocious and laterally fruitful individuals. Surviving seedlings are evaluated for phenology (leafing, flowering and harvest dates), precocity, lateral fruitfulness, estimated yield, blight incidence, and crack-out characteristics (shell shape, texture, thickness and strength, kernel weight, percent kernel, kernel color, fill, plumpness and ease of removal in halves). Samples of the most interesting selections are also sent to Diamond Foods for independent evaluation using their grading system.
Data is then presented at an annual crackout evaluation meeting that includes growers, processors, nurserymen, and farm advisors. Participants inspect kernel boxes and data sheets to

identify possible selections. Data available includes current year field and crack-out data, performance data from past years, Diamond evaluations and computer-assisted selection. Team evaluations are followed by a general group discussion of each team's recommendations.

Promising individuals are repropagated into selection blocks and to grower trials where evaluations continue. Grower field trials are an essential component of releasing a new cultivar. We continue to evaluate current trials, seek opportunities to expand at current locations, and attempt to identify growers interested in participating at additional locations.

In addition to evaluating seedlings of crosses designed to produce new varieties for growers, we continue to evaluate a large set of over 400 trees from a Chandler x Idaho cross designed to give significant segregation for traits of interest in evaluating varieties. The purpose is to be able to correlate the accumulated phenology, yield, bearing habit, nut, and kernel trait data with unique DNA coding regions that can be used to develop markers. Once developed, these could then be used to speed selection by identifying, while the seedlings are still very young, those most likely to express desirable mature-tree traits.

Backcross breeding for scion varieties resistant to cherry leafroll virus.

The backcross breeding project is designed to introduce genetic resistance to blackline disease from northern California black walnut into commercially acceptable English walnut cultivars. Crosses are conducted using the same methods as in conventional cultivar breeding but the selection process includes an additional component of screening for virus resistance. Seedlings are first screened for potential resistance to the cherry leafroll virus using a DNA marker as reported in Walnut Research Reports (1998) and modified more recently (see WRR 2003). Retained seedlings are then culled based on the same shell, kernel, yield, and horticultural traits used for conventional scion breeding.

The fidelity of the marker used for selection has a 10% chance of error, so as potential parents and selections advance in the program it is necessary to confirm resistance. For this process, described in previous reports, a selection is grafted on both black and English rootstock (two each). After the grafts are established, bark from a CLRV tree is patched into the English rootstock and into the selection scions grafted onto black rootstock. If a selection is resistant to the virus it will survive on the black rootstock because the inoculum patch was rejected, and die (exhibiting a black line) on the inoculated English rootstock. Confirmed resistant, thin-shelled individuals with the best commercial traits are then used as parents for the next generation of backcrosses to an English walnut parent.

New technologies for genetic improvement of walnut

In addition to conventional field breeding, the Walnut Improvement Program utilizes tissue culture and gene transfer techniques to enhance or develop traits of commercial interest, continues to establish and evaluate field trials of transgenic plants, and has worked to help facilitate transfer of genomics information from Walnut Genomics Project into practical markers for more efficient selection of key traits in the breeding process. Current laboratory work includes improvements in micropropagation methods, enhancement of procedures for introducing material into culture, better ways to control and eliminate contamination, methods for bench-budding small containerized plants, and generally increasing efficiency of clonal plant production for commercial use.

Germplasm resources

Germplasm collections are maintained and augmented when possible for future breeding use and are available for other researchers. Current field collections at Wolfskill and Davis include a diversity of California cultivars, leading cultivars and selections from around the world, material with unusual traits, and germplasm of interest for rootstock development. Our collection differs in emphasis, content, distribution policy, and cultural practices from that of the USDA Germplasm Repository.

The in vitro germplasm collection is maintained in the laboratory. It includes diverse scion and rootstock genotypes which are maintained for experimental use and to supply material to both research and commercial labs on request.

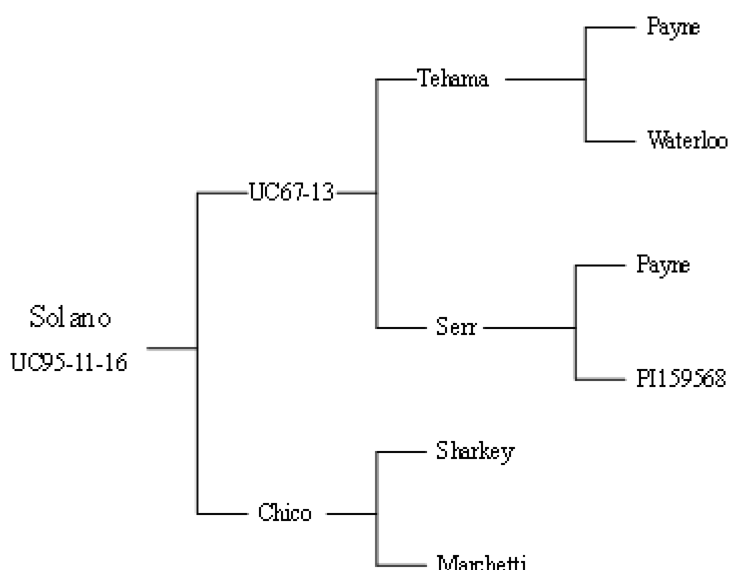
RESULTS AND DISCUSSION

Cultivar breeding

The conventional scion breeding portion of the improvement program currently includes over 4300 seedlings under evaluation in our orchard and 86 selections under evaluation at Davis and in state-wide selection blocks and grower trials (Table 1). Crosses, objectives, and numbers of seed and seedlings produced for each are shown in Tables 2-7. Phenology, yield, and nut trait data for the advanced selections under evaluation are provided in Tables 8-11 and a description of selections can be found in Appendix 1.

'Solano' an early-to mid-season variety with leafing, bloom, and harvest dates very similar to 'Vina', but with better color and a more upright branch structure, was released last year and we continued to provide information to interested growers through publications and grower meetings and to assist nurseries with wood requests. 'Solano' produces uniform nuts with good appearance and solid shells and both the yield and kernel quality were excellent in trials again this year. Due to its later leafing and male-first bloom habit, this variety is anticipated to be more suitable for planting in the Sacramento Valley than Ivanhoe and the nuts are larger with a stronger shell. Suggested pollenizers include 'Tulare', 'Chandler' and 'Howard'. Further data on 'Solano' can be found in Appendix 1 and Tables 8-11.

Pedigree of 'Solano'.



‘Ivanhoe’, a very early harvesting variety with excellent kernel color, was released to nurseries and growers three years ago and continues to exhibit very early harvest timing and excellent production of extra light kernels. The early leafing and flowering dates suggest planting this variety in the southern part of the Central Valley. The female flowers of ‘Ivanhoe’ open before the catkins. ‘Serr’ or ‘Payne’ would be suitable pollenizers. Ivanhoe trees are not expected to be large in stature so this variety should be grown on Paradox rootstock to ensure sufficient vigor and probably planted on closer spacing than ‘Chandler’. See additional information in Appendix 1 and Tables 8-11.

We also continue to collect data on observations on performance of ‘Sexton’, ‘Gillet’ and ‘Forde’ which were released in 2005 and described in the 2004 Report. Updated information is included in the Appendix 1 and the data tables at the end of this report. These three were originally released for anticipated low blight scores, harvest dates earlier than ‘Chandler’, and production of large light-colored kernels. The canopy structure of ‘Sexton’, with many narrow fork angles and a tendency to neck-bud, has limited its adoption by growers. The harvest date for ‘Forde’ has proven to be later than anticipated and yields in several young orchards the last two years have been disappointing. Hulls tend not to open promptly after loosening from the shells which impedes drying in the field and this variety also shows a tendency to produce multiple small branches if pruned heavily, so only light pruning is recommended. ‘Gillet’ continues to exhibit a mid-season harvest of large kernels but yields were not as strong this year as last and several growers reported color issues, perhaps do to a period of severe heat during the summer. At other locations color was excellent but stability of this trait needs to be watched further.

Several additional advanced selections with early to mid-season harvest dates and consistently light to extra-light kernel color are under active and serious consideration for release. Those with the most extensive evaluation data and most promising features are indicated with an asterisk next to the descriptions in Appendix 1. These are currently included in grower trials and wood distribution to interested nurseries is in progress. A comprehensive list of grower trials and nursery blocks that include new scion selections and recent releases, their locations by county, the year each was established, and the growers involved is included in Appendix 2.

Suggested pollenizers for recently released varieties

Cultivar	**Pollenizers**
Sexton	Sexton, Howard, Tulare
Gillet	Payne, Serr, Vina
Forde	Ivanhoe, Howard, Tulare
Ivanhoe	Serr, Payne
Solano	Chandler, Tulare, Howard

Backcross breeding for resistance to cherry leafroll virus.

Backcross breeding to develop English walnut cultivars with resistance to the cherry leafroll virus is proceeding. We continue to test backcross seedlings for nut quality, harvest date, and yield in addition to virus resistance, and currently retain under active evaluation 121 individuals from an original population of over 800 4th generation crosses tested as likely resistant to CLRV using a DNA marker. Several of the most promising individuals were used as parents again this spring to produce a third year of BC5 seed (Table 6). In addition, we expanded and continued to develop a bark patch testing block containing the most horticulturally promising of the DNA tested BC4 trees to confirm the marker results before moving these to new grower trials and continuing their use as parents for further improvements.

Field trials of virus resistant scion selections established in San Benito County by Bill Coates, Contra Costa County by Janet Caprile, and San Joaquin County by Joe Grant continue (see Appendix 2 and separate reports). In addition to patch testing on campus, graftwood of the more promising BC4 seedlings was sent this year for addition to Al Bonturi's San Benito County trial.

Another strategy for preventing blackline disease would be a gene silencing approach, somewhat similar to method we have already used to develop crown gall resistant rootstock, but in this case by developing a virus-inhibiting inter-stock (see 2013 proposal by Sudhi Mysore). Use of a male-sterile genotype to avoid any pollen production would greatly improve regulatory acceptance and we would need somatic embryo cultures of a genotype that also exhibits a tolerant (English type) response to cherry leaf roll virus. Tolerant backcross selections, those that will not go forward in the resistant scion development program, meet both these requirements. We have developed and maintained somatic embryos of line 48-12, developed from an immature nut of tolerant backcross selection 93-048-6 for this work. With the assistance of a visiting scholar in the lab this year we began exploring this approach. One suitable construct is currently available and will be evaluated first. Development of others is anticipated in conjunction with the Dandekar and Mysore labs.

Genomics and marker assisted breeding

We continue to maintain and evaluate a large block of a Chandler x Idaho seedlings generated for genomics work aimed at marker development. The parents of this cross were chosen to develop a large seedling population segregating for as many important traits as possible (lateral bearing, harvest date, kernel color, leaf date, bloom phenology, insect resistance, blight response, shell appearance, etc.). More than 400 seedlings were established and data has been collected annually on each. Trees from this cross continue to be evaluated as they mature to confirm horticultural traits and nuts will continue to be available for phenotyping development in support of the genomics initiative.

DNA has been collected from leaves of each of the trees in the Chandler x Idaho population and from all the existing seedling trees from the breeding program (2003-2013 crosses) for use by the Walnut Genomics Project in developing markers for key horticultural and pest or pathogen resistance traits. Discussions over the last several years, as part of the PRAC process and among the Walnut Genomic Project participants, have established priorities for marker development. These were lateral bearing, harvest date, kernel color, husk fly resistance, blight resistance, and shell traits such as seal, ease of halves, strength and size. New or improved evaluation methods will likely be needed in the course of developing markers for several of these traits. We are now in the process of implementing use of a lateral bearing marker and developing markers in order to screen seed or freshly germinated seedlings for traits of interest. Successful application will allow us to identify and discard seedlings prior to nursery and field planting, improving efficiency of the breeding program by reducing land costs, evaluation time, and management effort.

Transgenics

Additional rooted plantlets of eight lines expressing the construct for crown gall silencing in two different background genotypes (J1 and RR4) and the appropriate control plants were produced this year, rooted, and grown in the greenhouse for development of two new field trials and for further testing of efficacy in the greenhouse. An amended APHIS permit was filed for two plantings. One was established this fall at Armstrong Field Station on a site previously used for crown gall work and where trees can be exposed to crown gall under field conditions. The second was planted at a commercial nursery site. The nursery planting was intended to facilitate grafting a uniform set of these rootstocks for use in a future commercial orchard trial. After an additional year of observation and following additional testing by the Kluepfel lab we have now identified J1 1A as the preferred clone for deregulation. We continue to maintain this wider array of genotypes for the present for further comparative testing.

The current one-acre field trial of rootstock lines containing the RNAi construct for crown gall resistance and the appropriate controls, either grafted to Chandler or in a few cases kept as ungrafted trees, continues to be maintained in our orchard under APHIS field permit. Trees continue to be observed for both horticultural performance and any natural occurrence of crown gall. To date a single control seedling has developed a gall. These trees are also being used for DNA, RNA and protein analysis needed for deregulation.

Plants of genotypes exhibiting altered expression of shikimate dehydrogenase (SDH), an enzyme that regulates the production of gallic acid/tannin production were planted in a new field plot under APHIS permit in order to facilitate nut production for use in examining the role of tannins in nut quality and in insect, nematode and disease resistance. Walnut polyphenol oxidase (PPO) is thought to play a role in disease resistance and kernel color traits. Chandler trees expressing the cry1A(c) BT gene, and which have shown good efficacy against codling moth in previous USDA tests, also continue to be maintained in pots for future use if desired.

Improving micropropagation methods in the laboratory

Efforts in the laboratory to improve multiplication, rooting, acclimatization, and gene insertion methods continued this year. Although many walnut genotypes elongate and multiply well on the standard DKW formulation, others, particularly many *J. hindsii*, *J. cathayensis* and wingnut accessions, do poorly. In addition, improvements in elongation, multiplication, and rooting rates for standard rootstock varieties would contribute to more efficient plant production and reduce cost to growers. Laboratory results included an improved sterilization procedure that allowed more efficient introduction of new material into culture, identification of an alternate iron formulation that improved growth, and testing use of gibberellic acid for in vitro elongation of microshoots.

Improved sterilization method for introducing nodal cuttings to culture

This year, in the course of introducing field-grown material to culture by nodal cuttings, we developed a significantly improved method for removing surface contaminates prior to culturing without damaging the plant tissue. For this procedure we cut individual nodes of young, tender, field or greenhouse-grown branches directly into small bottles containing soapy water (a few drops of anti-bacterial lab soap), drained them for a quick 10-15 second rinse in 80% ethanol to dissolve surface waxes and oils, and then returned them to fresh soapy water and placed the bottles on a shaker for approximately one hour. Soapy water was again drained and nodes were sterilized for ten minutes in a 5% commercial bleach solution followed by a single short rinse in sterile water (nodes rinsed individually in glass tubes containing 8 mls of sterile water each) before culturing on DKW medium. This procedure causes much less phytotoxicity, and less phenolic leakage after culturing, than the previously used 15% bleach for 10-20 minutes while still yielding a high proportion of clean explants. The much higher success rate with this method makes introduction of material by nodal cuttings significantly more efficient and practical, and allowed us to attempt over 80 introductions by nodal cuttings in a single season, far exceeding any past efforts.

