State: Colorado

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1. **Impact Nugget:** The performance results of the various peach rootstocks tested under NC-140 have a significant impact on Colorado orchard productivity and grower profitability. Krymsk®86 an prunus hybrid rootstock that was tested the 2009 Peach Rootstock Evaluation Trial is dominating the new planting selections due to the findings of our studies regarding productivity, tree vigor, cold hardiness and fruit overall quality that were communicated to the CO industry through various means of outreach activities.

2. **New Facilities and Equipment:** Two new buildings were built in 2019 in the newly named Western Campus of Colorado State University. This construction took place in the original location of Western Colorado Research Center at Orchard Mesa were all NC-140 rootstock trials are planted in the State of Colorado. This $10+ million investment of the State of Colorado and the Colorado State University create tremendous potential for programs expansion and high-quality stakeholder engagement activities. This new facility is going to host the members of NC-140 in the 2020 Technical Committee Annual meeting in November 4-6. A new fertigation system with pH regulation for optimum nutrition management was installed in the experimental orchard of WCRC-OM during the growing season of 2019. This system has capacity to cover all NC-140 rootstock trials.

3. **Unique Project-Related Findings:** *Prunus* hybrid rootstocks released for peach and might be suitable for replant were field screened for up to 9 years in CO. New *Prunus* hybrid rootstocks exhibited increased productivity in the poor, alkaline and calcareous western Colorado soils compared to the industry's standard, Lovell. However, early acclimation and extensive vigor should be seriously considered prior planting in CO conditions. *Prunus* hybrids might have higher risk for cold damage early in the dormant season or higher risk for *Cytospora* sp. infections due to the subsequent more intensive pruning management required in more

vigorous trees. Among all successful *Prunus* hybrids tested in our trials Krymsk®86 provides a real alternative to the vigor of Lovell with improved mid-winter hardiness and high fruit quality.

4. Accomplishments Related to Each of the 4 Objectives:

Objective 1. To evaluate the influence of rootstocks on temperate-zone fruit tree characteristics grown under varying environments and training systems using sustainable management practices.

2009 'Red Haven' Peach Rootstock Evaluation Trial (cooperator)

There were significant differences in tree size and yields among the rootstocks tested in this trial that have been reported in our previous annual reports. *Prunus* hybrids rootstocks (Atlas, Viking and Bright's Hybrid-5) were the most productive in CO high soil pH conditions when compared to the peach seedling rootstocks. Among peach seedling rootstock cultivars 'Guardian' was the most productive. Non-destructive models were developed to estimate dry matter content (DMC) soluble solids concentration (SSC) and index of absorbance difference (I_{AD}) for 'Red Heaven' peaches and was used to measure the effect of the rootstock in peach fruit internal quality. Rootstocks of variable vigor were selected from this rootstock trial were: Atlas, Bright's Hybrid-5, Guardian, Krymsk 86, Lovell, Controller 5 and Krymsk 1. Data collected non-destructively on fruit of equal maturity in three consequent years (2016, 2017 and 2018) show a trend of lower DMC in the larger tree sizes (Atlas, Bright's Hybrid-5, Guardian) highlighting the importance of vigor control on maximizing peach internal quality (**Figure 1**).

2017 Semi-dwarf Peach Rootstock Evaluation Trial (coordinator)

The trial was established in WCRC-OM experimental orchard in May 8th, 2017. The scion cultivar was Cresthaven and the rootstocks are Controller™6, 7 and 8 (UC Davis); Rootpac®20 (Densipac) and Rootpac®40 (Nanopac) from Agromillora Iberica (Spain); MP-29 (USDA-Georgia); Lovell and Guardian® (Clemson/USDA). Higher levels of mortality observed in MP-29 mainly due to heavy root pruning on the nursery stock prior shipment for planting. The growth of MP-29 hasn't been resumed yet on the third season. In this second year of this trial we observed severe iron chlorosis symptoms mainly in Controller™7. Following application of chelated-Fe we were able to bring these trees in some balance. Other rootstocks that seem to experience iron deficiency/chlorosis were: Controller™8 and Guardian. Largest trees were produced by Guardian and smallest from Controller™7. This year (2019) was the first time we had fruit on the trees across all rootstocks except of Controller™7. It is worthy to highlight that Controlled 6, 8 and Rootpac®20 as well as Guardian exhibited the largest increase in TCSA compared to previous years. The rapid increase of the growth of Rootpac®20 as well as the fact that is significantly more vigorous from Rootpac®40 questions the initial consideration that this rootstock might exhibit a semi-dwarf phenotype. And should be further tested. However, Rootpac®20 seems to be the most precocious with the largest fruit in CO conditions followed by Controller™6 and Guardian®. Controller™6 so far looks like one promising semi-dwarf rootstock for potential utilization in high density plantings. In **Table 2** a summary overview of the 2019 collected data is provided.

