FINAL PROJECT REPORT

Project Title: MSU cherry rootstocks: Pre-commercialization

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Other funding sources

Agency Name: Michigan Economic Development Corporation
Amount awarded: $6,984
Notes: Funding was obtained to optimize the DNA diagnostic tests for commercial service providers.

Total Project Funding: $134,804

Budget History: Summed over budgets for MSU, WSU, OSU, and the WTFRC

Item	Year 1: 2014	Year 2: 2015	Year 3: 2016
Salaries	$23,359	$ 10,844	$12,086
Benefits	$ 6,391	$ 3,445	$ 3,855
Wages			
Benefits			
Equipment			
Supplies[a]	$1,900	$ 12,050	$ 5,550
Travel	$ 5,000	$ 7,040	$ 9,040
Plot Fees	$ 2,000	$ 1,340	$ 660
Miscellaneous[b]	$ 11,800	$ 18,344[c]	$ 100
Total	$50,450	$53,063	$31,291

[a]Including plot establishment items
[b]Including liner and tree cost

ORIGINAL OBJECTIVES RECAP:

1. Compare the performance of the MSU cherry rootstocks to currently available sweet cherry rootstocks using intensive cherry production systems.
   - **A.** 2009 planting of 'Bing' on MSU cherry rootstocks (removed after 2014 season).
   - **B.** 2015 planting of 3 replicated rootstock trials each containing 4 MSU cherry rootstocks and appropriate check rootstock cultivars with scion cultivars 'Early Robin', 'Regina', and 'Sweetheart'.
   - **C.** 2016 planting of three small replicated rootstock trials alongside the 2015 trials to evaluate the 5th MSU cherry rootstock.
2. Collaborate with commercial nurseries in liner and finished tree production to determine the nursery performance of the MSU cherry rootstocks.
3. Collaborate with the CPCNW-FT and cooperating nurseries to insure MSU cherry rootstocks are available as certified virus tested and genetically verified.

SIGNIFICANT FINDINGS: (bullets by objective)

- **1.A.** Five MSU cherry rootstocks produce dwarf precocious sweet cherry trees with 'Bing' scion based on six years of evaluation of the trees planted at the WSU-Prosser Roza Station in spring 2009. These five rootstocks, which are named after Michigan counties, are Clinton, Cass, Clare, Lake and Crawford. The trees produced were significantly smaller than 'Gisela®6' (Gi6) but of similar size to 'Gisela® 5' (Gi5) measured as trunk cross-sectional area (TCSA).
- **1.A.** In 2014, 'Bing' fruit maturity date differed among the seven rootstocks tested at the Prosser plot with Cass, Clare and Lake ripening ahead of Clinton, Crawford, Gi5 and Gi6.
- **1.A.** In 2014, all five of the MSU candidate rootstocks had yield efficiencies (kg fruit/cm^2) that were higher than that of Gi5 and Gi6. However, the fruit size for Crawford was significantly less than that for Gi5 due to the high crop load on Crawford compared to Gi5 and insufficient thinning of Crawford. These results suggest that producing large fruit is possible on the MSU rootstocks given the proper training system and crop load adjustments. The plantings established in 2015 and 2016 and to be established in 2017, will address these management systems and include a wide range of scion cultivars.
- **1.B.** Three plots were planted in 2015 to compare four MSU rootstocks (Cass, Clare, Clinton, and Lake) with the Gisela (5 and 6) and Krymsk rootstocks using intensive orchard systems with 'Regina', 'Early Robin' and 'Sweetheart' scions. The plots are in The Dalles, Mattawa, and East Wenatchee.
- **1.B.** Across all three scions and locations, in general, the MSU rootstocks Cass and Clare are the smallest trees followed by Lake and then Clinton.
- **1.C.** Crawford was not included in the 2015 plantings as it was delayed being released from the CPCNW-FT and then there was a delay in liner production. Three smaller plots comparing Crawford with the most similar rootstocks, Clinton and Gi5, are on track to be planted in spring 2017.
- **2.** The five MSU rootstocks performed well in liner and finished tree production at commercial nurseries; therefore, no nursery barriers to commercialization were identified.
- **3.** Virus certification of all five MSU rootstocks was completed by the CPCNW-FT.
- **3.** Certified budwood of all 5 MSU rootstocks was sent to nine commercial nurseries, followed by experimental production of liners and finished trees. DNA testing of the MSU rootstocks was done at critical stages in budwood transfer and liner and tree production. To date, DNA testing has verified the trueness-to-type of the stock plants at the nurseries and the trees for the 2015, 2016 and 2017 plantings.