Alternate forms of chelated iron - FeEDTA and FeEDDHA

Alternate formulations and concentrations of chelated iron were tested by substituting either 230µM or 90µM FeEDDHA in place of the standard DKW ‘F’ stock solution that uses 133 µM FeEDTA. The three media tested were: DKW standard medium [001], DKW without F stock + 230µM (100mg/L) [865 medium] and DKW without F stock + 90µM (39.1mg/L) [866 medium]. Genotypes used included VX211 (standard *J hindsii* x *J. regia* Paradox), JCS2 (*J. cathayensis*), W17 (*J. hindsii*), K3 (*J. microcarpa*) CR (*J. regia* ‘Chandler’) and 7-9 (*J. regia* x *J. cathayensis*), Px1 (standard *J hindsii* x *J. regia* Paradox), SC5 (J. cathayensis x J. regia ‘Serr’) and JCS1 (J. cathayensis x J. regia ‘Serr’). Experiments were run using of one plant per tube and 12 replications per genotype in each trial.

Differences were small for most genotypes tested (Table 12) but several difficult accessions, and notably wingnut in additional trials, showed improved growth and shoot quality on FeEDDHA. The lower concentration appeared to be slightly better for several genotypes. Based on experience this year, all cultures in the lab now have been moved to the 90µM FeEDDHA formulation.

Gibberellic acid for shoot elongation

A number of genotypes, including *J. regia* cultures, do not elongate rapidly enough for efficient production of rootable shoots. Inclusion of different concentrations of gibberellic acids, GA 3 or GA 4+7, in the standard DKW multiplication medium (001) to accelerate this process was tested using ‘Chandler’ microshoots. All GA was filter sterilized and add to media after autoclaving and experiments used12 replications of 1 plant per tube per genotype.

Although gibberellic acid applications have been successful in promoting elongation of greenhouse plants, both GA 3 and GA 4+7 at the concentrations tested had the opposite effect in vitro and reduced the elongation of shoots (Tables 12-13). The third experiment, using dipping in GA solutions, was undertaken to see if an interaction of GA with the tissue culture medium was somehow responsible for this effect but GA in water also reduced elongation (Table 14).

Improving greenhouse production methods for clonal rootstocks

Impact of container type on root development

One of our continuing goals is improvement of materials and procedures for efficient greenhouse production of clonal rootstocks. This year we ran a small experiment to look at a diversity of available pots and transplant options for walnut clonal rootstocks and their effect on root structure and plant health.

We examined three types of finished pots; one was our standard continuous wall pot, the 4” x 9.5” MT49 from Stuewe and Sons. The second was a similar sized severe air pruning pot developed by Brian Kemp and manufactured by Stuewe and Sons called a Pioneer pot (8” x 4”). This consists of bands of plastic interspersed with open air and comes in a tray with a sidewall designed to keep humidity in the root area. The third was an experimental Elle pot (120 mm x 120 mm). Elle pots are cylinders of special paper filled with media and then cut to a specific length. We also looked at a cell tray for rooting, also from Pioneer. This is a 60 count tray (1.75” x 3”), similar in form to the larger size Pioneer pot with bands of air and plastic interspersed, and with a tray sidewall designed to keep humidity in. We compared this to our Cone-tainer Stubby tree cell that we typically use (1.5” x 5.5”).

A secondary goal was to test the effect of shifting plants multiple times versus direct sticking in the final container. Our first set of plants, and the oldest, was rooted in our normal media in a cup, then transplanted to either the 60 count or the stubby, and then finally shifted to either the large Pioneer pot or the MT49 pot. Treatments were: CT2 (control transplanted twice) or PT2 (Pioneer pot transplanted twice). Our second set was stuck at rooting in either a 60 cell or Stubbys and then transferred to the final pot. These were treatments CT1 (control transplanted once) and PT1 (Pioneer pot transplanted once). Our final set was stuck directly into the final containers. These were treatments CT0, PT0, and L0 (Elle pot, never transplanted). At the conclusion of this experiment, we did a destructive inspection of half of the plants; the other half we lined out in the field and will evaluate rooting and survival in the spring.
During our destructive inspection we took root and shoot weights and tried to characterize the architecture. We measured the depth of the deepest root, the widest point of the root mass, and the depth to the widest root point. We also took a subjective depth assessment based on the radial array of the roots and the 3-dimensionalality of the root ball on a scale of 1-5.

There are several things to consider in interpreting the data. The first is that the age of the plant really matters and we used plants that came in production cycles, so the oldest plants (CT2 and PT2) were six weeks ahead of youngest plants (CT0, PT0, and L0), where differences were more pronounced. Also, we used the plants we had available, which were RX1, VX211, and Vlach, and there were not always comparable plants in each treatment. Finally, in collecting data for the Elle pot treatment (LO) it was difficult to ascertain weight due to roots growing through the paper pot and for the PT treatments it was sometimes difficult to get accurate weights due to root architecture holding soil very firmly underneath the root crown.

Overall root weights were larger in our standard pots, followed by Pioneer pots, followed by Elle pots (Table 15-16). To reiterate, there were clear biases in this test. Elle pots plants were the youngest, with the highest percentage of RX1, as that was what was available. RX1 had the smallest root mass of the clones, followed by Vlach, and then VX211 (Table 17). RX1 was also the shallowest rooted clone. The control pots had the largest root area, and generally the deepest rooting, followed by the Pioneer pot. The Pioneer pot had the greatest 3-dimensional root system as well as the greatest shoot weight.

The effect of transplanting was, in general, to distort natural tendencies genotypes. RX1 when transplanted did not root as shallowly as it did in untransplanted treatments. Transplanting also seemed to increase flaws, (root twisting, j-rooting, etc.) and observationally the degree of these flaws was not altered by choice of container.

Pot design did lead to drastically different root architecture. The Pioneer pot produced a dense, 3-dimensional rooting system with many small fine roots. The rooting was heavily concentrated away from the side walls and down the center of the container. This could have been exacerbated by our difficulty in fully saturating the media in this pot. It tended to dry very quickly, was hard to re-wet, and dried from the bottom up. Roots in the control pot immediately spread to the sidewalls, then grew down and tended to pool roots at the bottom of the container. Roots did not spread very thoroughly in the soil, giving the root architecture a bow-legged, flat appearance. The Elle pot seemed to split the difference. Roots grew more in the media but also sometimes grew along the sidewall. Roots sometimes failed to root prune, especially when media escaped from the container and filled the cell, possibly a result of over-watering.

The eventual goal is to find a container which transitions well to field conditions, and we will likely learn more as we examine the plants we lined out in the field. It is safe to say that although a continuous wall pot can contribute to a substantial root system, it may not lead to the best architecture for “pot to field” transition, especially when working with deep-rooted perennials. It is too early, and the data set is still too small to say which is the better alternative, but this is an area which needs to be explored further if commercial production of containerized clonal rootstocks continues increase.

<u>Gibberellin and Promalin treatments for elongating young clonal plantlets</u>

Last year we established that applying a low rate (5.5ml/L) of the commercial product Promalin (a GA4/7 BAP mix) early in the growing process and at frequent intervals (twice weekly) produced consistent and predictable shoot elongation of small liner plants. This year we adopted this protocol routinely and used it with good success to produce liner plants of a larger size and sustain active shoot growth for a longer period of time for our SCRI work. However, there were questions which remained, including the effect on root growth, differences in genotype responses, and effects on dormancy.

This year we undertook an experiment to clarify some of these factors, primarily the effect on root growth. We used four genotypes with diverse genetic backgrounds; AX1 *(J. californica* x *J. regia*), WIP3 (Paradox x *J. regia*), Vlach (*J. hindsii* x *J. regia*), and VX211 (*J. hindsii* x *J. regia*), and applied four hormone treatments and a control. The hormone treatments, all applied twice weekly, were: 0.1g/L BAP, 0.1g/L GA4+7, 0.1g/l BAP + 0.1g/l GA4 +7 (mixed treatment), or a 5.5ml/l dilution of Promalin. We applied the treatments for approximately one month and then assessed shoot height and root weight for half the trees in each treatment. The other half we potted into larger containers and continued to treat. After one additional month we also assessed root weight on these. All plants used were produced in our laboratory, rooted ex-vitro and grown in a stubby tree cell, using our standard Sunshine #4 + micronutrients media. After the initial month of treatment, the half of each set retained was grown in Tall-one Tree Pot (4"wide x 14"deep from Stuewe and Sons) containing UC mix potting soil. The chemicals were prepared in our lab, with the exception of Promalin which we obtained from Valent.

After one month, while plants were still small, the best root systems were on the non-GA plants (Table 19). These also had the greatest root to shoot ratio. At two months, after the plants had grown in larger pots, the best root systems were on the GA treated plants which were the larger plants. All treatments containing GA stimulated height growth and consistently produced greater root to shoot ratios at 2 months (Table 20). The BAP only treatment and controls never showed significant shoot elongation (Tables 21 and 22). The height differences were dramatic and GA-stimulated shoot growth clearly contributed to larger root systems overall as trees increased in size. There was a greater percent elongation when BAP and GA were applied together, but better root-shoot ratio and quality in the GA alone treatment.

There were also genotype differences in response. WIP3 sometimes elongated even without hormones but elongated incredibly consistently with GA application. Vlach seemed to have trouble elongating at all, even with hormone applications. These differences are consistent with observational experience with these clones and results from previous trials; Vlach seems least likely to respond to treatment. VX211 and PX1 also do not elongate readily, while RX1, AX1, WIP3 seem to elongate well both with, and to a lesser extent, without treatment.

As a note of caution, the initially high shoot to root ratio and suppressed root growth resulting from GA application can be a problem. Special care must be taken to prevent shoot desiccation if these plants are transplanted at this stage. Also, more work needs to be done to understand genotype differences. After attempting to apply GA for shoot stimulation to a broad range of genotypes for the SCRI program, it appears that this treatment may not be appropriate for every genotype. Also, we do not have good understanding of how this may affect subsequent plant dormancy or possible seasonal effects on response but the ability to consistently elongate plants without a cold treatment is a valuable tool that allows us to avoid the need to chill in order to stimulate elongation of young plantlets, saves us months of time in the testing process, and takes much of the seasonality out of pathogen resistance testing procedures.

<u>Field practices and observations</u>

This year we added infrastructure to our fields to allow us to fertigate whole blocks, dramatically cutting the time required to fertilize and increasing versatility in timing. This led to much improved leaf nitrogen levels when tested in July. We also applied 400 lbs KCl to fields this winter as leaf samples and soil testing showed some fields with potassium levels bordering on deficiency. Blight control is always difficult in our blocks due to the huge variation in seedling phenology. While we prefer some blight pressure so we can observe potential genetic differences, years of no spraying allowed populations to build to the point that evaluation for other traits was becoming difficult and we initiated a spray program two years ago. Although this was a drier spring than last, rains were late and unexpectedly large. This, combined with the sprayer being down for maintenance when rain occurred, let to incomplete spraying of blocks. The department acquired a new sprayer this year which should help in the future. Similar to other growers in the state, we are observing increased incidence of Botryosphaeria. We sprayed once last year and twice this year with Pristine, once with the last blight spray and once after rain in June and incidence of this disease seems to have improved since last year. We have also observed some occurrence of anthracnose. There appears to be variation among seedlings in susceptibility to both diseases and we are considering how best to begin phenotyping material in the breeding populations. Several years of husk fly sprays and careful attention to timing have significantly curtailed the serious infestation we were experiencing two years ago. We are seeing the same trend towards earlier emergence that other growers are seeing and began trapping in early June. Mites continue to present a problem in management and we hope to monitor more carefully and likely begin sprays earlier next year. With assistance from Bruce Lampinen and improved flexibility on the part of the department field staff we have increased our use of stem water potentials to manage irrigation, always a difficult task given our non-uniform tree ages, varied soil conditions, and limited infrastructure. Rodent control continues to be a serious problem particular as we farm in an increasingly urbanized area. This year, with the cooperation of the facility staff, we have continued to increase control of gophers and ground squirrels. A looming issue is the appearance of tree squirrels this year in one block. These have become common in residential areas of Davis in the last few years and could be devastating if they move into the orchards.

Germplasm resources and maintenance

We continue to manage large collections of both field and in vitro germplasm for use by the Walnut Improvement Program, cooperating researchers, and commercial labs and nurseries. We supply microshoots and somatic embryos to commercial laboratories on request and to research cooperators for a variety of projects. Among these are licensed commercial rootstock releases, CLRV tolerant selections, *Phytophthora* survivors from growers' orchards, and PDS selections for crown gall, nematode, and *Phytophthora* resistance. We also maintain a long-term *in vitro* nematode population for use in nematode resistance research by the Dandekar and Ferris labs. The field germplasm collection was used this year for genomics development work, by Bob Van Steenwyck for husk fly studies, by Nick Mills for aphid work, and for rootstock breeding. In addition we again supplied graftwood of germplasm from these blocks to fill a variety of research and nursery requests.