2017 Benton Sweet Cherry Training Systems and Rootstocks Evaluation Trial (cooperator)
The trial was established in WCRC-OM experimental orchard in May 2nd, 2017 and compares 3 systems (Tall Spindle Axe, TSA; Kim Green Bush, KGB; and Bi-Upright Fruiting Offshoot, Bi-UFO) using 8 rootstocks (Cass, Clare, Clinton, Gi3, Gi5, Gi12, Lake, and MxM14) with Benton as the scion. High tree mortality observed in MxM14 trained in TSA in year 1. Trunk circumference data as well as detailed extension growth and number of lateral shoots have been regularly collected per protocol instructions during these first three establishment years. Bending the cordons of Bi-UFO on MxM14 and Gi12 was really challenging due to the size of the branches of such trees. In addition, and because some of the freestanding Lake trees were bending down due wind it was suggested to the group that some support should be established on TSA trees. when comparing data from different rootstocks across all training systems MxM14 and Gi12 were the largest trees and Clare the smallest. Cass and Clinton gave trees of similar size with Gi3 and Gi5, respectively, while Lake trees stand in between those two groups size wise. Interestingly, there is a significant impact of the training system on tree size when comparing data across all rootstocks. KGB trees are significantly larger from TSA trees. In **Tables 3** and **4** an overview of the 2019 collected data is provided.

2015 'Modi' Apple Organic Rootstock Evaluation Trial (cooperator)
In 2019 which is the 5th year after orchard establishment. Yields remaining low and not economically acceptable. Improvement of nitrogen management is required. Trees were most vigorous on G.890 and G.222 and least vigorous on G.16, and G.41 when considering TSCA and canopy volume (tree height and canopy width) (**Table 5**).

2019 'Buckeye Gala' Apple Rootstock Evaluation Trial (cooperator)
In May 3rd, 2019, the new 2019 'Buckeye Gala' Apple Rootstock Evaluation Trial was established in 2 sites in CO. One site that will be managed conventionally (WCRC-OM) and one that is going to be managed under organic production system. This was the establishment year for both trials, however, the conventionally managed block in WCRC-OM exhibited significantly higher vigor compared to the organically managed block in WCRC-OARS. At the end of this first season the most vigorous trees in WCRC-OM and WCRC-OARS were G.41 and G.969, respectively. The smallest trees in both sites came from G.11 and G.4814 (**Tables 6 and 7**).

Objective 4. To investigate physiological processes, biotic and abiotic stresses and scion/rootstock interactions on tree growth and productivity.

2009 'Red Haven' Peach Rootstock Evaluation Trial (cooperator)
During the fall/winter seasons of 2017/18 and 2018/19 we performed an extensive cold hardiness analysis across 6 selected rootstocks form this trial using differential thermal analysis (DTA). DTA is a technique used to quantify cold tolerance in plants. When super cooled water freezes intracellularly creates a low-temperature exotherm (LTE) which represent the is lethal freezing event of the floral primordia tissues and the ovary. DTA is regularly used by our group to measure cold hardiness in reference cultivars to report reliable and accurate date to our CO tree fruit industry (**Figure 2**). DTA analysis performed on Red Haven bud samples coming from Atlas, Bright's Hybrid-5, Guardian®, Krymsk®86, Lovell, Controller™5 and Krymsk®1