RESULTS & DISCUSSION:

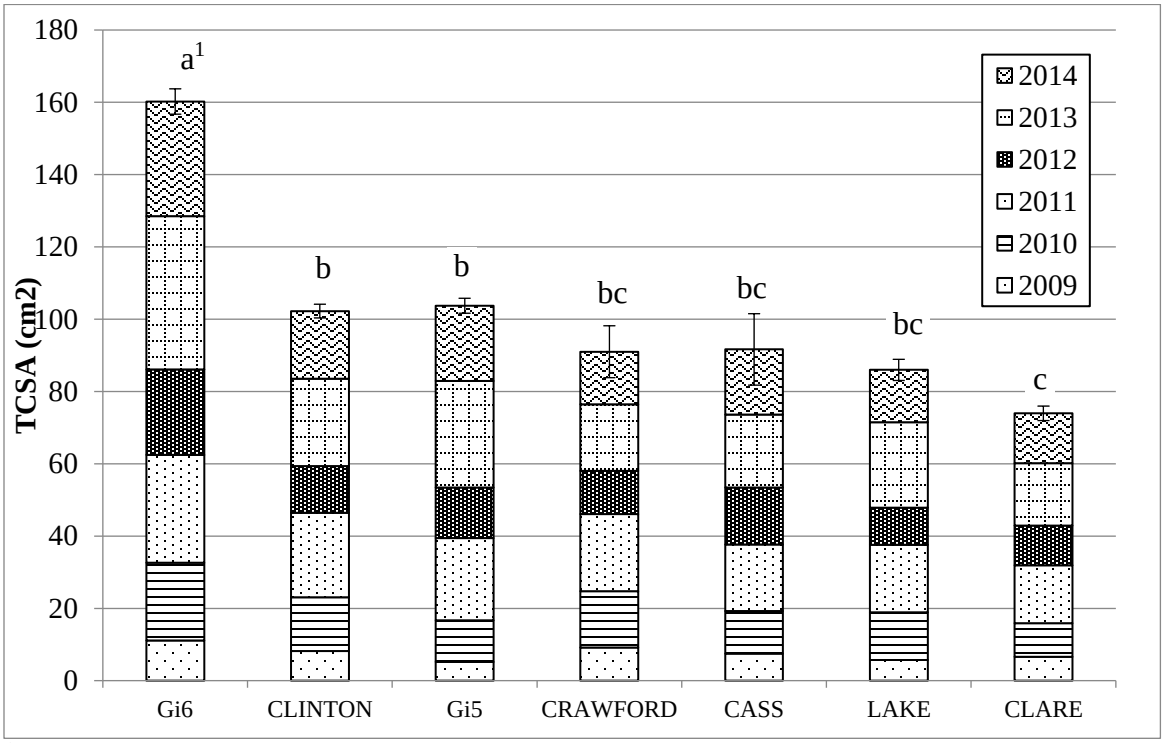
1. Compare the performance of the MSU cherry rootstocks to currently available sweet cherry rootstocks using intensive cherry production systems.

A. 2009 planting of 'Bing' on MSU cherry rootstocks (removed after the 2014 season)

This plot at WSU-Prosser Roza Station compared all 5 MSU cherry rootstocks and Gi5 and Gi6. It was planted in 2009 and removed after the 2014 season. Trees were spaced at 8 ft × 15 ft in five-tree replicates and trained to a multiple leader architecture.

All five MSU rootstocks produced 'Bing' trees significantly smaller than Gi6 but similar size to Gi5 measured as trunk cross-sectional area (TCSA), except Clare which produced trees significantly smaller than Gi5 (Fig. 1). In 2014, 'Bing' fruit harvest date differed among the seven rootstocks tested at the Prosser plot with Cass, Clare and Lake, ripening ahead of Clinton, Crawford, Gi5 and Gi6 (Table 1). The four day spread in harvest dates would likely have been more pronounced in a cooler June as the temperatures at Prosser were an average of 5 F above normal and June 19 had a maximum temperature of 85.7 F. In 2014, all five of the MSU candidate rootstocks had yield efficiencies (kg fruit/cm^2) that were higher than that of Gi5 and Gi6. However, fruit size for Crawford was significantly less than that for Gi5. This was due to the high crop load on Crawford compared to Gi5, where fruit thinning was not sufficient. These results suggest that producing large fruit is possible on the MSU rootstocks given the appropriate intensive training systems and crop load adjustments required for these dwarf precocious rootstocks. A series of additional plantings (Obj. 1B and 1C) were designed to address these management systems.

