FINAL PROJECT REPORT

Project Title: Replant disease tolerance of Geneva rootstocks

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Other funding sources: None.

Total Project funding:$95,230

Budget History

Item	2006	2007	2008
Salaries[1]	17,000	17,000	21,000
Benefits	5,000	5,000	6,000
Wages			
Benefits			
Equipment			
Supplies[2]	6,000	6,000	6,000
Travel[3]	1,530	1,530	1,530
Miscellaneous[4]			
Total	30,000	30,000	35,320

Footnotes: [1]Technician salary for part-time assistance in propagation budding and maintenance of stoolbeds.
[2]Includes cost for rootstock liners, trees, support system, laboratory supplies etc.
[3]Travel to and from trials.
[4]Includes shipping expenses, communication costs etc.

Progress Report
Objectives

1. To study the relative performance of Geneva dwarfing apple rootstocks compared to commercial controls in replant soils and the study of genetic mechanisms related to tolerance to ARD.
2. In the most recent visits we have come to appreciate the need by a certain segment of the industry to plant liners in place in the orchard either as sleeping eyes or as bench grafts. We would like to modify our existing protocol to discover "nursery in place" properties of rootstocks and how they interact with replant disease when the plants are so young. The question we are trying to answer is: how well do ARD tolerant sleeping eyes and bench grafts do in a replant situation?
3. To set up an early evaluation protocol for newly developed genotypes that screens for components of apple replant disease resistance in the early stages of breeding.

SIGNIFICANT FINDINGS AND DEVELOPMENTS

- **General replant tolerance has been confirmed in certain Geneva rootstocks (CG4214, G.41, G.935, and CG5890). Even though we did not intend to make these trials about fire blight resistance, this disease has killed several known susceptible rootstocks (M.9 Pajam 2 came in first with 35% dead and Supporter 1 and 2 with 20% trees each). Fire blight resistant B.9 continues to be one of the weakest and least productive rootstocks in all the replant experiments that have been planted so far. Malling 9 survival has been compromised by several fire blight events.**
- **Fumigation's positive effect on season's tree growth treatment disappeared in the fourth season, however, the initial boost in growth increased the cumulative effect on TCSA and Fruit Yield – it seems as if the replant susceptible rootstocks are behind one or two seasons.**
- **It is critical to plant replant and fire blight resistant rootstocks in orchards destined for organic management since losses due to rootstock susceptibility alone can amount to over 50% of the potential yield.**
- **First yield data from a graft in place replant experiment containing the widest selection of Geneva rootstocks ever tested in Vantage WA indicates that some new Geneva rootstocks match or surpass control rootstocks.**

OBJECTIVE 1. During this granting period we field tested a number of rootstocks (Table 1) at several documented diverse replant sites, including Wapato, Chelan, Brewster, Vantage, and Naches. These sites represent different soil, management and agro-ecological conditions and are a good representative test of the reliability of new rootstock genotypes in WA. Thanks to the efforts of the Washington Tree Fruit Research Commission, these trials also cover other traits that may be impacted by rootstocks such as fruit size, maturity, and other fruit disorders. Plans to establish larger plantings with selections from these experiments are well on their way. These trials will impact the apple production machinery in WA in a very significant way as federal and state regulation of fumigants increases and the amount of virgin land optimal for apple production decreases.
The study of the genetic factors that are impacting replant tolerance found in the Geneva breeding program is still in its early life. We have accomplished a very important step in this process: the confirmation that there are genetic differences in the interaction between components of ARD and a diverse pool of apple rootstocks. For example, Geneva rootstocks that shared common ancestry supported lower populations of lesion nematodes (*Pratylenchus penetrans*) and had lower incidence of *Phythium* infection in replant soils (Mazzola et. al, 2009 Plant Disease 93:51-57). Another example is a root morphological trait which produces a preponderance of fine roots and is shared by several replant tolerant Geneva apple rootstocks. We are in the process of characterizing this trait and its impact on nutrition, replant tolerance and productivity.