at seven time points the fall/winter season of 2017/18 (see 2018 report) and 2018/2019 (see addendum **Table 8**).
DTA data in both dormant seasons revealed that *Prunus* hybrids acclimate later in fall compared to peach seedling rootstock cultivars (Guardian® and Lovell) which are acclimating earlier and are cold hardy. However, among *Prunus* hybrids them Krymsk®86 exhibited maximum mid-winter hardiness and delayed deacclimation in late winter. It is worthy to highlight that during a period of 10 days between December 26th, 2018 and January 6th, 2019 the temperature remained below freezing for the whole time and daily lows were close to -9 to -17°C (**Figure 2**). This caused a dramatic acclimation in 'Red Haven' peach floral buds across all rootstocks tested. However, Red Haven' peach floral buds coming from trees on Guardian® and Krymsk®86 rootstocks exhibited incredible hardiness with LT_{50} of -26.3°C.

Objective 5. To integrate and disseminate research-based information that facilitates successful stakeholder adoption of rootstock technologies
Reports and presentations on peach, apple and cherry NC140 rootstock trials are regularly posted on CSU Pomology web page (http://minas.agsci.colostate.edu). In addition, an annual CSU Pomology Field Day was established for first time in WCRC-OM in May 18, 2017 and was repeated in June 2018. Attending tree fruit growers and extension personnel (50 people) were updated on the most recent information from the NC140 rootstock trials established in the CO site. In 2019 the CSU Pomology Field Day was not organized because of the construction of the new facilities that was going on from summer 2018 through summer 2019. A workshop 'Pruning & Training: Peaches & Cherries under different training systems' for growers was organized in January 15, 2019 (40 attendees) with filed demonstrations and rootstock trials tours. During the 2018/2019 fall/winter/spring season CO tree fruit growers received ~25 updates of peach cold hardiness through the CSU Pomology web page (http://minas.agsci.colostate.edu).

5. Impact Statements

Colorado peach growers through the different means of outreach and extension are informed on the most recent findings of the NC-140 rootstock trials in WCRC-OM to support their decisions on proper rootstock selection for CO growing conditions.

6. Published Written Works:

Li K, Mr DiLegge M, **Minas IS**, Hamm A, Manter D, Vivanco J. 2020. Soil sterilization leads to re-colonization of a healthier rhizosphere microbiome. *Rhizosphere in press.*

Reighard GL, Bridges WJr, Archbold D., Atucha A, Autio W, Beckman T, Black B, Chavez DJ, Coneva E, Day K, Francescatto P, Kushad M, Johnson RS, Lindstrom T, Lordan Sanahuja J, **Minas IS**, Ouellette D, Parker M, Pokharel R, Robinson T, Schupp J, Warmund M. Wolfe D. 2020. Nine-Year Rootstock Performance of the NC-140 'Redhaven' Peach Trial across 13 States. *Journal of the American Pomological Society, in press.*

Miller ST, Otto KL, Sterle D, **Minas IS**, Stewart JE. 2019. Preventive Fungicidal Control of *Cytospora leucostoma* in Peach Orchards in Colorado. *Plant Disease* 103, 1138-1147. *https://apsjournals.apsnet.org/doi/abs/10.1094/PDIS-05-18-0801-RE*

Karagiannis E, Michailidis M, Karamanoli K, Lazaridou A, **Minas IS**, Molassiotis A. 2018. Postharvest cold responses of sweet cherry fruit and stem tissues revealed by metabolomic profiling. *Plant Physiology and Biochemistry* 127, 478-484. https://www.sciencedirect.com/science/article/abs/pii/S0981942818301876

Minas IS*, Tanou G, Molassiotis A. 2018. Environmental and orchard bases of peach fruit quality. *Invited Review article for the Special Issue: Quality and Safety of Fresh Fruits and Vegetables*. *Scientia Horticulturae*, 325, 307-322. https://www.sciencedirect.com/science/article/pii/S0304423818300323