Appendix 1. Description of Selections 2013. (*indicates most promising)

Gillet (95-022-26) (76-80 x Chico) (selected 2002): Gillet is protogynous variety with excellent yield, large 7.8 g kernels, and a mid-season harvest date about two weeks earlier than Chandler. It is a large and vigorous tree that was selected in part for its low blight scores. The canopy is more open and allows better light penetration than Tulare. Nuts average 51% kernel and kernels are easily removed. Kernels color has been generally lighter than Tulare at comparable locations, averaging 87% light or extra light. Kernels have had little shrivel and few veins or blanks. Seals can be weak in young trees but were adequate this year at all locations sampled. This variety is suitable for cracking but not for in-shell use. Released 2004. (Trials: Whitney Warren, Scheuring, Crane, Modesto JC, Taylor, Headrick, Gilbert, Nickels, G. Anderson)

Forde (95-026-37) (Lara x Chico) (selected 2001): This selection produces kernels with good color and nuts have excellent kernel fill but it continues to harvest later than expected at release - close to or even later than Chandler. It has large, plump 8.2 g kernels, a protogynous bearing habit, and nuts that yield 53% kernel. Its shell and seal strength, kernel fill and plumpness all exceed Chandler and kernels seldom exhibit tip shrivel but nuts often loosen in the hulls before the hulls split and then hulls do not open widely, so nuts tend to stay in the canopy until shaken rather than fall readily on their own. This can impede drying of nuts in the field and some nuts appear to stick late after most are well past harvest time. This is a large vigorous tree with upright growth and little blight but yields in several young orchards the last few years have been poor. New growth can push and feather following heavy pruning so only light pruning or none is recommended. Released 2004. (Trials: Whitney Warren, Scheuring, Modesto JC, Crane, Stolp, Taylor, Headrick, Gilbert, Nickels, CSU-Chico)

Ivanhoe (95-011-14) (67-013 x Chico) (selected 2001): Ivanhoe is a protogynous selection released in 2010 as very early-harvesting variety with excellent color. It harvests with, or before, Payne and Serr and exhibits very good yield, smooth shells with excellent color and appearance, and mostly Chandler-like extra light kernels averaging 7.4 g. It likely will not have sufficient shell strength for in-shell use, the seals should be watched, and nut size is not large. Nuts yield 57% kernel with very easy removal of halves. Kernel quality and harvest date are excellent. Trees leaf and bloom early, at Payne and Serr time, and this variety is known to be susceptible to blight. Some summer heat damage to the foliage, summer nut drop, and tendency to sunburn has been observed and should be watched. Ethylene applications are being used successfully to move harvest even earlier. Trees should be planted on Paradox rootstock and/or closer spacing due to the relatively small stature of this variety and trees should be managed well to maintain nut size. Released 2010. (Trials: Scheuring, Whitney Warren, Moore, Spanfelner, Headrick, Carriere, Stolp)

Solano (95-011-16) (67-013 x Chico) (selected 2003): This new release is a protandrous early in-shell sibling of Ivanhoe that harvests about a week after Payne and is similar in timing to Vina with good yield and color. It has large, light colored kernels that average 8.0 g. Nuts have very solid oval shells that have sufficient strength and seal for in-shell use, give 54% kernel and have an attractive appearance. Leafing and flowering dates are about a week after Payne and similar to Vina. Trees appear upright and vigorous. Solano was released last year and is now available to growers through most nurseries. Released 2013. (Trials: Scheuring, Spanfelner, Stolp, Whitney Warren, Sierra Gold, Burchell, Moore)

****93-028-20** (Chandler x PI 159568) (selected 2001): This selection should be considered for use as a mid-season in-shell competitor with Hartley and is under strong consideration as a potential release in the near future. It has Tulare or earlier timing with large, oval, very attractive nuts. It leafs a few days before Chandler but harvests about two weeks earlier with good yield and has had almost no blight. The smooth, attractive, very solid shells have good seals and 55% kernel. The large, very plump kernels average 8.4 g and kernel color is consistently excellent. This selection is a candidate for release but needs additional observation for yield in young trees and performance in grower trials (Trials: Whitney Warren, Scheuring, Stolp, Carriere, Sierra Gold, Burchell, Stuke, Dave Wilson, Crane).

***00-006-227** (76-080 x O.P.) (selected 2009): This early-harvest date selection with very good yield harvests approximately with Vina, and is a potential release. The large, mostly extra light kernels average 8.0 g and appear to hold color well on the ground or after storage. The tree leafs ten days after Payne, a few days before Chandler. It produces nuts with 60% kernel and shells with good seals that are thin but sufficiently strong, like Serr. The tree is protogynous with a bloom period that is inverse of Chandler, so it could serve as a pollenizer for Chandler and vice versa. (Trials: Scheuring, Whitney Warren, Stolp, Sierra Gold, Suchan, Burchell, McDavid, Crane)

03-001-977 (Chandler x Phase II) (selected 2009): This short-season selection leafs with Chandler but harvests about two weeks earlier. The protogynous bearing habit, with flower timing inverse of Chandler, can provide good pollen coverage for Chandler. This selection has had no blight, even in years with late rain during bloom and had less husk fly than other trees in the same block. The nuts have an excellent shell appearance with good seals and very easy kernel removal in halves. Kernels average 8.2 g and nuts give 59% kernel. (Trials: Stolp, Whitney Warren, Scheuring, Sierra Gold, Suchan, Burchell, McDavid, Crane)

03-001-985 (Chandler x Phase II) (selected 2011): An early harvesting selection with solid shells that could be suitable for in-shell use. Harvests five days after Payne but also leafs with Payne and has a protogynous bloom habit. Nuts average 54% kernel. Kernels are mostly light color and average 8.6 g. Shells may be harder and stronger than necessary and are well filled but kernel removal has been good. Although early leafing, blight scores have been low.

***03-001-1372** (Chandler x Phase II) (selected 2010): This mid-season protandrous selection leafs with Chandler but harvests with Tulare. This selection has good yield of large 8.9 g kernels, kernels with excellent color, and almost no blight. The nuts average 56% kernel with excellent removal of halves. Kernel color is Chandler-like and almost entirely light to extra light. (Trial: Scheuring, Whitney Warren, Sierra Gold, Suchan, Burchell, McDavid, Crane)

***03-001-1457** (Chandler x Phase II) (selected 2010): This large vigorous tree exhibits excellent yield harvests about a week later than Payne, and has a protandrous bloom habit. Leafing is a week later than Payne and little blight has been observed. The nuts have excellent shell appearance, yield 59% kernel, and shells are thin but have sufficient strength. The 8.1 g kernels have good color and are very easily removed in halves. (Trial: Whitney Warren, Scheuring, Stolp)

***03-001-1938** (Chandler x Phase II) (selected 2010): Selected for its huge yields and mid-season harvest timing similar to Tulare, this protandrous selection produces 8.1 g kernels with very good kernel color. The smooth and light colored shells have good strength. The attractive round and well-filled nuts yield 57% kernel with easy removal of halves. (Trial: Whitney Warren, Scheuring)

***03-001-2357** (Chandler x Phase II) (selected 2010): This selection has consistently exhibited strong yields and produced attractive kernels with excellent color and easy removal of halves. The tree is protandrous and leafs five days later than Payne with harvest a week before Chandler. Kernels average 8.8 g and have consistently been mostly extra light in color. Shells are well filled, have an attractive appearance, are thin but not weak, and give 60% kernel yield. Harvests fairly close to Chandler but color, fill and yield merit consideration for release. (Trial: Scheuring, Whitney Warren, Stolp)

***03-001-2434** (Chandler x Phase II) (selected 2010): This protandrous tree is has excellent kernel color and strong mid-season yield about ten days before Chandler. The plump 8.9 g kernels have been entirely light or extra light and the well-filled nuts produce 57% kernel. The tree leafs approximately with Payne and has showed only moderate amounts of blight. (Trial: Scheuring, Whitney Warren, Stolp)

03-001-2556 (Chandler x Phase II) (selected 2010): This protandrous selection with outstanding kernel color harvests a week before Chandler and leafs a week later than Payne. Blight scores have been fairly low and yields very good. The nuts have smooth, light colored, attractive shells but are maybe too thin. The mostly extra light and very plump kernels average 8.7 g and are very easily extracted from nuts averaging 60% kernel. (Scheuring, Sierra Gold, Burchell)

***04-003-143** (Chandler x O.P) (selected 2011): This selection has very strong yields and excellent kernel color. The tree leafs mid-season and has a protogynous bloom habit that is inverse of, and overlaps, Chandler. The large round nuts have large plump kernels averaging 9.1 g with predominately Chandler-like light or extra light color. Nuts have smooth, light attractive shells that yield 55% kernel with easy removal of halves and a harvest date ten days before Chandler. (Trial: Scheuring, Crane)

04-003-293 (Chandler x O.P) (selected 2011): A selection with huge yield four days after Payne, excellent kernel color, and leafs a week after Payne but nuts continue to be small and kernels have averaged only 6.6 g. This selection has a protogynous bloom habit and its pollen shed covers Chandler well. The nuts have good shell traits with 51% kernel and kernels are entirely of light and extra light color. (Trial: Scheuring)

04-004-58 (91-096-3 x O.P.) (selected 2011): This is a late-leafing short-season protogynous offspring of a previous blight-resistant selection that harvests mid-season, leafs two days after Chandler, and produces kernels with excellent color. Nuts averaging 7.2 g, kernels are easily extracted in halves, and yield is good. Pollen would cover late Chandler bloom or Franquette. Used as parent in crosses. (Scheuring, Suchan, Spanfelner)

04-006-28 (90-027-23 x O.P) (selected 2012): This is an early harvest date selection with excellent yield and kernel color. Well-filled nuts yield 56% kernel and harvest six days after Payne. Kernels average 7.9 g with mostly extra light color but blight and seal strength should be observed further. (Trial: Scheuring)

05-002-233 (95-022-26 x O.P.) (selected 2012): This is a Gillet offspring with a harvest date four days after Payne, excellent yield, and nuts with solid shells and 55% kernel. Color has been consistently excellent with all light or extra light kernels that are plump and average 7.9 g. (Trial: Scheuring)

06-005-18 (Ivanhoe x 59-124) (selected 2013): This Ivanhoe offspring harvests and leafs with Payne, has a protogynous bloom habit, and excellent yield of extra light kernels. The attractive nuts are well filled with plump kernels and yield 52% kernel with easy removal in halves. No blight has been observed to date.

06-005-31 (Ivanhoe x 59-124) (selected 2013): This selection is harvesting with Payne and leafs a week later. The large, attractive, long-oval nuts yield 56% kernel. The very large shiny plump 10.4 g kernels have been entirely light or extra light in color and are very easily removed in halves. (Trial: Scheuring)

07-002-5 (91-077-6 x 93-028-20 (selected 2012): This is a short season selection that leafs out three days after Chandler and harvests with Tulare. It has 8.6 g pump kernels with excellent color and ease of removal, and nuts contain 59% kernel. This is still a fairly young selection that needs to be watched further for yield. (Trial: Scheuring, Suchan, McDavid)

Appendix 2. List of Current Field Trials of Scion Selections

Field Trials of CLRV-Resistant Selections

San Benito – Coates

Bonturi

2003: 87-041-2, 87-262-4, 92-016-1, 93-045-1

2007: 94-022-24, 94-026-20, 95-027-19

2010: 95-027-23, 95-030-10, 03-019-9, 03-019-10

2011: 06-032-18

2013: 95-030-10, 06-003-1, 06-032-6, 06-032-13, 07-047-4, 07-047-39, 07-051-6, 07-052-2, 07-056-29, 07-058-7, 07-063-20

Contra Costa –Caprile

Tennant

92-016-1, 94-022-24, 97-027-55

San Joaquin - Grant

Barton

92-016-1, 93-045-1, 94-026-20, 95-027-19

Field Trials and Nursery Blocks of Standard Selections

Tehama - Buchner

Spanfelner

2008: 91-077-6, 91-090-41, 91-094-18, 91-096-3, 93-028-20, 94-020-35, Ivanhoe, Solano, 95-026-16, 98-001-442, 00-006-227, 01-001-107, 01-007-2, 01-016-11, 03-001-507, 03-001-942, 03-001-977, 03-001-1938, 03-001-2357, 03-001-2822, 03-001-3382, 03-001-3682, 03-005-4, 04-003-417, 04-004-26, 04-004-58

H. Crain

Blight resistant variety trial

Butte – Connell

Chico State Farm

Chico State Selection Block

Chico State Farm Trial 2004: Sexton, 91-090-41, 95-026-22

Stolp

2003: 94-020-5, 94-020-35, Forde

2007: 94-019-85, Ivanhoe, 95-026-16

2008: Solano, 00-006-54, 00-006-179, 00-011-88, 01-004-2, 01-016-11, 02-005-870, 03-001-1098, 03-001-1747

2010: Solano, 98-002-129, 00-006-227, 01-007-1, 02-005-671, 02-005-999, 03-001-1457, 03-001-1649, 03-110-2357, 03-001-2434, 03-001-2824, 03-001-2825, 03-001-3382, 03-001-3395, 03-001-3441, 03-001-4097, 03-005-4, 04-001-390, 04-003-403, 04-007-48

2011: 93-028-20

<u>Stuke Nursery</u>

2012: Solano

2013: 93-028-20, 03-001-1457

<u>Bertagna - red kernels</u>

2006: 91-084-6, 90-024-3, 95-014-3

<u>B. Crain</u>

2013: 93-028-20

Lake – Elkins

<u>Suchan</u>

2007: 95-018-23, 96-014-12, 00-002-27, 00-006-48

2010: 00-006-48, 00-006-227, 03-001-977, 03-001-1098, 03-001-1372, 03-001-3441

2011: 00-006-54, 04-003-107, 04-004-58, 04-006-92

2013: 07-002-5

Glenn –

<u>Carriere</u>

2007: Ivanhoe

2013: 93-028-20, 95-007-13

Colusa - Edstrom

<u>Nickels Trial - pruning</u>

2008: Gillet, Forde, Tulare, Chandler

Sutter-Yuba - Hasey

Whitney Warren Ranch

Selection trials

2001-2010: 91-077-40, 91-090-41, 92-070-12, 93-026-6, 93-028-20, 94-016-33, 94-019-85, 94-020-35, 94-028-20, 95-007-13, Ivanhoe, Solano, Gillet, Forde, 98-001-415, 98-001-520, 98-002-129, 00-004-44, 00-005-15, 00-005-30, 00-005-44, 00-005-144, 00-005-153, 00-006-227, 00-011-107, 01-007-2, 01-016-33, 02-005-870, 03-001-507, 03-001-665, 03-001-943, 03-001-977, 03-001-1372, 03-001-1457, 03-001-1938, 03-001-2357, 03-001-2434, 03-001-2440, 03-001-2822, 03-001-3383, 03-001-3395, 03-001-3446, 03-001-3701, 03-001-4097, 04-001-56

Selections for reduced tree stature

2009: Howard, Forde, Sexton, 91-077-40, Ivanhoe on RX1, VX211, Vlach rootstock

Gilbert

2008: Sexton, Gillet, Forde

Sierra Gold

2001-2010: Graft wood block – numerous selections

2011: 93-028-20, 95-007-13, Solano, 95-026-16, 00-006-227, 00-011-107, 03-001-977, 03-001-1372, 03-001-2556

Noreen

2001: 91-096-3, 93-026-6, 94-017-69, 94-019-29, 95-017-47

Yolo -

Scheuring

2002, 2004, 2008: 90-027-21, Ivanhoe, Solano, Gillet, Forde, Sexton, 95-007-13, 91-096-3

2011: 00-006-54, 03-001-507, 03-001-977, 03-001-1457, 03-001-1938, 03-001-2556, 03-001-3382, 03-001-3446, 03-001-3682, 04-004-58

2012: 93-028-20, 03-001-475, 03-001-665, 03-001-958, 03-001-985, 03-001-3701, 04-001-390, 04-003-293, 04-008-28, 05-002-233, 07-002-5, 07-005-17, 07-019-16, 07-022-30

2013: 03-001-1457, 05-002-393, 05-005-295, 05-034-11, 06-004-2, 06-005-31, 06-012-21, 06-013-20, 06-025-21, 06-026-19, 06-027-16

Martinez

2013: Solano, 93-028-20

UCD Selection Blocks

San Benito – Coates

Bonturi

2002-2010: 91-077-6, 94-019-85, Ivanhoe

San Joaquin - Grant

Taylor

2005: Sexton. Gillet, Forde, 95-026-22

Calaveras - Grant

McDavid

2010: 00-006-227, 00-006-48, 03-001-977, 03-001-1098, 03-001-1372, 03-001-3441

2013: 07-002-5

Stanislaus – Anderson

MJC

2004: Sexton, Gillet, Forde, Tulare

Deardorff

2006: 91-077-6, 94-020-28, Ivanhoe, 97-003-208, 97-003-311, 97-003-319

2007: 91-090-41, 91-077-6, 93-028-20, 94-019-85, 94-020-5, 94-020-35, Ivanhoe, 95-026-16

Orestimba Nursery

2012: Solano

2013: 93-028-20, 03-001-1457

Burchell Nursery

2009: Ivanhoe

2010: Solano, 00-005-30, 03-001-977

2011: 95-007-13, 95-026-16, 00-006-227, 00-011-107, 03-001-1372, 03-001-2556

Dave Wilson Nursery

2013: 93-028-20, 03-001-1457

Merced – Doll

Crane Sr.