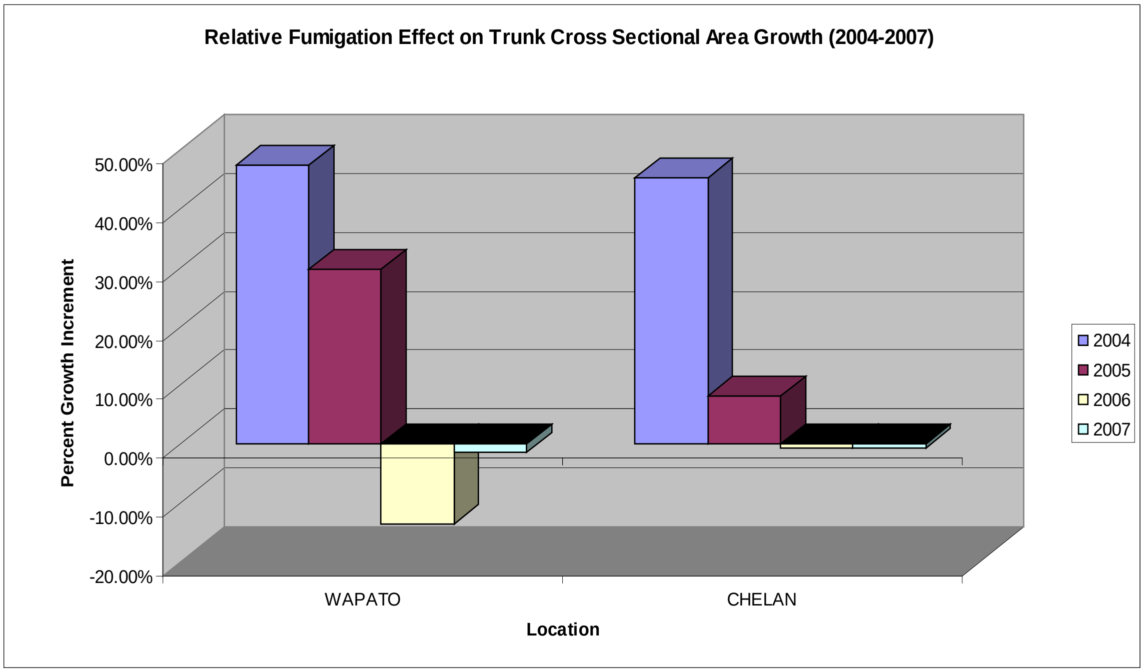

Figure 1. This figure depicts the effect of fumigation on growth relative to unfumigated samples over three years. It is evident that the effect on tree growth is significant in the first two years and then dissipates in following years. To have a major impact on production planting must follow soon after fumigation (within safety limits) otherwise the benefits disappear.

Table 1. Locations and rootstocks planted in ARD trials 2003-2008.

Rootstock	Location*	Scion Varieties
G.16	WA, CH, NA	Brookfied Gala, Honeycrisp
G.11	WA, CH, BR, VA	Brookfied Gala, Torres Fuji, Aztec Fuji
G 3041	WA, CH, VA	Brookfied Gala, Aztec Fuji
G 5935	WA, CH, NA, VA	Brookfied Gala, Honeycrisp, Aztec Fuji
PiAU-56-83	WA, CH	Brookfied Gala
Pajam 2	WA, CH	Brookfied Gala
M.26 EMLA	WA, CH, NA	Brookfied Gala
Bud 9	WA, CH, NA	Brookfied Gala
Supporter 1	WA, CH	Brookfied Gala
Supporter 2	WA, CH	Brookfied Gala
Supporter 3	WA, CH	Brookfied Gala
4214	WA, NA, BR, VA	Brookfied Gala, Torres Fuji
4003	NA	Honeycrisp
4814	NA, BR, VA	Honeycrisp, Torres Fuji, Aztec Fuji
4210	NA, BR, VA	Honeycrisp, Torres Fuji, Aztec Fuji
G.30	NA, VA	Honeycrisp, Aztec Fuji
5087	NA, VA	Honeycrisp, Aztec Fuji
G 4202	NA	Honeycrisp
4013	NA	Honeycrisp
4213	NA	Honeycrisp
M.9 EMLA	NA, BR	Honeycrisp, Torres Fuji
5757	BR	Torres Fuji
G.202	BR, VA	Torres Fuji, Aztec Fuji
6879	BR	Torres Fuji
MM.106	BR	Torres Fuji

Rootstock	Location*	Scion Varieties
6006	BR	Torres Fuji
7707	BR	Torres Fuji
5257	BR, VA	Torres Fuji, Aztec Fuji
3007	BR, VA	Torres Fuji, Aztec Fuji
4011	BR, VA	Torres Fuji, Aztec Fuji
5935	BR	Torres Fuji
5463	BR, VA	Torres Fuji, Aztec Fuji
4003	BR	Torres Fuji
6001	BR	Torres Fuji
6210	WA	
M.7	BR, WA	Torres Fuji
JTE-B	BR	Torres Fuji
Ottawa 3	BR	Torres Fuji
JTE-C	BR	Torres Fuji
5890	BR	Torres Fuji
2034	VA	Aztec Fuji
2406	VA	Aztec Fuji
3001	VA	Aztec Fuji
4002	VA	Aztec Fuji
4004	VA	Aztec Fuji
4013	VA	Aztec Fuji
4172	VA	Aztec Fuji
4288	VA	Aztec Fuji
5046	VA	Aztec Fuji
5179	VA	Aztec Fuji
5202	VA	Aztec Fuji
4019	VA	Aztec Fuji
Mark	VA	Aztec Fuji
Supporter 4	VA	Aztec Fuji