Fig. 1. Trunk cross-sectional area (TCSA; cm^2) of 'Bing' trees grafted on 5 MSU rootstocks, Gi5, and Gi6 for trees planted in 2009 at the WSU-Prosser. Boxes represent growth over one season. TCSA measurements in 2014 were taken on June 16. Bars represent standard error of the means for 2014 TCSA.



[1]Means that are significantly different for 2014 TCSA ($P < 0.05$) are denoted by different letters.

Table 1. Year 2014 average tree yield, yield efficiency, fruit weight and mean row size, for 'Bing' grown on five MSU rootstocks[1].

Rootstock selection	Harvest date (June)	Average Tree Yield (lb)	Average Tree Yield (kg)	Yield efficiency (kg/cm^2)	Fruit weight (g)	Mean row size
Gi5	20th	23.4 b	10.7 b	0.10 c	10.4 a	10.0 b
Gi6	20th	26.2 ab	11.9 ab	0.07 c	10.3 ab	10.3 ab
CASS	16th	32.7 ab	14.9 ab	0.16 ab	8.9 ab	10.6 ab
CLARE	16th	25.1 ab	11.4 ab	0.16 ab	9.3 ab	10.5 ab
CLINTON	20th	28.8 ab	13.1 ab	0.13 bc	9.8 ab	10.5 ab
CRAWFORD	20th	33.2 a	15.1 a	0.17 a	8.7 b	10.9 a
LAKE	16th	23.9 ab	10.9 ab	0.13 abc	9.2 ab	10.6 ab

[1]Means that are significantly different ($P < 0.05$) are denoted by different letters.

B. 2015 planting of 3 replicated rootstock trials each containing 4 MSU cherry rootstocks and appropriate check rootstock cultivars with scion cultivars 'Early Robin', 'Regina', and 'Sweetheart'.

Plot descriptions: For the 2015 planting, Cass, Clare, Clinton and Lake liners were budded with three scions: 'Early Robin', 'Regina' and 'Sweetheart' at Willow Drive Nursery, Cameron Nursery and Willow Drive Nursery, respectively, along with Gisela and Krymsk rootstocks as controls (Table 2). The plots were planted in The Dalles (hosted by Tim Dahle), Mattawa (hosted by Wash. Fruit and Produce), and East Wenatchee (hosted by McDougall & Sons) using a range of tree spacings and training systems (Table 2). Of the 22 scion/rootstock combinations needed for the 2015 planting, only the combination 'Regina'/Cass was not included at one site (East Wenatchee) due to low tree numbers.

Table 2. Summary of rootstock plantings made in spring 2015 at three locations: The Dalles (TD), Ore., Mattawa (MA) & East Wenatchee (EW), Wash.

Scion cultivars	Regina, Early Robin, Sweetheart
MSU rootstocks	Cass[a], Clare, Clinton and Lake
Control rootstocks	Gi5, Gi6, Krymsk 6 (Sweetheart), Krymsk 5 (Regina, Early Robin)
Pollinators	Chelan (Early Robin), Sam (Regina)
Replication	20 trees per each scion/rootstock combination (four 5 tree replications)
Training system: TD	Sweetheart and Early Robin trees were headed to establish a bush system. Regina trees were trained to a steep leader system.
Training system: MA	Two narrow rows on a 4 wire Angle canopy trellis
Training system: EW	Super Slender Axe, 2 very narrow rows on 4 wire angle canopy trellis[b]
Within row spacing: TD	8 ft
Within row spacing: MA	3 ft (Gi6), 2.5 ft (K5, K6, Clinton), 2ft (Cass, Lake, Clare)
Within row spacing: EW	4 ft (Gi6, K5, K6, Clinton), 2 ft (Cass, Lake, Clare)

[a]'Regina'/Cass was not included at East Wenatchee due to insufficient tree numbers.

[b]Wires 2.3 (0.7m) apart vertically

Tree survival: On average the tree sizes on the MSU rootstocks at planting were smaller than that for trees on the Krymsk and Gisela rootstocks (Figs. 2, 3, and 4). The reduced size was especially pronounced for the 'Regina' trees. Overall, the poorest year 1 survival was for trees on Cass followed by Clinton suggesting that these trees are slower in recovering from transplant stress (data not presented). Additional trees of 'Regina' on Cass have been propagated for 2017 planting allowing a second evaluation for this combination, as the trees planted in 2015 were very small (mean TCSA of 0.7 cm^2) compared to trees on the other rootstocks and there were insufficient trees for the East Wenatchee planting. No trees died in 2016.