2002: Sexton, 90-023-11, 90-023-37, 91-094-18, 91-096-3, Tulare

2003: 92-070-12

Crane Jr.

2004: Sexton, Forde, 95-022-26

2010: 03-001-977

2012: Solano, 93-028-20, 03-001-1372, 00-006-227, 03-001-977, 04-003-143

Fresno - Brar

KAC

KAC Blight resistant variety block

Kings - Beede

Miya Farms

2009: Ivanhoe

Jeb Headrick

91-077-6, 94-020-28, 94-020-35, Ivanhoe, Forde, Gillet

Tulare –Fichtner

Moore

2004: Ivanhoe

2012: Solano

Swall

2004: Sexton. Forde, Gillet

Appendix 3. Current Clonal Rootstock Field Trials.

County	Grower	Genotypes	Date Established	Comments
Tehama	H. Crain	RX1, VX211, Vlach, Paradox sdlg.	2009	Budded Sept 2009 New orchard Scion: Howard
Butte	Deseret	RX1, AZ2	2006	New orchard Scion: Chandler
Lake	Valadez	VX211, Vlach, Paradox seedlings	2011	Nematode Scion: VX211 and Vlach are grafted to Chandler; seedlings will be grafted to Chandler in 2012
Lake	Valadez (Suchan)	VX211, Vlach, Paradox seedlings	2011	Unfumigated new planting Nematode site Scion: black walnut scion for nursery trees, so will be Chandler inter-stems on the VX211 and Vlach
Lake		VX211, Vlach, Paradox sdlg.	2012	No fumigation, walnut to walnut; will be budded to Chandler in 2013
Lake		VX211, Vlach, Paradox sdlg.	2012	No fumigation, pear, fallowed, then to walnut; will be budded to Chandler in 2013
Glenn	Anderson	Vlach, Paradox sdlg	2006	Grafted to Howard
Sutter/Yuba	Whitney Warren	RX1,VX211, Serr, Vlach	2007	New orchard Spot fumigated old Hartley site
Sutter/Yuba	Whitney Warren	RX1, VX211, Vlach	2009	Power-line planting Scions: Ivanhoe, Howard, Sexton, 91-077-40 New orchard
Sutter/Yuba	Noreen	VX211, RX1, Vlach, Paradox seedlings.	2013	New orchard To be grafted 2014
Sutter/Yuba	Conant	VX211, RX1, Vlach, Paradox seedlings. Black seedlings	2011	New orchard Scion: Gillet
Solano	Cilker	RX1, VX211, Burbank, Vlach, Paradox sdlg.	2009	New orchard Budded fall 2009 Scion: Tulare
Yolo	Turkovich	RX1, VX211	2011	New Orchard Grafted: 2011 Scion: Forde,
Contra Costa	Tennant	WIP2, WIP3, clonal Sunland and Vina, Paradox sdlg.	2005	Blackline tolerant New orchard Scion: Vina
Contra Costa	Maggiore	WIP3, clonal Chandler, Paradox sdlg., WIP1, WIP2	2011	Blackline tolerant New orchard Scion: Chandler

County	Grower	Genotypes	Date Established	Comments
San Joaquin	Taylor	WIP3, WIP5, WIP6	2005	Blackline tolerant New orchard Scion: Chandler
San Joaquin	Lagorio (Concar)	RX1, VX211, WIP3, AZ025, Vlach June-bud, Vlach-grafted, Chandler own-rooted, Paradox sdlg.	2007	New orchard Scion: Chandler
San Joaquin	Chiappi	RX1, Paradox seedlings	2010	Phytophthora plot Replanted block Scion: Serr
Stanislaus	MJC	Clonal Vina and Chandler, Vlach, 84-121, Sunland sdlg., Px sdlg.	1999	Planted 1999 Grafted 2000 New orchard
Kings	Verboon	VX211, Px sdlg, with Vlach buffer	2008	Fumigation trial treatments New orchard Scion: Tulare

Appendix 4. Laboratories Licensed to Produce Liners of UC Clonal Rootstock Selections

Acemi Nursery

License: RX1, VX211

Agromillora – Gridley

License: RX1, VX211

California Seed and Plant Lab – Micro Grown

License: RX1, VX211

Test agreement: Px1, WIP3

Duarte Nursery

License: RX1, VX211

Test agreement: WIP3

Golden Roots Nursery

License: RX1, VX211

North American Plants

License: RX1, VX211

Test agreement: WIP2, WIP3, WIP6

ProTree

License: VX211, RX1

Sierra Gold Nursery

License: VX211, RX1

Tissue Grown Corporation

License: VX211, RX1

V-Tree

License: VX211, RX1

Fig 1. Pedigree of UC Davis Walnut Improvement Program releases and several selections

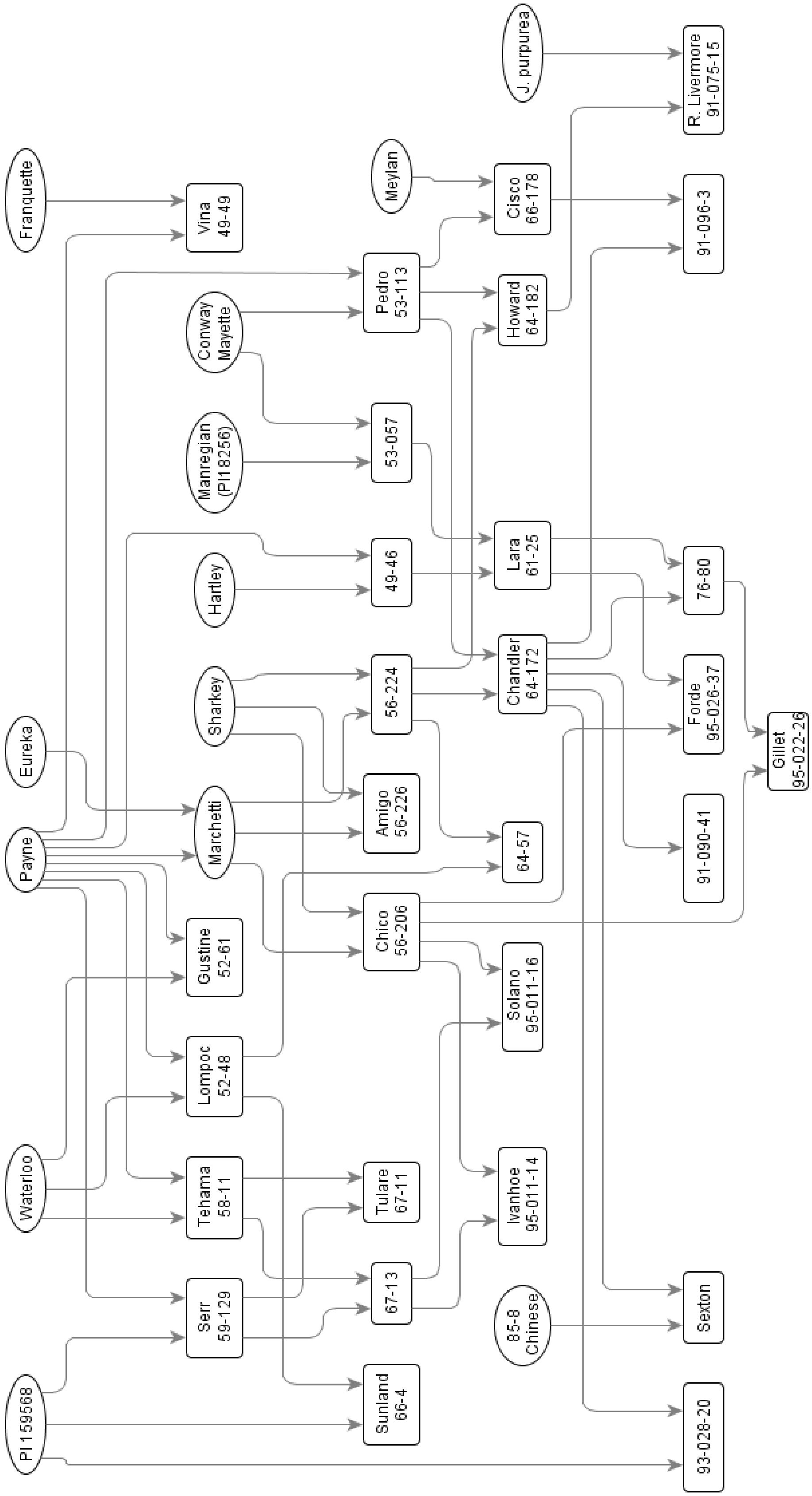


Table 1. Number of individual crosses completed, seedlings planted, number of selections retained, and trees remaining under evaluation by year of cross.

Year	Crosses (n)	Original seedlings (n)	Selections (n)	Under Evaluation (n)
1990	15	591	-	-
1991	18	493	1	1
1992	15	243	-	-
1993	14	116	1	1
1994	15	587	-	-
1995	15	758	-	1
1996	7	333	-	-
1997	13	611	1	3
1998	5	1759	1	3
1999	1	993	-	-
2000	12	2503	1	6
2001	16	210	-	1
2002	5	1200	1	1
2003	11	4608	12	20
2004	7	6000	8	30
2005	9	3332	16	68
2006	22	954	22	57
2007	27	1045	22	67
2008	33	929	-	234
2009	32	1187	-	638
2010	32	1081	-	966
2011	37	761	-	761
2012	60	1475	-	1475
2013	83	2510	-	-
Total	488	34279	86	4333

Table 2. Seedling trees from 2010 crosses grown in nursery in 2011, planted at Davis in 2012.

	Ivanhoe	95-018-23	95-026-16	98-002-129	00-005-30	00-005-44	00-005-173	00-005-174	00-006-227	00-011-107	03-001-665	03-001-977	03-001-2357	03-001-2434	Unknown
93-028-20 **color, shell, blight res.**	81					53									
95-007-13 **Early, vigor, size, shell**	57		22	103	7		97								
Ivanhoe **Very early, color, yield**		17	22	1	8	17	27	101	73	22	15	41	38	18	
Solano **Mid-season, quality**				14									4		
00-005-44 **Early, yield**													36		
Cisco **Late Leafing**															37
Fernor **Late Leafing**															41

Table 3. Seedling trees from 2011 crosses grown in nursery in 2012, planted at Davis in 2013.

	01-007-2	03-001-507	03-001-665	03-001-958	03-001-985	03-001-1372	03-001-2105	03-001-3382	04-002-342	04-003-107	04-004-58	04-004-117
93-028-20 **color, shell, blight res.**	69											
95-007-13 **Early, vigor, size, shell**			37									
Ivanhoe **Very early, color, yield**		3		11	1		29	8		70		30
95-026-16 **Early color, blight res.**			5					14			11	
98-002-129 **Early size and color**		4	6									
00-005-30 **Very early, size, blight res.**								3				
00-005-44 **Early, yield**						4			2		7	
00-006-227 **Early, size, color**		15	2									
01-007-2 **Very early, size**		12	21				19					

Table 4. Seedling trees from 2012 crosses, grown in nursery in 2013 for at Davis in 2014.

	93-028-20	Ivanhoe	98-002-129	00-006-227	03-001-507	03-001-665	03-001-825	03-001-958	03-001-977	03-001-985	03-001-1372	03-001-1457	03-001-1743	03-001-1938	03-001-2357	03-001-2434	03-001-2440	03-001-2556	03-001-3382	04-004-58	04-004-117	04-002-342	05-002-233
93-028-20 **Color, shell, plump**						44	2	2				34	1	16					1				2
Ivanhoe **Very early, color, yield**					28					3	3								9			6	18
Solano **Early-mid, yield, color**								29	3			8			20								
95-026-16 **Early color**					6				7			21		24									
98-002-129 **Early, size, color**								14	1	9				21									
00-005-30 **Very early**					1						7						16			2	4		
00-005-44 **Early, yield**																	33	16			60		
00-005-144 **Size, color, plump**												20											
00-006-227 **Early, size, color**	19								31		4	30				5				1			
01-007-2 **Very early**																1	24		33		3		
03-001-1743 **Early color, yield, %**																					22		

Table 5. Seed collected from 2013 color and harvest date crosses for germination and planting in 2014.

	93-028-20	Ivanhoe	Solano	00-005-44	03-001-1938	05-001-94	05-001-434	06-004-2	06-005-4	06-005-5	06-005-18	06-005-27	07-002-5	07-005-17
93-028-20 **Color, shell, plump**						35	35	10	7	31	29	28	23	13
Ivanhoe **Very early, color, yield**				224	148									
Solano **Early-mid, yield, color**														
59-124 **Early, thick shell, plump**		29	55				106							
91-090-41 **HF resistance, Color**	49	79					86							
95-026-16 **Early color**					86		11							
96-013-13 **Early color**	81				65									
03-001-985 **Early color, yield, %**	6						67			11				
03-001-1457 **Mid, color, size, yield**	18		62					21		5				
03-001-1938 **Mid, color, shell**	31		27											
03-001-2434 **Color, size**	6	18												
05-002-233 **Early-mid, color yield**										11				
05-002-396 **Early color and yield**							46							

Table 6. Seed collected from 2013 CLRV resistant crosses for germination and planting in 2014.

	93-028-20	Solano	03-001-1457	05-001-94	05-001-434	06-005-5
03-019-9					23	28
06-003-1			28			
07-047-4					10	1
07-047-39	3					6
07-063-20	9	19		6	9	

Table 7. Seeds for germination and planting in 2014 collected from 2013 crosses for blight resistance.