*** WA=Wapato, CH=Chelan, NA=Naches, VA=Vantage, BR=Brewster**

<u>FINDINGS BY LOCATION:</u>

2004 CHELAN REPLANT TRIAL – HOW IMPORTANT ARE ROOTSTOCKS UNDER ORGANIC MANAGEMENT?

This was the fifth growing season for this trial. We have learned that rootstocks play a very big role in the success of an organic orchard. Pervasive tree death due to fire blight or vole damage was predominant in M.9 trees. B.9 survived fire blight but several trees were lost and the surviving ones failed to fill their space and looked extremely stunted in both fumigated and non-fumigated treatments. The fumigation effect on tree productivity is still significant in the overall planting, especially for susceptible rootstocks; the difference in fruit per tree between treatments (Figure 2) is significant. That difference may be due to the increased scaffold build in the first two seasons of growth due to the fumigation effect. Overall, the initial growth spurt due to fumigation is still noticeable throughout the orchard but as shown in Figure 3 there were no differences in growth due to the fumigation treatment this year. When we look at the performance of the individual rootstocks (figures 2 and 3 we notice that some are relatively unaffected by the replant problem and seem to do relatively well in fumigated and non-fumigated soils. G.41 and G.935 continue to perform well in this trial and anecdotally tree deaths due to vole damage seem to be less in Geneva rootstocks than other rootstocks. In the extra non fumigated rows of this trial are several plants of CG4214 (data not shown) that performed relatively well compared to G.41 and G.935.

2004 WAPATO REPLANT TRIAL – This trial has come into full production and most rootstocks (B.9 being the exception) have filled the canopy space. In this planting in the overall effect of the fumigation is still detectable. CG4214, G.41, G.935 have performed well and have shown that having fire blight resistance along with apple replant tolerance is a very good thing.

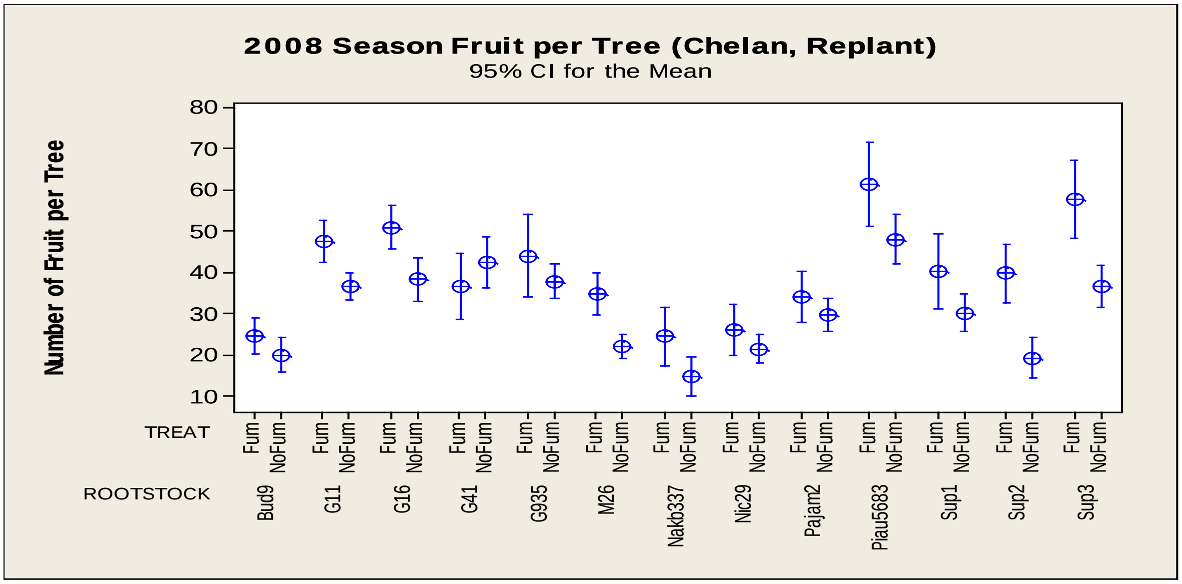

Figure 2. Yield per tree 2007. In this organic planting in Chelan the overall effect of the fumigation is still detectable. Some rootstocks however do not seem to be affected as much (3041 aka G.41, 5935 aka G.935). A mixture was identified in G.41 rootstock. Every G.41 tree in the trial was DNA fingerprinted resulting in the identification of all misidentified trees (roughly 20% of the total). This rootstock was labeled 27R5-1.