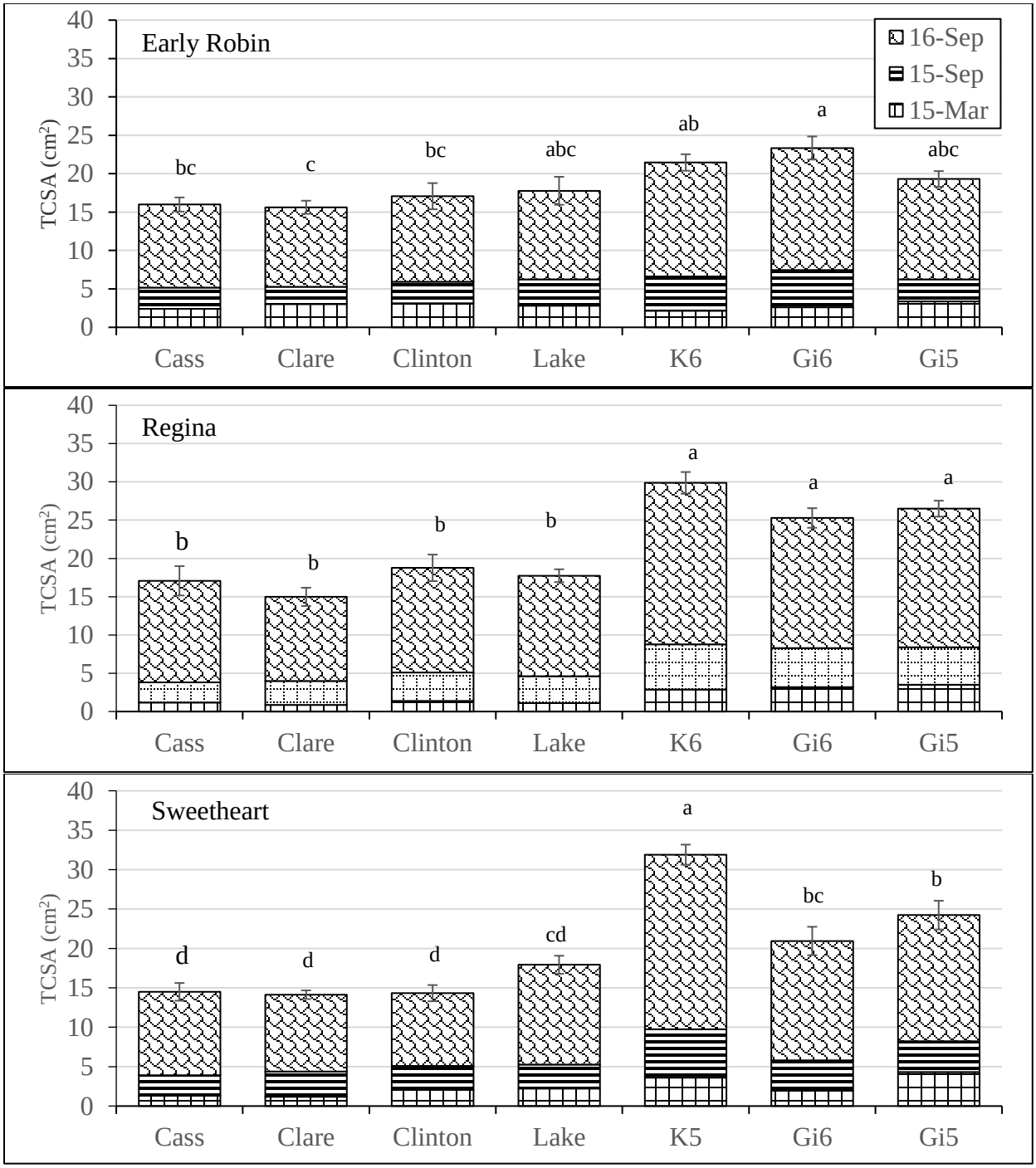
Tree growth: For the planting at The Dalles, the 'Regina' and 'Sweetheart' trees on the four MSU rootstocks (Cass, Clare, Lake and Clinton) were in general significantly smaller (measured as TCSA, cm^2) than the trees on the Krymsk and Gisela rootstocks (Fig. 2). A similar trend was apparent for 'Early Robin'; however, the differences were not as significant as in general 'Early Robin' on K6, Gi5 and Gi6 were smaller than 'Regina' and 'Sweetheart' on these rootstocks (Fig. 2). The TCSAs for 'Regina' and 'Sweetheart' on K6 and K5, respectively, were on average about two times larger than for trees on Cass and Clare. This result is consistent with K5 and K6 being vigorous rootstocks compared to the other rootstocks.