	91-015-2	91-028-1	91-028-2	91-031-8	91-056-9	91-096-3
Ivanhoe **Very early, color, yield**				159		33
Solano **Early-mid, yield, color**	19				3	
93-28-20 **Color, shell, plump**				37		
95-26-16 **Early, color, yield**				38		
00-005-144 **Size, color, plump**						19
00-006-227 **Yield, color, %**					1	
03-001-1457 **Early-mid, color, size, yield**			8	7		
03-001-1938 **Early-mid, color, shell**	8	8				
03-001-2434 **Color, size**	18					
05-001-94 **Early-mid, size, color**				13		78
05-001-434 **Early pollen, color**	24	1				91
05-002-396 **Early, color, yield**				11		
06-005-4 **Early, color**				14		
06-005-5 **Shell, strength, color, early**			12	25		58
06-005-18 **Very early, color, yield**				13		45
06-005-27 **Very early, color, yield**		4				

Cultivars													
Payne	G	3/19	0	3/24	3/30	4/7	7	3/30	4/5	4/9	100	7	9/4
Hartley	G	4/1	13	4/8	4/15	4/21	7	4/15	4/19	4/23	0	6	9/25
Franquette	G	4/19	31	4/16	4/24	5/2		4/28	5/3	5/8	0	5	10/7
Idaho	G	3/18	-1	4/1	4/6	4/15	6	3/25	3/28	4/1	0	5	9/7
Vina	G	3/23	4	3/26	4/5	4/12	7	4/9	4/12	4/15	100	7	9/14
Serr	G	3/19	0	3/24	3/30	4/6	8	4/3	4/7	4/12	20	5	9/10
Chandler	G	4/4	16	4/3	4/12	4/22	7	4/16	4/20	4/28	100	7	10/2
Howard	G	4/2	14	4/2	4/7	4/14	7	4/15	4/19	4/23	100	8	9/21
Cisco	G	4/11	23	4/13	4/17	4/24	7	4/25	4/28	5/3	100	7	9/30
Tulare	G	4/3	15	4/3	4/9	4/19	7	4/13	4/17	4/21	100	7	9/28
Lara	G	4/1	13	4/3	4/9	4/20	7	4/15	4/19	4/26	100	7	9/17
Gillet	G	3/20	1	4/5	4/10	4/16	7	3/27	4/4	4/9	100	8	9/28
Forde	G	3/28	9	4/8	4/14	4/23	5	4/1	4/5	4/10	100	7	9/25
Ivanhoe	G	3/17	-2	4/1	4/6	4/15	7	3/18	3/25	3/31	100	8	9/1
Solano	G	3/21	2	3/26	4/4	4/9	8	4/6	4/9	4/12	100	7	9/14
Selections													
64-057	G	3/26	7	4/6	4/15	4/22	8	3/28	4/5	4/11	100	7	9/21
91-077-40	G	3/29	10	4/8	4/14	4/22	8	3/29	4/4	4/10	100	7	9/25
91-090-41	G	3/31	12	4/1	4/7	4/15	7	4/10	4/13	4/20	100	7	9/22
93-028-20	G	3/28	9	3/25	4/1	4/12	7	4/8	4/11	4/15	100	7	9/18
95-007-13	G	3/23	4	3/24	3/28	4/7	7	4/2	4/7	4/11	100	7	9/11

97-003-11	G	3/27	8	3/31	4/5	4/15	7	4/9	4/12	4/16	100	7	9/19
98-002-129	G	3/17	-2	3/24	3/29	4/3	5	4/3	4/6	4/10	100	6	9/10
00-006-227	G	3/25	6	4/7	4/11	4/15	7	4/2	4/6	4/10	100	7	9/13
02-005-870	G	3/19	0	3/23	3/28	4/4	7	4/3	4/7	4/11	100	7	9/18
03-001-475	S	3/21	2	3/25	3/30	4/4	7	4/3	4/8	4/13	100	7	9/16
03-001-665	S	3/25	6	3/29	4/5	4/9	8	4/6	4/9	4/12	100	8	9/21
03-001-825	S	3/29	10	4/1	4/7	4/14	7	4/13	4/16	4/20	100	7	10/1
03-001-977	S	4/1	13	4/10	4/17	4/22	7	4/4	4/8	4/12	100	7	9/20
03-001-985	S	3/18	-1	3/31	4/7	4/11	7	3/22	3/26	4/2	100	7	9/15
03-001-1098	S	3/30	11	4/2	4/7	4/11	7	4/9	4/12	4/15	100	8	9/22
03-001-1372	S	4/4	16	4/5	4/9	4/18	7	4/13	4/16	4/21	100	7	9/20
03-001-1457	S	3/26	7	3/27	3/31	4/5	7	4/5	4/8	4/13	100	7	9/15
03-001-1743	S	3/27	8	3/28	4/4	4/9	7	4/7	4/11	4/17	100	6	9/15
03-001-1938	S	3/21	2	3/24	3/30	4/4	8	4/3	4/7	4/10	100	7	9/19
03-001-2357	S	3/28	9	3/29	4/4	4/12	7	4/10	4/12	4/14	100	8	9/24
03-001-2434	S	3/22	3	3/25	4/2	4/8	7	4/3	4/6	4/9	100	7	9/25
03-001-2440	S	4/1	13	4/1	4/6	4/11	7	4/11	4/15	4/20	100	6	9/25
03-001-2556	S	4/1	13	4/2	4/6	4/10	7	4/10	4/13	4/16	100	7	9/18
04-001-390	S	4/1	13	4/3	4/7	4/13	7	4/10	4/13	4/17	100	8	9/6
04-003-143	S	4/1	13	4/8	4/13	4/21	7	4/3	4/6	4/9	100	7	9/24
04-003-293	S	4/4	16	4/12	4/18	4/22	6	4/5	4/8	4/13	100	8	9/5
04-003-403	S	4/2	14	4/11	4/15	4/21	5	4/4	4/7	4/12	100	7	9/22

04-003-417	S	3/26	7	4/9	4/12	4/15	5	4/2	4/7	4/11	100	8	9/24
04-006-28	S	3/31	12	4/1	4/8	4/15	5	4/9	4/12	4/16	100	8	9/11
05-001-94	S	3/23	4	4/3	4/8	4/14	7	3/24	3/28	4/3	100	7	9/18
05-001-97	S	3/24	5	3/30	4/4	4/9	7	4/6	4/9	4/12	100	7	9/20
05-001-295	S	3/24	5	4/2	4/5	4/9	4	4/8	4/12	4/16	90	8	9/10
05-001-434	S	3/15	-4	3/19	3/25	3/31	8	3/31	4/1	4/3	100	7	9/11
05-002-233	S	3/24	5	3/26	3/31	4/5	7	4/4	4/7	4/10	100	7	9/18
05-002-393	S	3/29	10	4/2	4/4	4/6	2	4/10	4/12	4/14	100	7	9/14
05-002-396	S	3/17	-2	4/8	4/11	4/14	5	3/22	3/26	4/1	100	7	9/9
05-014-59	S	3/26	7	3/27	4/4	4/9	7	4/7	4/9	4/12	100	7	9/21
05-014-197	S	4/1	13	4/3	4/8	4/12	7	4/12	4/14	4/17	100	7	9/23
05-034-11	S	4/1	13	4/2	4/7	4/11	7	4/12	4/14	4/16	100	8	9/20
06-004-2	S	3/26	7	4/8	4/11	4/17	7	4/3	4/5	4/8	100	6	9/13
06-005-2	S	3/24	5	4/1	4/6	4/12	5	4/7	4/11	4/16	100	7	9/12
06-005-5	S	3/20	1	3/26	3/28	3/31	7	4/3	4/8	4/11	100	7	9/14
06-005-18	S	3/20	1	4/4	4/9	4/13	6	3/27	4/2	4/8	100	7	9/4
06-005-31	S	3/26	7	4/2	4/7	4/11	5	4/9	4/12	4/16	100	6	9/8
06-005-33	S	4/1	13	4/3	4/9	4/12	7	4/11	4/13	4/16	100	6	9/16
06-012-21	S	3/25	6	4/4	4/10	4/16	6	3/27	3/31	4/3	100	6	9/14
06-013-19	S	3/25	6	3/31	4/2	4/5	4	4/6	4/9	4/11	100	7	9/11
06-013-20	S	3/22	3	3/26	4/1	4/3	5	4/8	4/10	4/12	100	7	9/15
06-023-9	S	3/23	4	3/28	3/30	4/1	5	4/3	4/6	4/10	100	7	9/5

06-025-21	S	4/3	15	4/5	4/9	4/14	5	4/13	4/15	4/18	100	7	9/23
06-026-14	S	4/10	22	4/8	4/11	4/17	8	4/18	4/21	4/26	100	7	9/12
06-026-19	S	4/3	15	4/3	4/8	4/15	6	4/10	4/16	4/19	100	7	9/17
06-027-16	S	4/1	13	4/3	4/7	4/11	5	4/11	4/14	4/17	100	7	9/13
06-030-20	S	3/23	4	3/25	3/29	4/1	5	4/5	4/8	4/11	100	7	9/14
07-002-5	S	4/8	20	4/8	4/11	4/14	4	4/17	4/20	4/22	100	6	9/16
07-004-15	S	4/4	16	4/13	4/16	4/22	6	4/4	4/8	4/13	100	7	9/13
07-005-17	S	3/19	0	3/26	3/30	4/2	7	3/30	4/1	4/2	100	7	9/15
07-018-54	S	3/29	10	4/9	4/11	4/14	4	4/4	4/7	4/11	100	6	9/13
07-022-49	S	3/26	7	3/31	4/2	4/4	5	4/4	4/8	4/12	100	7	9/13
07-029-1	S	3/24	5	3/29	4/1	4/4	4	4/6	4/8	4/11	100	7	9/11
07-029-15	S	3/29	10	3/31	4/4	4/7	3	4/7	4/10	4/13	100	8	9/3

Cultivars																
Payne	G	9/4	0	152	3	5	1.3	13.3	6.6	49.5	5	5	0	100	0	0
Hartley	G	9/25	21	159	6	6	1.5	14.4	6.7	46.4	4	6	0	90	10	0
Franquette	G	10/7	33	157	5	6	1.7	12.9	5.5	42.6	4	4	40	60	0	0
Vina	G	9/14	10	155	5	6	1.4	16.8	8.7	51.9	5	6	0	0	100	0
Serr	G	9/10	6	156	5	5	1.2	16.5	9.6	58.0	7	5	0	70	30	0
Chandler	G	10/2	28	165	5	5	1.4	14.7	7.6	51.7	5	4	90	10	0	0
Howard	G	9/21	17	155	5	6	1.5	14.3	7.0	49.0	5	5	22	78	0	0
Cisco	G	9/30	26	155	5	5	1.7	13.8	6.3	45.5	4	5	11	89	0	0
Tulare	G	9/28	24	164	5	5	1.2	17.3	9.9	57.3	5	6	0	100	0	0
Gillet	G	9/28	24	177	5	5	1.4	19.2	9.9	51.5	5	5	0	40	60	0
Forde	G	9/25	21	173	6	6	1.7	16.7	8.6	51.7	6	6	50	40	10	0
Ivanhoe	G	9/1	-3	160	5	5	1.2	12.9	7.3	56.4	5	4	50	50	0	0
Solano	G	9/14	10	158	5	5	1.3	16.8	9.6	57.2	5	4	30	70	0	0
Selections																
91-077-40	G	9/25	21	174	6	7	1.7	17.9	9.3	52.0	7	6	10	50	40	0
91-090-41	G	9/22	18	162	4	5	1.2	13.5	7.8	57.9	5	4	44	56	0	0
93-028-20	G	9/18	14	160	5	5	1.3	17.3	10.3	59.3	5	4	30	70	0	0
95-007-13	G	9/11	7	157	5	5	1.3	18.1	10.3	57.0	6	4	70	10	20	0

97-003-319	G	9/16	12		5	6	1.2	15.8	8.2	51.8	5	3	11	44	33	11
00-006-227	G	9/13	9	160	5	5	1.1	14.2	8.5	60.1	5	6	80	20	0	0
02-005-870	G	9/18	14	164	5	6	1.5	18.1	9.8	54.1	7	5	0	100	0	0
03-001-665	S	9/21	17	165	5	4	1.1	14.4	8.8	61.2	5	4	60	40	0	0
03-001-825	S	10/1	27	168	5	5	1.2	16.9	10.0	59.1	5	5	89	11	0	0
03-001-977	S	9/20	16	165	5	6	1.3	16.0	8.9	55.6	6	5	0	100	0	0
03-001-985	S	9/15	11	173	6	6	1.4	15.3	8.4	54.7	6	5	0	90	10	0
03-001-1098	S	9/22	18	163	5	5	1.2	14.4	8.5	59.1	5	5	60	40	0	0
03-001-1372	S	9/20	16	157	5	5	1.3	16.6	9.4	56.6	5	4	70	30	0	0
03-001-1457	S	9/15	11	160	5	5	1.2	13.0	7.6	58.7	5	4	60	40	0	0
03-001-1743	S	9/15	11	157	5	4	1.1	12.7	7.2	56.4	3	4	100	0	0	0
03-001-1938	S	9/19	15	165	4	5	1.3	14.5	8.5	58.3	6	5	10	90	0	0
03-001-2357	S	9/24	20	165	5	5	1.3	14.3	8.5	59.5	6	5	100	0	0	0
03-001-2434	S	9/25	21	172	5	6	1.3	17.3	9.7	55.9	7	7	70	30	0	0
03-001-2556	S	9/18	14	158	5	5	1.2	15.5	9.6	61.9	6	3	10	90	0	0
03-001-3395	G	9/20	16		5	4	1.1	14.2	8.7	61.3	5	5	0	100	0	0
03-001-3446	G	9/13	9	161	5	7	1.5	16.4	8.6	52.3	6	5	40	50	10	0
04-001-390	S	9/6	2	146	5	5	1.3	15.4	8.1	52.4	5	3	0	100	0	0
04-002-342	S	9/23	19	159	5	5	1.3	17.3	9.4	54.3	5	5	0	56	44	0
04-003-143	S	9/24	20	171	5	5	1.3	17.9	9.9	55.1	4	4	0	60	40	0

04-003-293	S	9/5	1	150	5	4	1.2	11.4	6.0	52.4	4	5	100	0	0	0
04-003-403	S	9/22	18	168	5	4	1.2	14.9	8.1	54.5	3	4	0	100	0	0
04-003-417	S	9/24	20	170	5	5	1.2	15.1	8.7	57.6	5	5	10	80	10	0
04-004-117	S	9/18	14	157	5	6	1.3	16.6	9.5	57.3	7	6	0	20	80	0
04-004-411	S	9/17	13	154	5	5	1.4	13.6	7.3	53.6	6	5	30	70	0	0
04-006-28	S	9/11	7	152	5	5	1.2	15.2	8.8	58.0	6	5	90	0	10	0
05-001-94	S	9/18	14	174	5	5	1.2	17.7	10.4	58.6	5	4	100	0	0	0
05-001-97	S	9/20	16	164	5	5	1.2	15.0	8.7	57.5	6	5	0	100	0	0
05-001-271	S	9/13	9	169	5	5	1.3	14.2	8.2	57.4	6	4	0	100	0	0
05-001-295	S	9/10	6	151	5	4	1.1	12.6	7.6	60.2	5	4	0	100	0	0
05-001-362	S	9/14	10	169	5	5	1.2	14.5	9.0	62.1	6	4	50	50	0	0
05-001-402	S	9/11	7	160	5	6	1.5	14.9	8.0	53.7	6	5	80	20	0	0
05-001-412	S	9/22	18	167	5	6	1.4	18.3	9.6	52.5	6	5	100	0	0	0
05-001-434	S	9/11	7	163	5	7	1.5	17.7	8.8	50.0	5	4	60	20	10	10
05-002-233	S	9/18	14	164	5	6	1.3	16.0	8.9	55.8	6	5	20	80	0	0
05-002-393	S	9/14	10	155	5	5	1.2	16.0	8.6	53.9	4	4	40	60	0	0
05-002-396	S	9/9	5	167	5	5	1.3	14.4	7.6	53.1	5	4	60	40	0	0
05-003-256	S	9/24	20	166	5	6	1.4	17.2	9.1	53.1	5	5	40	60	0	0
05-014-59	S	9/21	17	165	5	5	1.1	15.1	8.8	58.2	5	4	90	10	0	0
05-014-118	S	9/11	7	153	5	5	1.2	15.2	9.2	60.0	5	5	0	100	0	0