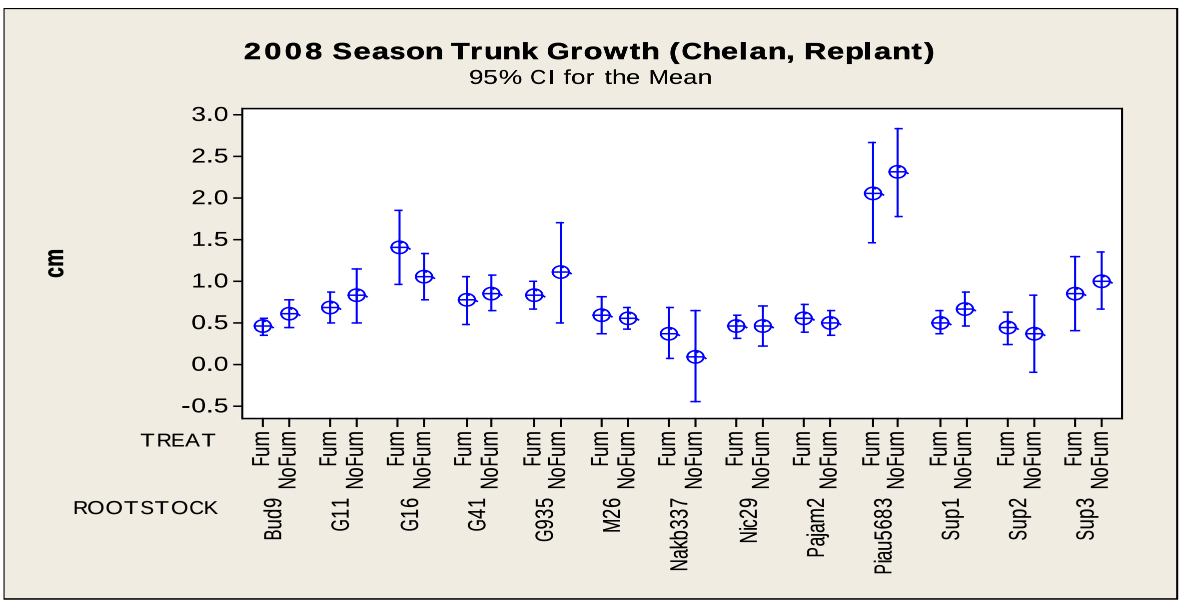

Figure 3. 2008 Season trunk growth shows virtually no difference between the fumigated and non fumigated treatment: a sign that the effect is gone and that the productivity now and in the future is in the hands of genetic resistance of individual rootstocks.

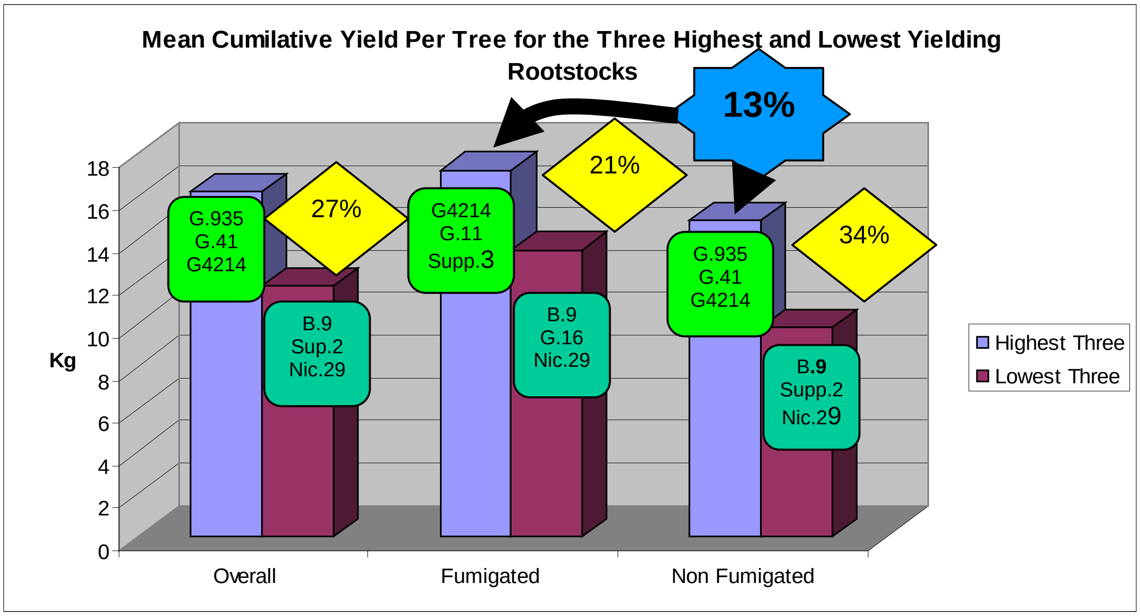

Figure 4. To generate the above graph we took the best and worst three performers in the different categories and calculated the means of cumulative yield. In Wapato G.935, G.41 and G.4214 are consistently the best rootstocks producing up to 34% more apples per tree that the three low producing rootstocks. In the fumigated block Supporter 3 and G.11 ranked in the top three indicating yield potential in fumigated or virgin soil. While fumigation increases production by 13% in the best genetic scenario (resistant rootstocks), using resistant rootstocks increases production by 21% in fumigated ground and by 34% in non fumigated ground (data up to 2007).