Karagiannis, E., Tanou, G., Samiotaki, M., Michailidis, M., Diamantidis, G., Minas, I., Molassiotis, A. (2016). Comparative Physiological and Proteomic Analysis Reveal Distinct Regulation of Peach Skin Quality Traits by Altitude. *Frontiers in plant science* **2016***, 7*, 1689. https://www.frontiersin.org/articles/10.3389/fpls.2016.01689/full

Autio, W, Robinson, T, Black, B, Blatt, S, Cochran, D, Cowgill, W, Lang, G, **Minas, IS**, Hampson, C, Hoover, E, Miller, D, Parra Quezada, R, Stasiak, M. Budagovsky, Geneva, Pillnitz, and Malling apple rootstocks affect 'Honeycrisp' performance over the first five years of the 2010 NC-140 Honeycrisp Apple Rootstock Trial. *Journal of American Pomological Society* **2017**, 71, 149-166. http://www.pubhort.org/aps/71/v71_n3_a3.htm

Tanou G, **Minas IS**, Scossa F, Belghazi M, Xanthopoulou A, Ganopoulos I, Madesis P, Fernie A, Molassiotis A. Exploring priming responses involved in peach fruit acclimation to cold stress. *Scientific Reports* **2017**, 7, 11358. https://www.nature.com/articles/s41598-017-11933-3

Extension fact sheets:

Stewart, J.E., Miller, S.T., **Minas, I.S.** 2018. Preventive Control for Cytospora Canker on Peach. Colorado State University Extension, Crop Series, Diseases, Fact Sheet No. 2.954.

7. Scientific and Outreach Oral Presentations:

Minas, I.S. 2019. The peach industry in USA: challenges & opportunities. Keynote Speaker, International Peach Conference, Freskon 2019, April 11th, 2019, Thessaloniki, Greece.

Minas, I.S. 2019. Peach Cold Hardiness & Rootstock Research Update. Invited Speaker, 2019 Michigan Spring Peach Meeting, Michigan Peach Sponsors & Michigan Horticultural Society, March 5, 2019, SW Michigan Research and Extension Center, Benton Harbor, MI.

Minas, I.S. 2019. Environmental bases for cold hardiness & damage in peach. Invited Speaker, Indiana Horticultural Congress & Trade Show, Departments of Horticulture and Landscape Architecture, Purdue University & Purdue Cooperative Extension Service, February 14th, 2019, Indianapolis, IN.

Minas, I.S. 2019. Pre- & postharvest factors affecting peach fruit quality. Invited Speaker, Indiana Horticultural Congress & Trade Show, Departments of Horticulture and Landscape Architecture, Purdue University & Purdue Cooperative Extension Service, February 14th, 2019, Indianapolis, IN.

Minas, I.S. 2019. Environmental Bases for Cold Hardiness and Damage in Peach. Invited Speaker, Western Colorado Horticultural Society 2019 Annual Meeting, Western Colorado Horticultural Society, January 16, 2019, Grand Junction, CO.

Minas, I.S. 2019. CSU Pomology Research Program Update. Invited Speaker, Western Colorado Horticultural Society 2019 Annual Meeting, Western Colorado Horticultural Society, January 17, 2019, Grand Junction, CO.

Minas I.S. 2018. Peach Cold Hardiness & Damage. Invited Speaker, Great Lakes EXPO 2018, December 2018, Grand Rapids, MI,

Minas I.S. 2018. Pre- & Postharvest Factors Affecting Quality of Peach and Plum. Invited Speaker, Great Lakes EXPO 2018, December 2018, Grand Rapids, MI,

Minas, I.S. 2018. Cytospora Canker Research & Management Practices. 2018 Utah Fruit School for Commercial and Hobbyist Producers, Utah State University Extension. Spanish Fork, Fairgrounds, November 29, 2018, Spanish Fork, UT

Minas, I.S. 2018. Managing Cold Hardiness in Peach. 2018 Utah Fruit School for Commercial and Hobbyist Producers, Utah State University Extension. Spanish Fork, Fairgrounds, November 29, 2018, Spanish Fork, UT

Minas, I.S. 2018. Pre- & Postharvest Factors Affecting Quality of Peach. 2018 Utah Fruit School for Commercial and Hobbyist Producers, Utah State University Extension. Spanish Fork, Fairgrounds, November 29, 2018, Spanish Fork, UT

Minas, I.S. 2018. Understanding the environmental bases for cold hardiness and damage in peach. Invited Speaker, Idaho State Horticultural Society, Nampa, Idaho, November 2018.