05-014-197	S	9/23	19	162	5	4	1.2	15.0	8.9	59.0	5	4	60	40	0	0
05-019-12	S	9/17	13	155	5	5	1.3	14.3	7.7	53.8	5	4	100	0	0	0
05-034-11	S	9/20	16	159	5	5	1.2	13.2	7.8	59.1	6	5	0	90	10	0
06-004-2	S	9/13	9	161	5	6	1.3	14.6	7.7	52.7	6	6	0	100	0	0
06-004-5	S	9/21	17	162	5	6	1.5	16.2	8.5	52.4	6	4	50	50	0	0
06-005-2	S	9/12	8	154	5	5	1.1	14.5	8.5	58.5	4	4	60	40	0	0
06-005-5	S	9/14	10	159	6	7	1.5	17.2	9.4	55.0	7	5	0	100	0	0
06-005-18	S	9/4	0	155	5	6	1.5	15.6	7.9	50.6	5	4	90	10	0	0
06-005-31	S	9/8	4	149	5	5	1.3	19.8	11.3	57.2	6	4	90	10	0	0
06-005-33	S	9/16	12	156	5	6	1.4	15.5	8.6	55.4	7	6	90	10	0	0
06-005-36	S	9/2	-2	156	5	5	1.2	13.2	8.1	61.5	5	4	0	100	0	0
06-011-1	S	9/12	8	153	5	5	1.1	14.0	8.1	57.6	5	4	0	100	0	0
06-012-21	S	9/14	10	167	5	6	1.4	16.8	9.0	53.9	5	5	90	10	0	0
06-013-19	S	9/11	7	155	5	6	1.3	14.6	8.3	57.2	6	4	70	30	0	0
06-013-20	S	9/15	11	158	5	5	1.4	20.5	11.1	53.9	6	4	70	30	0	0
06-017-51	S	9/18	14	159	5	6	1.4	17.4	9.5	54.7	5	5	60	40	0	0

Location	Variety or Selection	Sample Wt	Nuts per sample	Avg nut wt (g)	% Large	% Med	% Baby	% Large Sound	% Stain	% Broken	% Adh Hull	% External Damage
Woodland	Serr	1003	65	15.43	100%	0%	0%	100%	0%	0%	0%	0%
Davis	Chandler	1000	78	12.82	100%	0%	0%	96%	1%	0%	1%	3%
Chico	Chandler	1000	91	10.99	92%	7%	1%	93%	0%	0%	0%	0%
Woodland	Chandler	1000	79	12.66	96%	3%	1%	97%	0%	0%	0%	0%
Durham	Chandler	1000	76	13.16	100%	0%	0%	97%	0%	0%	0%	0%
Chico	Hartley	1003	85	11.80	96%	0%	4%	93%	0%	0%	0%	0%
Davis	Tulare	1000	66	15.15	100%	0%	0%	98%	0%	0%	0%	0%
Chico	Tulare	1004	66	15.21	100%	0%	0%	97%	0%	0%	0%	0%
Woodland	Tulare	1004	73	13.75	100%	0%	0%	99%	0%	0%	0%	0%
Davis	Howard	1001	80	12.51	96%	1%	3%	95%	0%	0%	0%	0%
Davis	Forde	1004	61	16.46	100%	0%	0%	99%	0%	0%	0%	0%
Chico	Forde	1000	59	16.95	100%	0%	0%	99%	0%	0%	0%	0%
Durham	Forde	1002	60	16.70	100%	0%	0%	99%	0%	0%	0%	0%
Woodland	Forde	1004	71	14.14	100%	0%	0%	100%	0%	0%	0%	0%
Woodland	Forde	1004	61	16.46	100%	0%	0%	99%	0%	0%	0%	0%
Davis	Gillet	1000	57	17.54	100%	0%	0%	96%	0%	0%	0%	0%
Chico	Gillet	941	58	16.22	100%	0%	0%	96%	0%	0%	0%	0%
Davis	Ivanhoe	1002	79	12.68	100%	0%	0%	99%	0%	0%	0%	0%
Chico	Ivanhoe	1004	76	13.21	100%	0%	0%	99%	0%	0%	0%	0%
Woodland	Ivanhoe	1004	73	13.75	100%	0%	0%	99%	0%	0%	0%	0%
Wheatland	Ivanhoe	1004	74	13.57	100%	0%	0%	99%	0%	0%	0%	0%
Durham	Ivanhoe	1002	82	12.22	100%	0%	0%	100%	0%	0%	0%	0%
Chico	Sexton	1003	65	15.43	100%	0%	0%	99%	2%	0%	0%	2%
Davis	Solano	1003	60	16.72	100%	0%	0%	98%	0%	0%	0%	0%
Davis	Solano	1000	60	16.67	100%	0%	0%	100%	0%	0%	0%	0%
Woodland	Solano	1003	71	14.13	100%	0%	0%	100%	0%	0%	0%	0%
Durham	Solano	1004	69	14.55	100%	0%	0%	97%	3%	0%	0%	3%
Durham	Solano	1002	67	14.96	100%	0%	0%	100%	0%	0%	0%	0%
Chico	91-90-41	1000	81	12.35	100%	0%	0%	95%	0%	0%	0%	0%
Davis	93-28-20	1004	67	14.99	100%	0%	0%	96%	0%	0%	0%	0%

Location	Variety or Selection	% Insect	% Mold	% Shrivel	% Offgrade	% Edible Yield	% Total Yield	Extra Light	Light	Light Amber	Amber	RLI	Relative Value
Woodland	Serr	0%	0%	0%	0.0%	**58.5%**	58.5%	35%	46%	17%	2%	**53.8**	**1.134**
Davis	Chandler	0%	0%	3%	0.6%	**52.9%**	53.2%	100%	0%	0%	0%	**58.8**	**1.120**
Chico	Chandler	0%	0%	1%	0.4%	**50.2%**	50.4%	70%	28%	2%	0%	**55.5**	**1.003**
Woodland	Chandler	0%	0%	1%	0.4%	**53.3%**	53.5%	94%	6%	0%	0%	**58.1**	**1.115**
Durham	Chandler	0%	0%	5%	1.0%	**52.5%**	53.0%	59%	41%	0%	0%	**55.8**	**1.055**
Chico	Hartley	0%	4%	2%	4.3%	**46.9%**	48.9%	19%	64%	17%	0%	**52.8**	**0.891**
Davis	Tulare	2%	0%	2%	1.4%	**55.6%**	56.4%	83%	12%	4%	0%	**56.4**	**1.129**
Chico	Tulare	2%	0%	2%	1.9%	**51.6%**	52.6%	9%	25%	40%	25%	**50.7**	**0.942**
Woodland	Tulare	0%	0%	1%	0.2%	**55.9%**	56.0%	31%	52%	14%	3%	**51.4**	**1.034**
Davis	Howard	3%	0%	3%	2.2%	**49.5%**	50.5%	64%	30%	5%	0%	**57.2**	**1.018**
Davis	Forde	0%	2%	0%	1.3%	**53.5%**	54.2%	68%	21%	11%	0%	**57.8**	**1.113**
Chico	Forde	0%	0%	3%	0.4%	**49.2%**	49.4%	9%	84%	7%	0%	**53.0**	**0.939**
Durham	Forde	0%	0%	3%	0.4%	**52.6%**	52.8%	26%	72%	2%	0%	**52.8**	**1.000**
Woodland	Forde	0%	0%	0%	0.0%	**56.3%**	56.3%	68%	19%	11%	2%	**53.8**	**1.090**
Woodland	Forde	0%	0%	2%	0.2%	**53.5%**	53.6%	67%	21%	10%	2%	**55.1**	**1.061**
Davis	Gillet	4%	0%	2%	3.7%	**48.7%**	50.5%	14%	78%	7%	0%	**52.5**	**0.920**
Chico	Gillet	0%	2%	3%	2.3%	**46.2%**	47.3%	0%	31%	47%	22%	**49.1**	**0.817**
Davis	Ivanhoe	0%	0%	1%	0.2%	**56.1%**	56.2%	59%	31%	10%	0%	**57.2**	**1.155**
Chico	Ivanhoe	0%	0%	1%	0.2%	**54.4%**	54.5%	66%	32%	3%	0%	**55.0**	**1.077**
Woodland	Ivanhoe	0%	0%	1%	0.5%	**55.4%**	55.7%	23%	63%	14%	0%	**55.9**	**1.114**
Wheatland	Ivanhoe	0%	1%	0%	1.6%	**56.6%**	57.5%	64%	32%	4%	0%	**57.5**	**1.171**
Durham	Ivanhoe	0%	0%	1%	0.2%	**57.3%**	57.4%	72%	20%	8%	0%	**55.5**	**1.145**
Chico	Sexton	0%	2%	0%	1.6%	**50.2%**	51.0%	17%	71%	11%	0%	**51.0**	**0.923**
Davis	Solano	2%	0%	2%	1.8%	**55.2%**	56.2%	51%	42%	8%	0%	**56.7**	**1.127**
Davis	Solano	0%	0%	0%	0.0%	**57.2%**	57.2%	73%	24%	3%	0%	**58.4**	**1.203**
Woodland	Solano	0%	0%	0%	0.0%	**54.1%**	54.1%	34%	62%	4%	0%	**54.1**	**1.054**
Durham	Solano	0%	0%	0%	0.0%	**57.6%**	57.6%	64%	36%	0%	0%	**57.3**	**1.188**
Durham	Solano	0%	0%	0%	0.0%	**57.3%**	57.3%	67%	21%	12%	0%	**55.9**	**1.153**
Chico	91-90-41	2%	2%	1%	5.4%	**53.3%**	56.2%	19%	51%	24%	6%	**51.3**	**0.984**
Davis	93-28-20	0%	0%	7%	2.6%	**58.1%**	59.6%	92%	8%	0%	0%	**58.5**	**1.223**

Location	Variety or Selection	Sample Wt	Nuts per sample	Avg nut wt (g)	% Large	% Med	% Baby	% Large Sound	% Stain	% Broken	% Adh Hull	% External Damage
Chico	93-28-20	1000	69	14.49	100%	0%	0%	99%	0%	0%	0%	0%
Woodland	93-28-20	1000	61	16.39	100%	0%	0%	100%	0%	0%	0%	0%
Durham	93-28-20	1000	64	15.63	100%	0%	0%	100%	0%	0%	0%	0%
Durham	93-28-20	1004	66	15.21	100%	0%	0%	99%	0%	0%	0%	0%
Durham	95-26-16	1001	75	13.35	99%	1%	0%	98%	1%	0%	0%	1%
Davis	00-006-227	1000	75	13.33	100%	0%	0%	98%	0%	0%	0%	0%
Davis	00-006-227	1003	74	13.55	100%	0%	0%	98%	0%	0%	0%	0%
Woodland	00-006-227	1000	75	13.33	100%	0%	0%	100%	0%	0%	0%	0%
Davis	03-001-1372	1004	65	15.45	100%	0%	0%	99%	0%	0%	2%	2%
Woodland	03-001-1372	1000	62	16.13	100%	0%	0%	100%	0%	0%	0%	0%
Davis	03-001-1457	1000	81	12.35	100%	0%	0%	99%	0%	0%	0%	0%
Davis	03-001-1743	1000	87	11.49	100%	0%	0%	94%	3%	2%	0%	6%
Davis	03-001-1938	1001	73	13.71	100%	0%	0%	98%	0%	0%	0%	0%
Davis	03-001-1938	1004	74	13.57	100%	0%	0%	95%	0%	0%	0%	0%
Davis	03-001-2357	1004	79	12.71	97%	3%	0%	98%	0%	0%	0%	0%
Woodland-d	03-001-2357	1004	68	14.76	100%	0%	0%	100%	0%	0%	0%	0%
Davis	03-001-2434	1004	67	14.99	99%	1%	0%	98%	1%	0%	0%	1%
Woodland	03-001-2434	1000	65	15.38	100%	0%	0%	99%	0%	0%	0%	0%
Davis	03-001-665	1004	77	13.04	100%	0%	0%	100%	0%	0%	0%	0%
Davis	04-001-191	1002	81	12.37	100%	0%	0%	85%	2%	0%	0%	2%
Davis	04-001-238	1004	69	14.55	100%	0%	0%	96%	1%	0%	0%	1%
Davis	04-001-390	1004	66	15.21	100%	0%	0%	97%	0%	0%	0%	0%
Davis	04-002-342	1002	75	13.36	100%	0%	0%	89%	0%	0%	0%	0%
Davis	04-003-143	1000	69	14.49	100%	0%	0%	91%	0%	1%	0%	1%
Davis	04-004-446	988	79	12.51	100%	0%	0%	89%	0%	5%	3%	8%
Davis	05-005-295	1004	61	16.46	100%	0%	0%	98%	0%	0%	0%	0%
Davis	05-019-5	1002	71	14.11	100%	0%	0%	77%	0%	0%	0%	0%
Davis	07-002-5	1004	69	14.55	100%	0%	0%	100%	0%	0%	0%	0%
Davis	07-051-6	1000	58	17.24	100%	0%	0%	96%	0%	0%	0%	0%