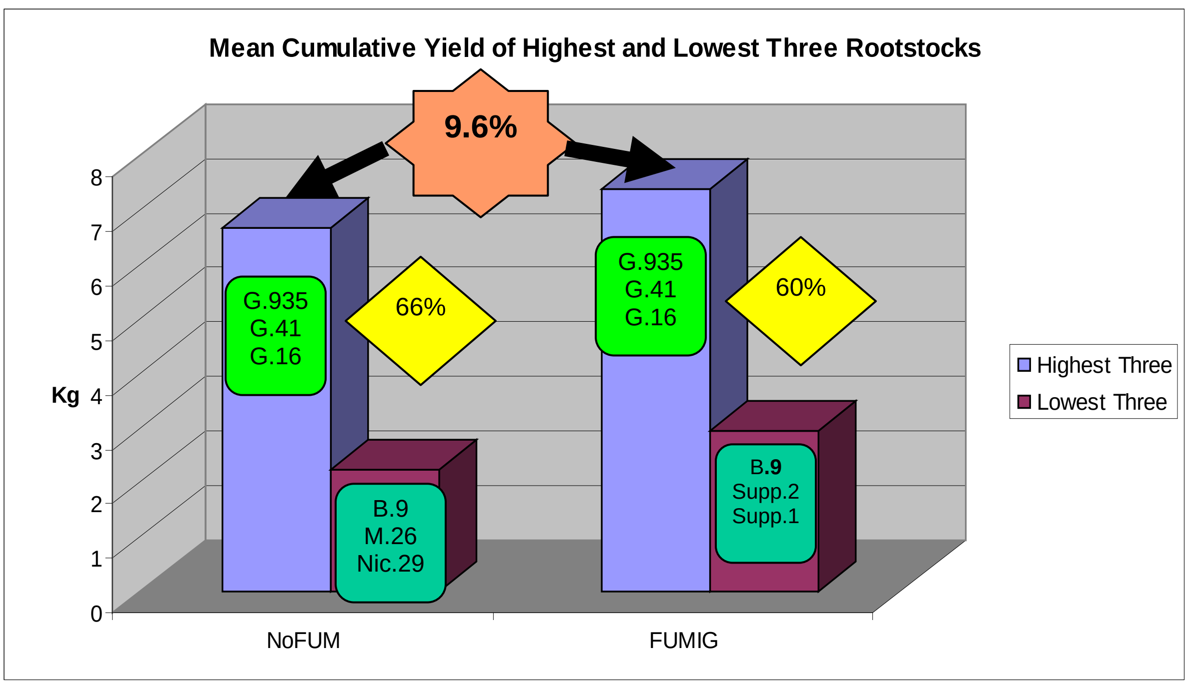

Figure 5. Same analysis as in Figure 4 but for the Chelan Replant Trial. The Advantage of planting resistant rootstocks is very clear.

2006 BREWSTER REPLANT TRIAL

This trial is set in the quintessential replant location having been cultivated in apple for over 100 years. This trial is a good indication that trying to escape replant by fumigating and planting vigorous rootstocks such as MM106, M.7 or 5463 is futile – they produced too much unproductive wood and were hard to manage. Despite the harsh replant environment a few Geneva rootstocks performed well and had a good crop load in both fumigated and non fumigated treatments. CG5980 is one of those rootstocks in the semi-dwarf category that performed well in this trial and other trials in NY state with Honeycrisp as the scion. Along with 4214 it is slated for release in the near future.

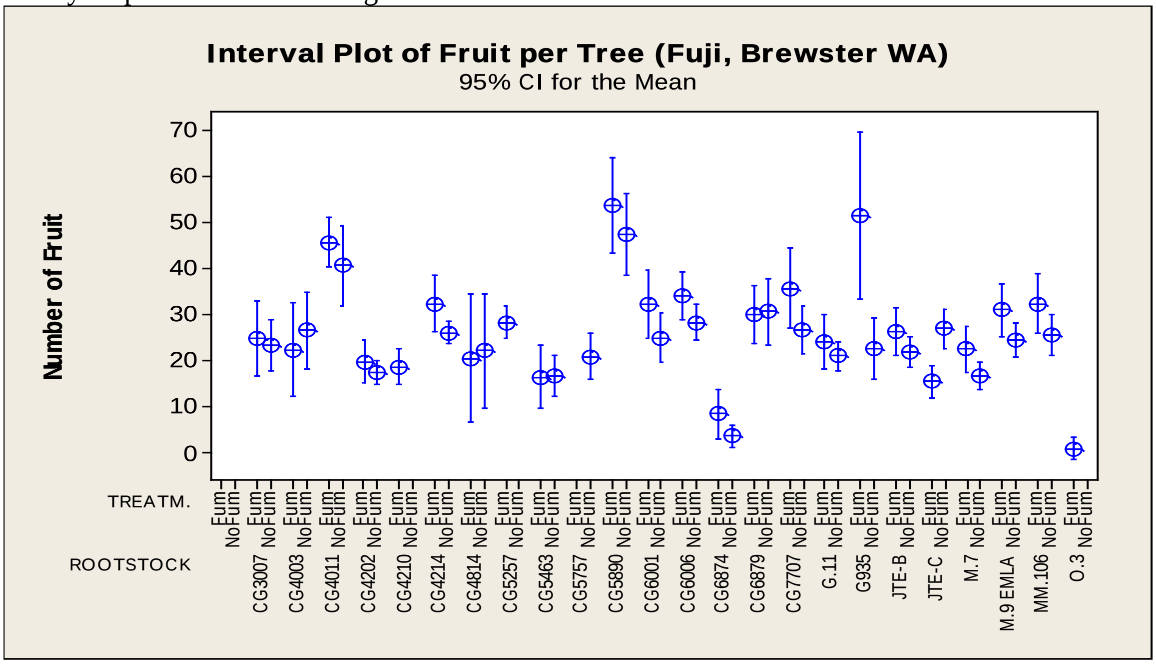

Figure 6. Brewster Trial planted in 2006. 5890 and 4011 are the top performers. Vigorous rootstocks in this trial were inefficient.