The relative sizes for the trees at East Wenatchee were similar to those at The Dalles, except for Clinton (Fig. 3). Three of the MSU rootstocks (Cass, Clare and Lake) had tree sizes significantly less than trees on the Krymsk or Gisela rootstocks, although trees on Lake tended to be larger than trees on Cass or Clare. The size reductions for 'Early Robin' and 'Sweetheart' on Clinton were not significant compared to the Gisela rootstocks, indicating that at this site, Clinton is a more vigorous rootstock than the other three MSU rootstocks. Similar to The Dalles, the combination of 'Sweetheart'/K5 was especially vigorous.

At the Mattawa planting, the results varied by scion (Fig. 4). For 'Regina' and 'Sweetheart' the four MSU rootstocks were significantly smaller than the trees on the Krymsk or Gisela rootstocks, with the smallest trees on Cass. For 'Early Robin', trees on Lake were not significantly smaller than trees on K6, Gi6 or Gi5. Gi6 and Clinton, showed more heat and sandy soil stress than K5, K6, Lake and Clare.

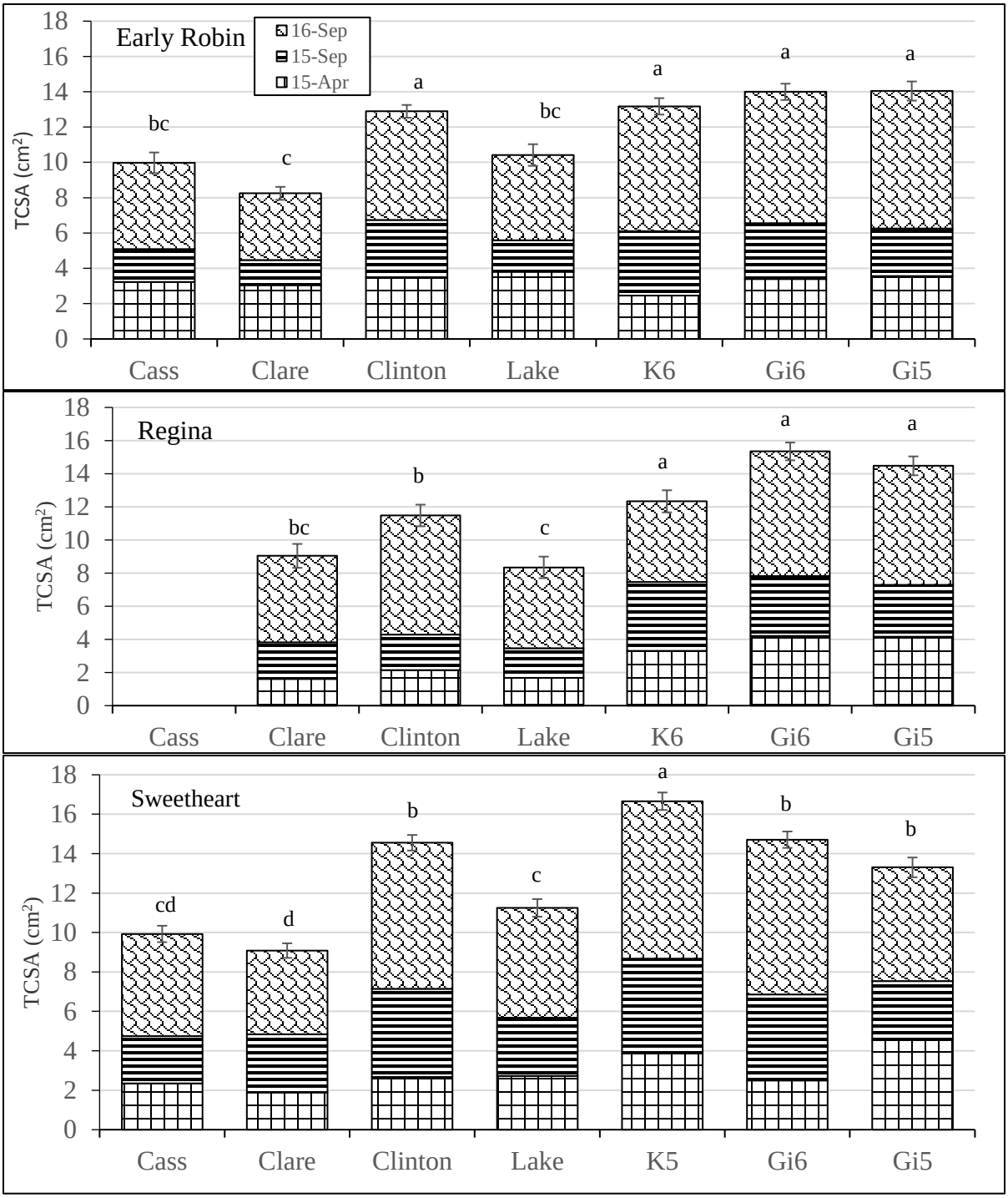
In summary, on average across all three scions and locations, the trees on the four MSU rootstocks were significantly smaller than those on the Gisela or Krymsk rootstocks. Among the MSU rootstocks, Cass and Clare produced the smallest trees followed by Lake and Clinton. The relatively larger TCSA for Lake at the sandy Mattawa location relative to the other MSU rootstocks agrees with results from Michigan that suggest that Lake may be more tolerant to sandy soils than Clinton. The poorest tree survival of trees on Cass and Clinton suggests that these trees may be slower in recovering from transplant stress. Additional trees of 'Regina' on Cass have been ordered for 2017 planting allowing a second evaluation for this combination which is under represented in the 2015 plantings.