Location	Variety or Selection	% Insect	% Mold	% Shrivel	% Offgrade	% Edible Yield	% Total Yield	Extra Light	Light	Light Amber	Amber	RLI	Relative Value
Chico	93-28-20	0%	0%	3%	0.4%	**54.4%**	54.6%	17%	50%	27%	5%	**49.1**	**0.962**
Woodland	93-28-20	0%	0%	2%	0.2%	**59.3%**	59.4%	35%	58%	7%	0%	**52.5**	**1.121**
Durham	93-28-20	0%	0%	0%	0.0%	**57.6%**	57.6%	70%	27%	3%	0%	**58.0**	**1.203**
Durham	93-28-20	0%	0%	2%	0.2%	**57.8%**	57.9%	67%	17%	13%	3%	**55.8**	**1.160**
Durham	95-26-16	0%	0%	0%	0.0%	**52.2%**	52.2%	0%	60%	40%	0%	**51.5**	**0.969**
Davis	00-006-227	0%	0%	4%	0.5%	**62.6%**	62.9%	61%	24%	13%	2%	**56.1**	**1.264**
Davis	00-006-227	0%	0%	4%	0.5%	**61.6%**	61.9%	50%	34%	13%	3%	**56.8**	**1.260**
Woodland	00-006-227	0%	0%	0%	0.0%	**62.6%**	62.6%	77%	23%	0%	0%	**57.0**	**1.285**
Davis	03-001-1372	0%	0%	0%	0.0%	**56.0%**	56.0%	70%	27%	2%	0%	**54.5**	**1.098**
Woodland	03-001-1372	0%	0%	0%	0.0%	**59.4%**	59.4%	33%	60%	7%	0%	**53.2**	**1.138**
Davis	03-001-1457	0%	0%	1%	0.2%	**56.3%**	56.4%	86%	11%	3%	0%	**57.7**	**1.169**
Davis	03-001-1743	2%	0%	3%	2.4%	**57.5%**	58.9%	63%	19%	18%	0%	**56.0**	**1.159**
Davis	03-001-1938	0%	1%	3%	1.4%	**56.2%**	57.0%	77%	20%	3%	0%	**58.4**	**1.182**
Davis	03-001-1938	0%	0%	11%	2.4%	**54.1%**	55.4%	69%	23%	9%	0%	**54.4**	**1.059**
Davis	03-001-2357	0%	0%	1%	0.2%	**59.9%**	60.0%	72%	18%	9%	0%	**59.7**	**1.287**
Woodland-d	03-001-2357	0%	0%	0%	0.0%	**63.2%**	63.2%	90%	8%	2%	0%	**57.8**	**1.316**
Davis	03-001-2434	0%	0%	0%	0.0%	**54.7%**	54.7%	66%	21%	11%	2%	**57.2**	**1.126**
Woodland	03-001-2434	0%	2%	0%	0.8%	**59.8%**	60.3%	87%	13%	0%	0%	**58.5**	**1.259**
Davis	03-001-665	0%	0%	1%	0.3%	**61.0%**	61.2%	79%	17%	4%	0%	**57.9**	**1.271**
Davis	04-001-191	12%	0%	4%	14.9%	**46.8%**	53.8%	44%	32%	22%	3%	**53.8**	**0.907**
Davis	04-001-238	0%	0%	6%	1.0%	**52.4%**	52.9%	33%	55%	13%	0%	**53.6**	**1.011**
Davis	04-001-390	3%	0%	0%	3.3%	**47.7%**	49.3%	23%	52%	20%	5%	**52.1**	**0.895**
Davis	04-002-342	0%	0%	24%	5.4%	**47.8%**	50.4%	0%	31%	62%	7%	**50.4**	**0.867**
Davis	04-003-143	0%	0%	19%	5.2%	**49.6%**	52.2%	28%	33%	35%	4%	**53.1**	**0.948**
Davis	04-004-446	0%	0%	19%	4.0%	**53.6%**	55.8%	44%	53%	3%	0%	**53.9**	**1.041**
Davis	05-005-295	2%	0%	2%	1.9%	**57.5%**	58.6%	0%	76%	15%	9%	**52.4**	**1.084**
Davis	05-019-5	21%	0%	6%	28.7%	**40.6%**	52.3%	46%	43%	9%	2%	**53.9**	**0.788**
Davis	07-002-5	0%	0%	0%	0.0%	**62.1%**	62.1%	81%	5%	14%	0%	**56.7**	**1.267**
Davis	07-051-6	0%	2%	5%	2.0%	**54.4%**	55.5%	0%	63%	24%	13%	**47.7**	**0.934**

Table 10. Leafing, male and female bloom, and harvest dates at UC Davis during 2013 (in harvest date order).

Cultivar/Selection	Leaf Date	Harvest Date
Ivanhoe	3/17	9/1
07-029-15	3/29	9/3
Payne	3/19	9/4
06-005-18	3/20	9/4
06-023-9	3/23	9/5
04-003-293	4/4	9/5
04-001-390	4/1	9/6
Idaho	3/18	9/7
Chico	3/21	9/8
06-005-31	3/26	9/8
05-002-396	3/17	9/9
Serr	3/19	9/10
06-017-14	3/25	9/10
05-001-295	3/24	9/10
06-013-19	3/25	9/11
07-029-1	3/24	9/11
05-001-402	3/18	9/11
05-001-434	3/15	9/11
04-006-28	3/31	9/11
95-007-13	3/23	9/11
03-001-3443	3/26	9/11
06-005-2	3/24	9/12

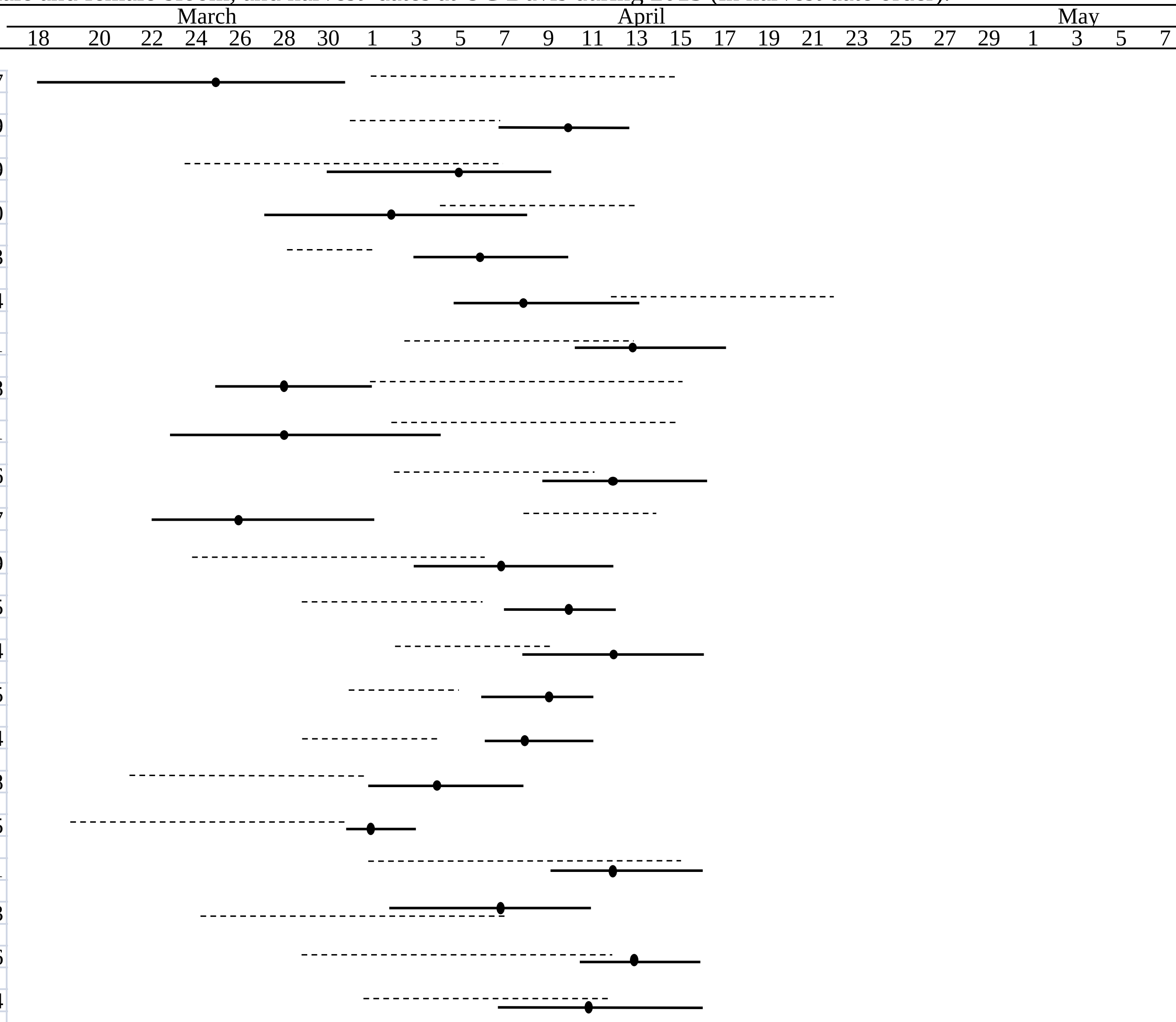
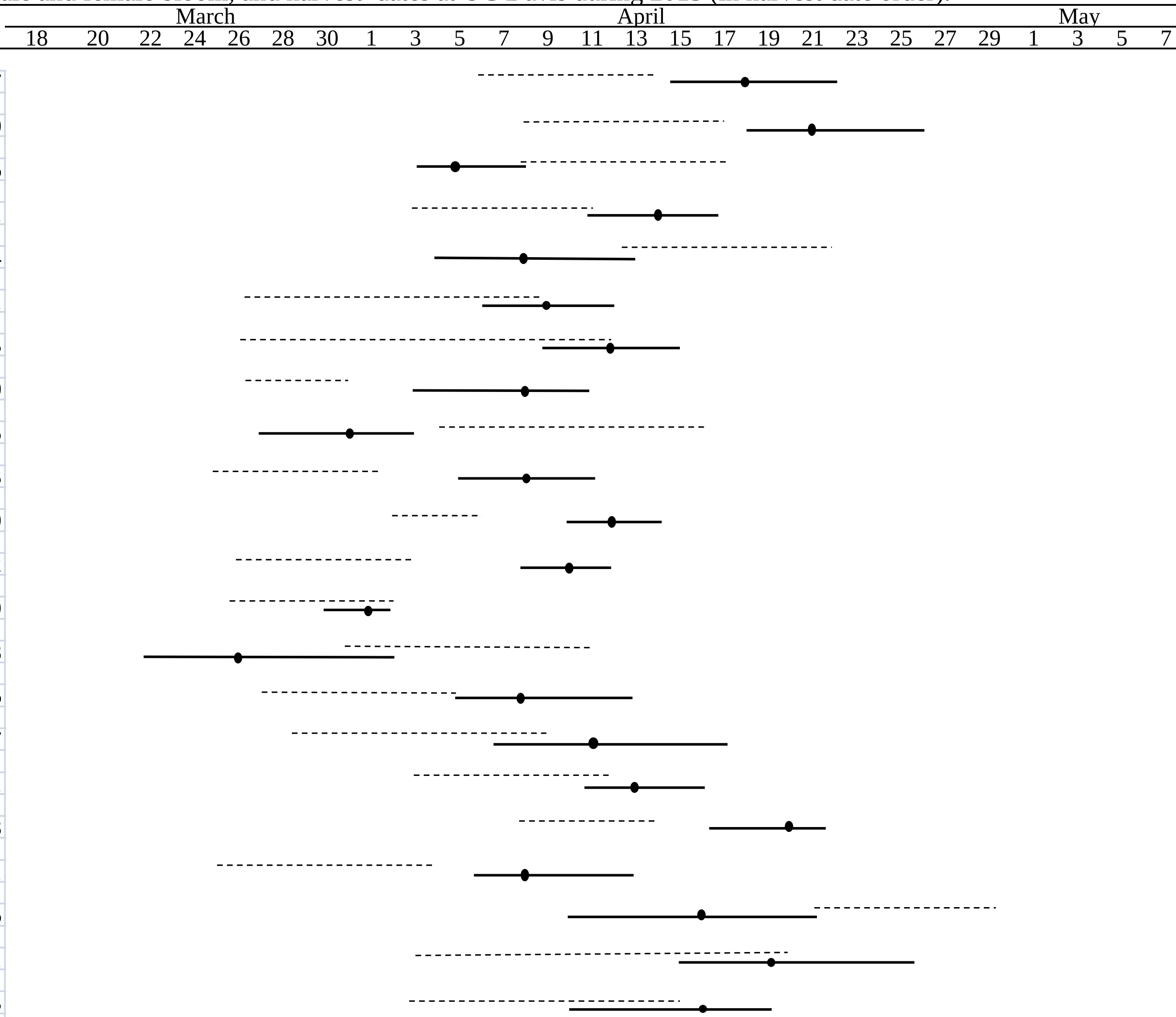
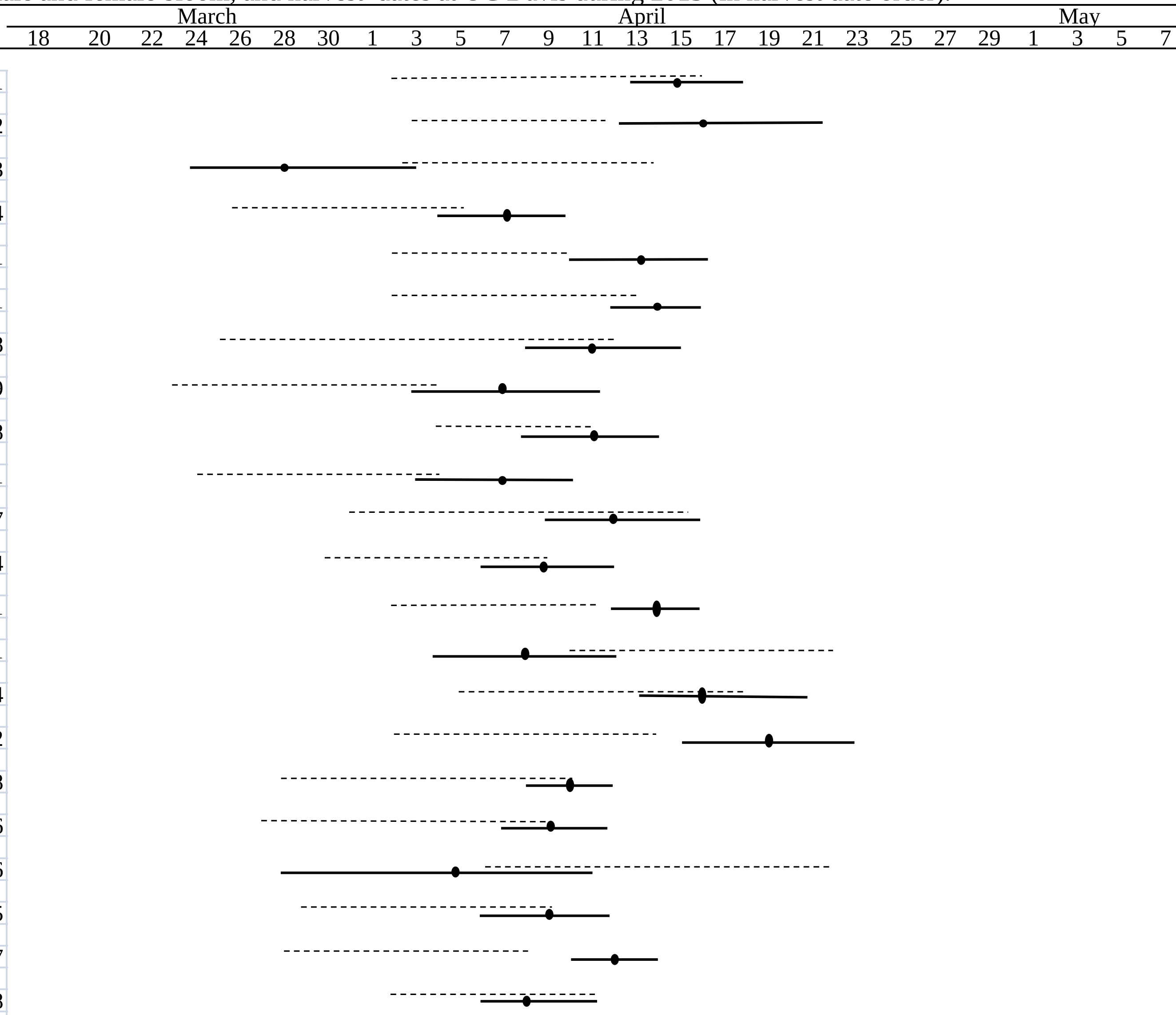


Table 10. Leafing, male and female bloom, and harvest dates at UC Davis during 2013 (in harvest date order).