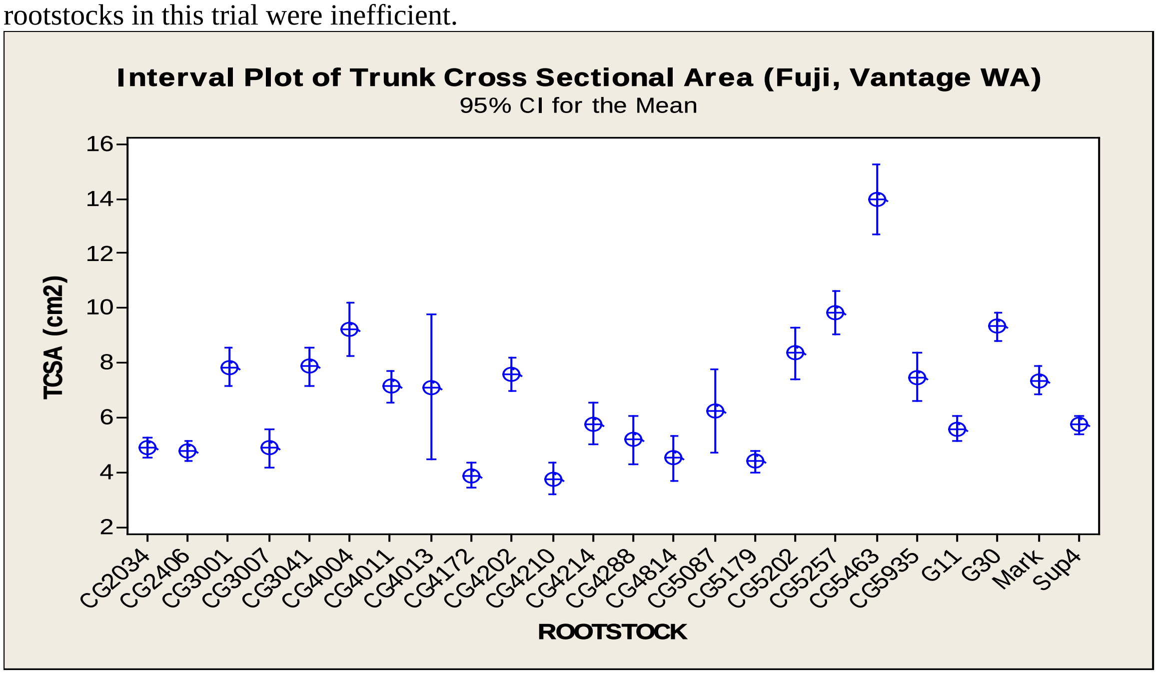

Figure 7. Tree size after two seasons. CG5202, CG5463, CG4004 and G.30 may be too vigorous for this type of management.

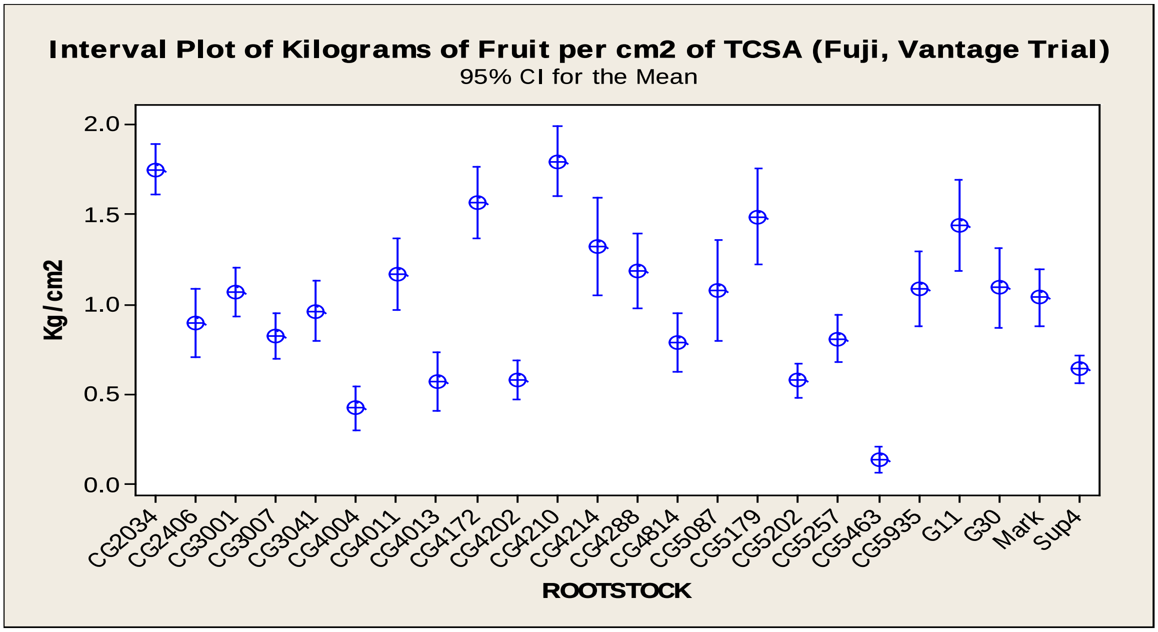

Figure 8. Several Geneva rootstocks were as yield efficient as Mark. CG.5463 will have to be removed from this trial.