Fig. 2. Trunk cross-sectional area[1] (TCSA; cm^2) of 'Early Robin', 'Regina', and 'Sweetheart' trees grafted on 4 MSU rootstocks, Krymsk 5, Krymsk 6, Gi6, and Gi5 for trees planted in 2015 in The Dalles, OR. Measurements were obtained in Mar. and Sept., 2015 and in Sept., 2016.



[1]The lower boxes represent TCSA at planting and the two upper boxes represent growth in 2015 and 2016. Bars represent standard error of the means for September TCSA.
[2]Means that are significantly different for September 2016 TCSA ($P < 0.05$) are denoted by different letters.

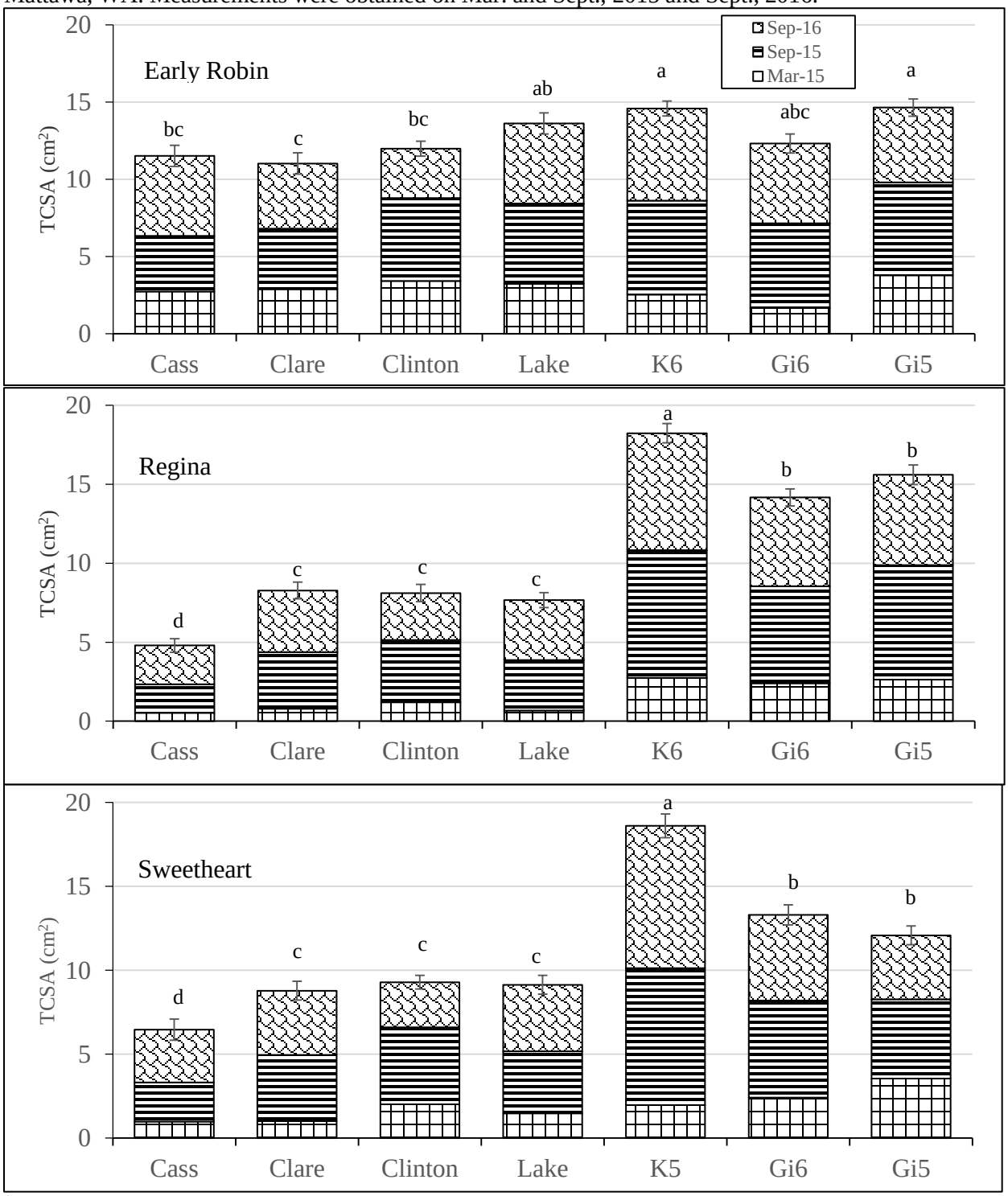
Fig. 3. Trunk cross-sectional area[1] (TCSA; cm^2) of 'Early Robin', 'Regina', and 'Sweetheart' trees grafted on 4 MSU rootstocks, Krymsk 5, Krymsk 6, Gi6, and Gi5 for trees planted in 2015 in East Wenatchee, WA. Measurements were obtained on April and Sept., 2015 and in Sept., 2016.