Cultivar/Selection	Leaf Date	Harvest Date
06-012-14	4/7	9/12
06-026-14	4/10	9/12
06-004-2	3/26	9/13
06-027-16	4/1	9/13
07-004-15	4/4	9/13
Solano	3/21	9/14
Vina	3/23	9/14
06-005-5	3/20	9/14
06-012-21	3/25	9/14
06-030-20	3/23	9/14
05-002-393	3/29	9/14
06-013-20	3/22	9/15
07-005-17	3/19	9/15
03-001-985	3/18	9/15
03-001-1457	3/26	9/15
03-001-1743	3/27	9/15
06-005-33	4/1	9/16
07-002-5	4/8	9/16
03-001-475	3/21	9/16
04-004-58	4/6	9/16
Lara	4/1	9/17
06-026-19	4/3	9/17

Table 10. Leafing, male and female bloom, and harvest dates at UC Davis during 2013 (in harvest date order).



Cultivar/Selection	Leaf Date	Harvest Date
05-019-12	4/1	9/17
04-004-411	4/2	9/17
05-001-94	3/23	9/18
05-002-233	3/24	9/18
03-001-2556	4/1	9/18
04-004-117	4/1	9/18
93-028-20	3/28	9/18
02-005-870	3/19	9/18
06-015-15	3/28	9/19
03-001-1938	3/21	9/19
97-003-11	3/27	9/19
05-001-97	3/24	9/20
05-034-11	4/1	9/20
03-001-977	4/1	9/20
03-001-1372	4/4	9/20
Howard	4/2	9/21
05-001-122	3/28	9/21
05-014-59	3/26	9/21
64-057	3/26	9/21
03-001-665	3/25	9/21
03-001-2105	3/27	9/21
05-001-412	3/28	9/22

Table 10. Leafing, male and female bloom, and harvest dates at UC Davis during 2013 (in harvest date order).

Cultivar/Selection	Leaf Date	Harvest Date
03-001-1098	3/30	9/22
04-003-403	4/2	9/22
91-090-41	3/31	9/22
06-025-21	4/3	9/23
05-014-197	4/1	9/23
04-002-342	4/1	9/23
03-001-2357	3/28	9/24
04-003-143	4/1	9/24
04-003-417	3/26	9/24
Hartley	4/1	9/25
03-001-2434	3/22	9/25
03-001-2440	4/1	9/25
91-077-40	3/29	9/25
Forde	3/28	9/25
Poe	4/5	9/25
Sexton	3/23	9/28
Tulare	4/3	9/28
Gillet	3/20	9/28
Cisco	4/11	9/30
03-001-825	3/29	10/1
Chandler	4/4	10/2
Franquette	4/19	10/7

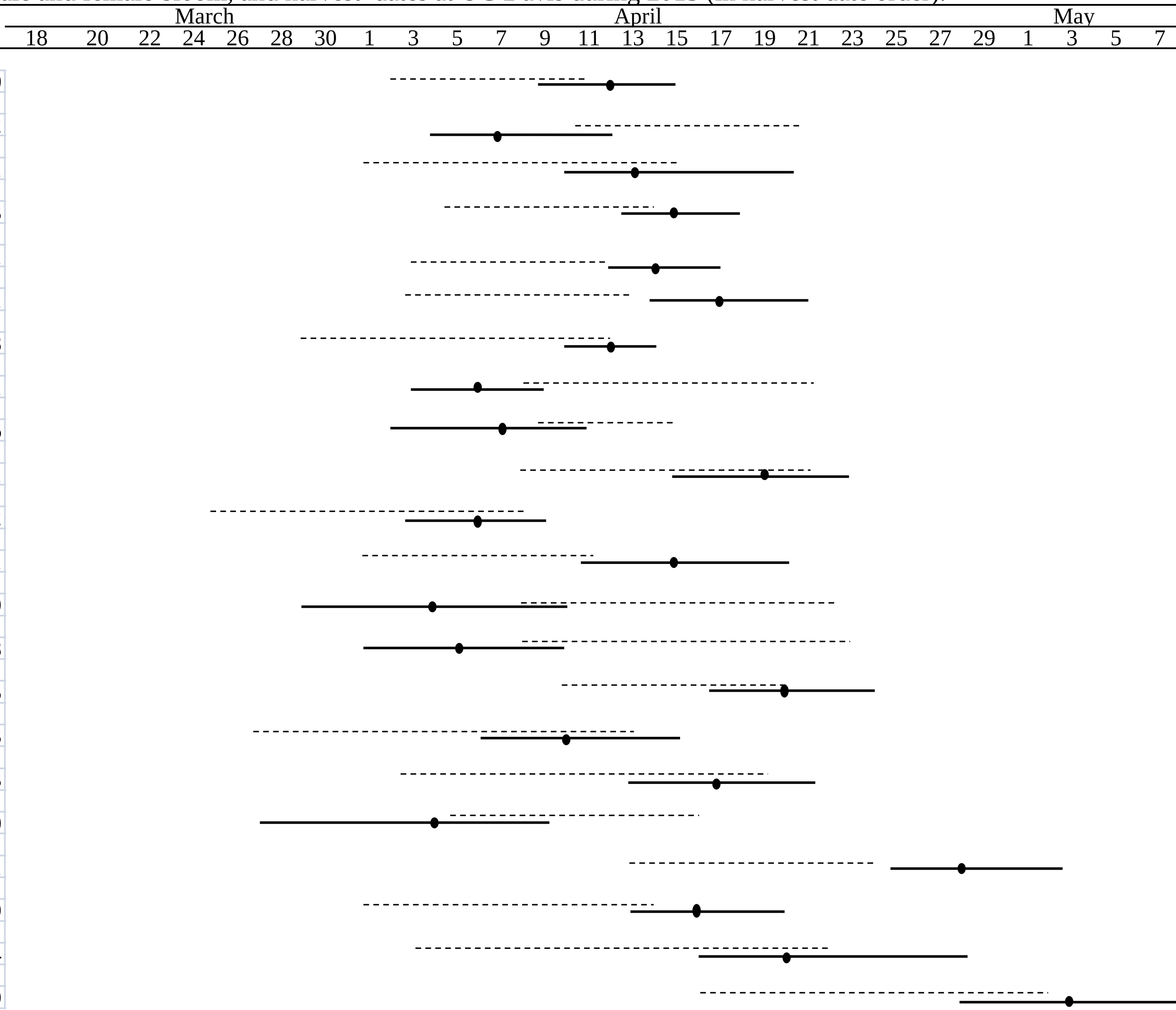


Table 12 Average shoot height (mm) of walnut genotypes grown on standard DKW medium or formulations substituting FeEDDHA in place of FeEDTA.

Genotypes	1st evaluation 1/7/13			2nd evaluation 2/6/13		
	001 DKW Standard	866 230µM FeEDDHA	865 90µM FeEDDHA	001 DKW Standard	866 230µM FeEDDHA	865 90µM FeEDDHA
K3	26	26	25	27	35	39
CR	18	23	21	23	29	29
7-9	14	13	13	20	18	16
W17	40	47	29	53	55	40
JCS2	16	23	24	14	38	25
VX211	31	33	35	39	34	35
PX1	13	24	36	18	35	38
SC5	13	14	13	14	17	16
JCS1	15	14	10	19	16	15

Table 13. Chandler microshoots cultured on DKW medium with gibberellic acid.

Medium	**Average of variables**	
	Height (mm)	**# shoots**
001	25.58	2.75
0.1 mg/L GA 3	12.67	2.25
0.1 mg/L GA 4+7	10.75	1.75
5.0 mg/L GA 3	13.67	2.58
5.0 mg/L GA 4+7	11.92	1.66

Table 14. Chandler microshoots cultured on DKW medium with gibberellic acid.

Medium	**Average of variables**	
	Height (mm)	**# shoots**
001 (bad batch)	14.08	2.66
0.1 mg/L GA 3	13.08	2.83
0.1 mg/L GA 4+7	13.91	2.58
5.0 mg/L GA 3	14.66	2.41
5.0 mg/L GA 4+7	15.08	2.33

Table 15. Chandler microshoots dipped in filter sterilized solutions of gibberellic acid in water.

Media	**Height (mm)**
water	28.5
1 mg/L GA 3	30
1 mg/L GA 4+7	22.5
20 mg/L GA 3	20.5
20 mg/L GA 4+7	22.5

Table 16. Influence of pot type on root growth and architecture.

All control pot results by genotype						
Genotype	#	Average Root Weight (g)	Average Shoot Weight (g)	Average Root Area (in^2)	Average Depth to Widest Point (in)	Average Subjective Depth Score
Rx1	9	1.8	1.5	12.1	1.6	1.4
Vlach	16	9.9	3.4	20.7	3.7	1.6
Vx211	15	19.2	6.0	33.0	4.6	2.9
Total	**40**	**11.6**	**3.9**	**23.4**	**3.6**	**2.1**
All Pioneer pot results by genotype						
Genotype	#	Average Root Weight (g)	Average Shoot Weight (g)	Average Root Area (in^2)	Average Depth to Widest Point (in)	Average Subjective Depth Score
Rx1	10	2.7	1.6	15.4	1.9	2.7
Vlach	11	7.3	3.0	15.5	2.3	2.5
Vx211	16	15.0	6.4	20.5	2.7	3.9
Total	**37**	**9.4**	**4.1**	**17.6**	**2.4**	**3.2**
All Elle Pot results by genotype						
Genotype	#	Average Root Weight (g)	Average Shoot Weight (g)	Average Root Area (in^2)	Average Depth to Widest Point (in)	Average Subjective Depth Score
Rx1	7	1.9	1.6	18.3	1.6	1.6
Vlach	8	2.6	2.5	17.3	2.5	2.8
Vx211						
Total	**15**	**2.3**	**2.1**	**17.9**	**2.1**	**2.2**

Table 17. Effect of pot type and transplant treatment on root growth and architecture of greenhouse-grown walnut plantlets.

All treatments						
Treatment	#	Average Root Weight (g)	Average Top Weight (g)	Average Root Area (in^2)	Average Depth to Widest Point (in)	Average Subjective Depth Score
l0	15	2.3	2.1	17.9	2.1	2.2
Ct0	7	3.6	1.9	21.2	2.5	1.6
Pt0	5	3.6	2.4	19.6	2.3	2.8
Ct1	16	4.8	3.5	17.6	4.0	1.6
Pt1	18	4.3	2.4	14.8	2.3	2.7
Ct2	17	21.3	5.2	29.7	3.6	2.7
Pt2	14	18.0	6.9	20.6	2.5	3.9
Ct All	**40**	**11.6**	**3.9**	**23.4**	**3.6**	**2.1**
Pt All	**37**	**9.4**	**4.1**	**17.6**	**2.4**	**3.2**
l All	**15**	**2.3**	**2.1**	**17.9**	**2.1**	**2.2**

CT2 (Control transplanted twice), PT2 (Pioneer pot transplanted twice). CT1 (Control transplanted once), PT1 (Pioneer pot transplanted once). CT0, PT0, and L0 (Control, Pioneer and Elle pot, never transplanted).

Table 18. Effect of genotype on root growth and architecture of greenhouse grown plantlets.

All Genotypes						
	#	Average Root Weight (g)	Average Top Weight (g)	Average Root Area (in^2)	Average Depth to Widest Point (in)	Average Subjective Depth Score
RX1	26	2.2	1.6	15.0	1.7	2.0
Vlach	35	7.4	3.0	18.4	3.0	2.2
VX211	31	17.1	6.2	26.5	3.6	3.4
Total	**92**	**9.2**	**3.7**	**20.2**	**2.8**	**2.5**

Table 19. Root and shoot mass of young greenhouse plantlets after 1 month of GA and/or BAP treatments applied twice weekly.

Roots 1 Month Stubby Cell Test					
	# Plants	Avg. Root mass (g)	Avg. Shoot mass (g)	Avg. Plant mass (g)	root/shoot ratio
BAP	7	6.7	7.0	13.7	1.1
BAP + GA	8	4.4	7.6	12.0	1.6
Control	8	5.7	5.1	10.8	0.9
GA	7	5.0	9.4	14.4	2.2
Promalin	8	4.7	11.0	15.7	3.2
Total	38	5.3	8.0	13.3	1.8

Table 20. Root and shoot mass of young greenhouse plantlets after 2 months of GA and/or BAP treatments applied twice weekly.

Weights 2 Month Tall-One Pot Test					
	# plants	Avg. Root mass (g)	Avg. Shoot mass (g)	Avg. Plant mass (g)	root/shoot ratio
Bap	10	14.7	6.3	21.0	0.47
Bap + Ga	10	18.7	15.5	34.1	0.86
Control	10	15.6	5.5	21.1	0.40
Ga	9	21.8	20.3	42.2	1.06
Promalin	10	18.0	14.9	32.8	1.20
Total	49	17.8	12.5	30.2	0.80

Table 21. Shoot elongation of young greenhouse plantlets after 1 month of GA and/or BAP treatments applied twice weekly.

Heights Stubby Cell					
	Average Height change (cm)	Average % Increase	Total #	# significantly elongating	% elongation
BAP	1.6	61.1	17	4	23.5
BAP + GA	9.0	265.5	17	12	70.6
Control	1.2	40.9	18	3	16.7
GA	14.6	490.2	16	13	81.3
Promalin	18.8	736.2	18	17	94.4
Total	9.0	318.4	86	49	57.0

Table 22. Shoot elongation of young greenhouse plantlets after 2 months of GA and/or BAP treatments applied twice weekly.

Heights Tall One					
	Average Height change (cm)	Average % Increase	Total #	# significantly elongating	% elongating
Bap	7.0	28.4	10	1	10.0
Bap + Ga	22.9	71.4	10	6	60.0
Control	6.3	80.9	10	2	20.0
Ga	34.4	84.9	9	8	88.9
Promalin	34.4	61.2	10	10	100.0
Total	21.0	65.4	49	27	55.8