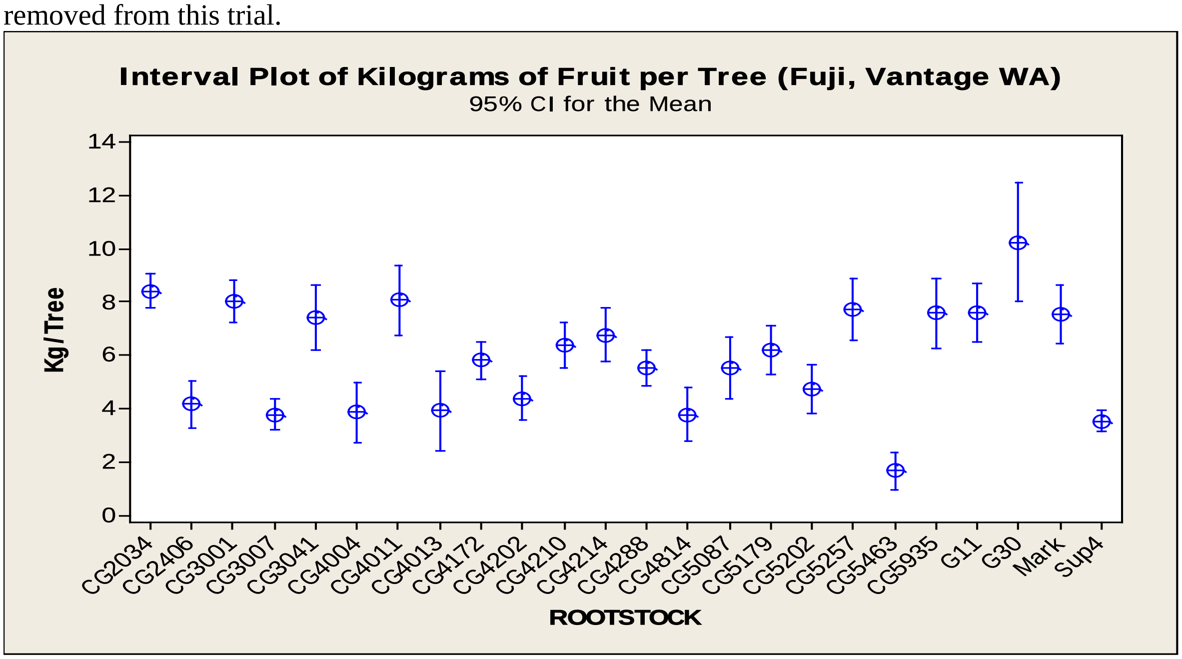

Figure 9. Several Geneva rootstocks were able to produce a “target” number of fruit per tree similar to the check Mark. S

OBJECTIVE 2

This trial represents one of the most diverse trials in WA in terms of new rootstocks from the Geneva breeding program (Figures 7-10). This year represented the first crop on the BenchGrafts (BG) replant trial at the Auvil Fruit Tree Farm (Vantage, WA). This is a very discriminatory trial because of the intensive precision management intended to push the rootstocks to the maximum of their ability. As a result we have eliminated several rootstocks that seem to be overwhelmingly susceptible to latent viruses since the benchgrafting material was not clean. A few new rootstocks such as CG2034 and CG3001 have shown promise under this type of management. Other rootstocks such as G.41 (CG3041), G.11, G.935 all performed as well as the check rootstock Mark. It will be interesting to watch CG2034 to see if it comes back with a similar crop in the next season.