[1]The lower boxes represent TCSA at planting and the two upper boxes represent growth in 2015 and 2016. Bars represent standard error of the means for September TCSA.

[2]Means that are significantly different for September 2016 TCSA ($P < 0.05$) are denoted by different letters.

Fig. 4. Trunk cross-sectional area[1] (TCSA; cm^2) of 'Early Robin', 'Regina', and 'Sweetheart' trees grafted on 4 MSU rootstocks, Krymsk 5, Krymsk 6, Gi6, and Gi5 for trees planted in 2015 in Mattawa, WA. Measurements were obtained on Mar. and Sept., 2015 and Sept., 2016.



[1]The lower boxes represent TCSA at planting and the two upper boxes represent growth in 2015 and 2016. Bars represent standard error of the means for September TCSA.

[2]Means that are significantly different for September 2016 TCSA ($P < 0.05$) are denoted by different letters.

C. 2016 planting of three small replicated rootstock trials alongside the 2015 trials to evaluate the 5th MSU cherry rootstock (Crawford).

'Regina' and 'Sweetheart' trees grafted onto the MSU cherry rootstocks Crawford and Clinton, plus the control Gi5, along with 'Regina' grafted on Cass, will be dug at ProTree Nursery in fall 2016 for shipping spring 2017. DNA tests of rootstock liners sampled determined that the liners were labeled correctly (Obj. 3). It was initially anticipated that the trees would be budded in 2015 and planted in the test orchards in 2016. However, a delay in liner production pushed back the planting until spring 2017. The delay allowed the addition of 'Regina'/Cass, which is under-represented in the 2017 plantings. Two of the plots will be planted next to the 2015 plantings [The Dalles (hosted by Tim Dahle) and East Wenatchee (hosted by McDougall & Sons)] while the Mattawa plot will be hosted by Zirkle Fruit Co. due to lack of space next to the current Mattawa plot.

2. Collaborate with commercial nurseries in liner and finished tree production to determine the nursery performance of the MSU cherry rootstocks.

Distribution of rootstock budwood for pilot propagation trials and limited liner production: Nine commercial nurseries have all five MSU cherry rootstocks that originated from virus certified materials from the CPCNW-FT. These nurseries are gaining experience propagating these rootstocks. To date, liner production appears to be most efficient using tissue culture, while techniques to propagate from softwood cuttings are in development as an alternative to tissue culture. Since the rootstock materials established at the nurseries originated from virus certified and genetically verified plant material, liners from these plant materials could be commercialized if a decision is made to release one or more of the MSU cherry rootstocks.

Finished tree nursery performance: Liners of four of the MSU rootstocks (Cass, Clare, Clinton and Lake) were planted at three Washington nurseries in spring 2013. Because of the late delivery/planting time, only liners at one nursery were of sufficient size to bud in fall 2013. The other two nurseries budded in spring 2014. The scions used were those for the 2015 plantings: 'Regina', 'Early Robin' and 'Sweetheart'. Once the liners were established, they all had acceptable nursery characteristics, including sufficient apical dominance and minimal branching. For those liners that were of sufficient size to bud, the bud take was over 90% for all four MSU rootstocks across all three scion cultivars.

In addition, 600 liners of four of the MSU rootstocks (150 each - Cass, Clare, Clinton and Lake) were planted at one Washington nursery in spring 2014 to provide additional information on the performance of these rootstocks in a finished tree nursery. Budding with 'Skeena' was done in spring 2015. As in prior experience, the bud take was excellent. The bud take percentages for the four rootstocks were as follows: Lake 95%, Clare 93%, Clinton 96% and Cass 96%. In 2016, liners of all 5 MSU rootstocks, including Crawford, were planted at ProTree Nursery at their Davis, Calif. location for spring budding. As with the other nursery plot observations, no barriers to nursery performance were identified for any of the five MSU rootstocks.