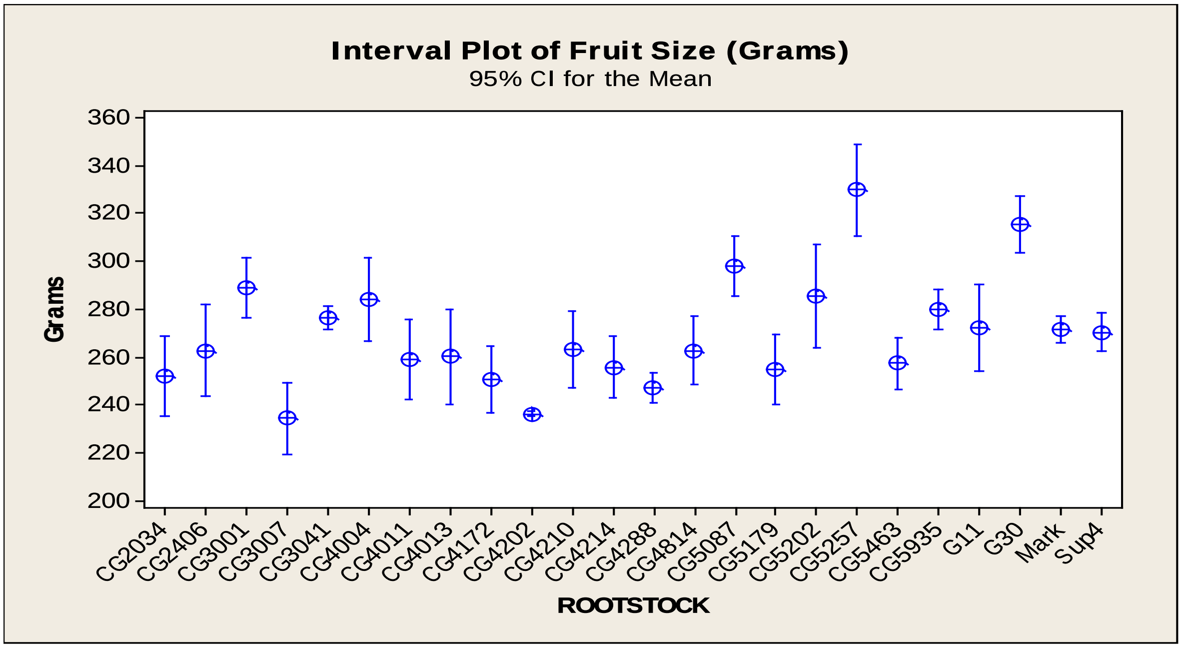

Figure 10. Fruit size varied somewhat in the first production year of this trial. CG3001, G.41 stands out as having a high crop load and yet maintaining fruit size.

OBJECTIVE 3

We planted a large replant experiment in Geneva this year that included some of our more advanced selections as well as commercial checks – all rootstocks were made into bench grafts with the Brookfield Gala as the scion variety. This experiment was planted in pots using two different soils (Clay Loam and Sandy Loam) where half of each soil was steam pasteurized. Sensitivity or resistance to ARD was evaluated by measuring tree height, stem diameter, fresh total plant weight, fresh scion and rootstock weight, increase of total and rootstock fresh weight, number of feathered trees, number of branches and total branch length. This was a destructive experiment since we also measured root mass and took data on root architecture differences. We have collected leaves for mineral analysis. This experiment will help us develop better screening techniques for future releases. Preliminary results show that there were significant differences in the sensitivity of certain rootstocks depending on the type of soil. There was good correlation between WA field experiments and the resistance or sensitivity to ARD in this experiment.

AKNOWLEDGEMENTS

We would like to express heartfelt gratitude to the many growers that are cooperating in this effort by hosting trials as well as the staff members at the WTFRC that have worked very, very, hard to obtain this data.

EXECUTIVE SUMMARY

We have learned that the future survival of the apple industry will be highly dependent on the implementation of new scion and rootstock varieties obtained through advances of breeding, genetics and genomics. In relation to apple rootstocks these sets of experiments showed that breeding for disease resistance and increased yield was successful and that even though these rootstocks were selected under New York conditions there was enough genetic diversity in the group to show adaptability to Washington conditions. These trials will impact the apple production machinery in Washington in a very significant way as federal and state regulation of fumigants increases and the amount of virgin land optimal for apple production decreases. **With regards to fumigation – the positive effect on tree growth disappeared after the second season. The initial boost in growth increased the cumulative effect on TCSA and Fruit Yield – BUT – this increase was less than half of what planting genetically tolerant rootstocks did in the same seasons.** This productivity due to genetic resistance is maintained throughout the life of the orchard.

It is critical to plant replant and fire blight resistant rootstocks in orchards destined for organic management since losses due to rootstock susceptibility alone can amount to over 50% of the potential yield. General replant tolerance has been confirmed in certain Geneva rootstocks (CG4214, G.41, G.935, and CG5890). Even though we did not intend to make these trials about fire blight resistance, this disease has killed several known susceptible rootstocks (M.9 Pajam 2 came in first with 35% dead and Supporter 1 and 2 with 20% trees each). Although fire blight resistant B.9 continues to be one of the weakest and least productive rootstocks in all the replant experiments that have been planted so far. Malling 9 survival has been compromised by several fire blight events.

First yield data from a bench-graft plant in place replant experiment under intensive precision management intended to push the rootstocks to the maximum of their ability in Vantage WA indicates that some Geneva rootstocks match or surpass control rootstocks. This trial has the widest selection of Geneva rootstocks ever tested in Washington state and promises to uncover other useful qualities about Geneva rootstocks.

We have discovered that there may be several components to the genetic resistance of Geneva rootstocks to apple replant disease. These genetic components may act as traditional disease resistance genes, as genes that control nutrient uptake and genes that modify morphological characters of the root system that increase soil profile exploration. Thanks to the support of these grants we are closer to understanding which of these components stand out and are selectable in our large breeding pool – so that future rootstocks releases from this program will have improved performance with regard to apple replant disease.

With regards to the availability and propagation of G.41 and G.935, we have spearheaded a massive effort to micropropagate the material. We realize that the conversion to these new rootstocks by the nursery industry is somewhat viscous because of the nature of propagation of apple rootstocks, some lack of capital and in some cases because of the mediocre propagation ability of these new genotypes. We are trying to provide as much support as possible to the nurseries to foster such conversion by helping in the Tissue Culture process, certifying the material through DNA fingerprinting and researching better ways to propagate this new material. We have had some success in tissue culture and this spring our collaborators may be able to produce up to 300,000 plantlets of G.41 which will get us closer to our target of 1.5 million liners of G.41 in two or three years.