3. Collaborate with the CPCNW-FT and cooperating nurseries to insure MSU cherry rootstocks are available as certified virus tested and genetically verified.

Virus certification: The virus certification of Crawford was completed at the CNCNW-FT and in 2015 budwood was sent to nursery collaborators who had not previously received this selection. All five MSU rootstocks are virus certified and plants are being maintained at the CPCNW-FT.

Genetic verification: The goal of this sub-objective is to assure that the genetic identities of the five MSU rootstocks are correct at key points in propagation and distribution. A DNA test, involving two

DNA markers, has been developed that distinguishes among all five MSU rootstocks along with Gi3, Gi5 and Gi6. This DNA test that was developed at MSU was verified by four other laboratories including two commercial service providers.

The MSU rootstocks that were used to make the trees for the 2015 and 2017 plantings were subjected to DNA testing by the MSU lab to confirm rootstock identify. These DNA diagnostic tests have confirmed that the MSU cherry rootstocks are labeled correctly. All the participating nurseries have been informed that MSU will perform DNA diagnostics on the MSU rootstocks at no cost to the nursery if there are any identity concerns. The goal of this strategy is to avoid any delays and financial losses at the nurseries that would be associated with a plant material mix-up.

EXECUTIVE SUMMARY

Project Title: Establishment and testing of MSU sweet cherry rootstocks

Five MSU sweet cherry rootstocks were identified that induce precocious abundant flowering and significantly reduce tree size compared to Gi6. This result was based on a trial at WSU-Prosser with 'Bing' scion planted in 2009 and removed after the 2014 season. All five MSU rootstocks named after Michigan counties (Cass, Clare, Clinton, Crawford and Lake) produced trees of similar size to Gi5 or smaller. In 2014, 'Bing' fruit maturity date differed among the rootstocks tested at the Prosser plot with Cass, Clare and Lake ripening ahead of Clinton, Crawford, Gi5 and Gi6. Also in 2014, all five of the MSU candidate rootstocks had yield efficiencies (kg fruit/cm^2) that were higher than that of Gi5 and Gi6. However, the fruit size for Crawford was significantly less than that for Gi5 due to the high crop load on Crawford compared to Gi5 and insufficient thinning of Crawford. These results suggest that producing large fruit is possible on the MSU rootstocks given the proper training system and crop load adjustments.

Despite the potential of the MSU dwarfing cherry rootstocks to contribute to profitability due to precocious fruiting, and a reduced cost of harvest labor, critical performance-related questions have not yet been answered. These include performance with scions with different cropping potential, and suitability with different training systems, soils and growing conditions. All the fruit data for the MSU rootstocks from the Pacific Northwest is from one plot at WSU-Prosser with 'Bing' scion trained to a multiple leader architecture. Therefore plantings were established in 2015 and will be established in 2017 (see new proposal) to include a wider range of scions and management systems.

The 2015 plantings were established at three locations (The Dalles, Mattawa, and East Wenatchee), with four MSU rootstocks (Cass, Clare, Clinton, and Lake) plus Gisela and Krymsk controls, and three scion cultivars ('Regina', 'Early Robin' and 'Sweetheart'). In general, across all three scions and 2015 planting locations, the MSU rootstocks Cass and Clare resulted in the smallest trees followed by Lake and then Clinton. The first fruit data will be obtained in 2017 (see new proposal). Crawford was not included in the 2015 plantings as it was delayed being released from the CPCNW-FT and then there was a delay in liner production. Three smaller plots comparing Crawford in comparison with the most similar rootstocks, Clinton and Gi5, are on track to be planted in spring 2017 along with several other producer-led plantings. Collectively these plantings are designed to provide the information needed for producers to decide whether to plant trees on any of the new MSU cherry rootstocks.

In anticipation of commercializing one or more of the MSU cherry rootstocks, progress was made to enable an ample future supply of virus-certified and genetically verified plant materials. Virus certification of all five MSU rootstocks was completed by the CPCNW-FT. Certified budwood of these five roots was sent to nine commercial nurseries followed by experimental production of liners and finished trees. The five MSU rootstocks performed well in liner and finished tree production at commercial nurseries; therefore, no nursery barriers to commercialization were identified. DNA testing of the MSU rootstocks was done at critical stages in budwood transfer and liner and tree production. To date, DNA testing has verified the trueness-to-type of the stock plants at the nurseries and the trees for the past and future plantings.