Minas, I.S. 2018. Colorado Tree Fruit Research Challenges & Opportunities. Invited Speaker, Idaho State Horticultural Society, Nampa, Idaho, November 2018.

Minas I.S., Sterle D., Blanco-Cipollone F. 2018. Near infrared spectroscopy can non-destructively assess the effect of rootstock, crop load and canopy position on peach fruit

harvest maturity and internal quality. 30th International Horticultural Congress, ISHS, Istanbul, Turkey, August 2018.

Minas I.S., Sterle D. 2018. Differential thermal analysis sheds light on the effect of environment, cultivar, rootstock, and crop load in peach floral buds early acclimation and maximum cold hardiness. 30th International Horticultural Congress, ISHS, Istanbul, Turkey, August 2018.

Minas, I.S. NC-140 Peach & Apple Rootstock Trials Update. 2018 CSU Pomology Field Day, WCRC-OM, Grand Junction, CO, May 2017.

Minas, I.S. 2018. Orchard Bases of Peach Fruit Quality, Oral presentation at Western Colorado Horticultural Society 2017 Annual Meeting, Western Colorado Horticultural Society, January 19, 2017, Grand Junction, CO.

Minas, I.S. 2017. CSU Pomology Research Program Update, Oral presentation at Western Colorado Horticultural Society 2017 Annual Meeting, Western Colorado Horticultural Society, January 19, 2017, Grand Junction, CO.

Minas I.S., Sterle D., Caspari H. 2017. Understanding the environmental bases for cold hardiness and cold damage in peach floral buds using differential thermal analysis. Oral presentation at 9th International Peach Symposium, July 2-6, Bucharest, Romania.

Minas I.S., Blanco-Cipollone F. 2017. Non-destructive assessment of the effect of crop load and canopy position on peach fruit harvest maturity and internal quality using near infrared spectroscopy. Oral presentation at 9th International Peach Symposium, July 2-6, Bucharest, Romania.

Miller S.T., Otto K., Sterle D., Minas I.S., Stewart J.E. 2017. Developing strategies for managing Cytospora canker in peach orchards in Colorado. Poster presentation at 9th International Peach Symposium, July 2-6, Bucharest, Romania.

Minas, I.S, Sterle, D., Caspari, H. 2017. Differential thermal analysis to understanding the environmental bases for cold hardiness and cold damage in peach floral buds. Oral presentation at 2017 American Society for Horticultural Science (ASHS) Annual Conference, September 19-22, 2017, Waikoloa, Hawaii.

Minas, I.S. 2017. CSU Pomology Research Program Update, Oral presentation at Western Colorado Horticultural Society 2017 Annual Meeting, Western Colorado Horticultural Society, January 19, 2017, Grand Junction, CO.

Minas, I.S. NC-140 Peach & Apple Rootstock Trials Update. 2017 CSU Pomology Field Day, May 18, 2017, WCRC-OM, Grand Junction, CO.

Minas, I.S, Sterle, D., Caspari, H. 2017. *Cold hardiness assessment of peach flower buds using differential thermal analysis (DTA) in western Colorado (dormant season 2016 - 17)*. CSU

Pomology web page. https://minas.agsci.colostate.edu/files/2017/03/Peach-fruit-bud-cold-hardiness-update24-3_13_17.pdf

8. Fund Leveraging:

Minas, I., Grant, "Establishment of a Tree Fruit Physiology and Quality Program at Western Colorado", Western Colorado Horticultural Society, $10,000.00, Active. (start: October 1, 2016).

Minas, I., Grant, "WCRC Pomology", Colorado Apple Administrators Commission, Other, $7,414.50, Active. (start: September 5, 2016).

Jayanty, S. S., Minas, I., Bartolo, M. E., Grant, "Postharvest handling strategies for Colorado specialty crops to increase marketability and improve consumer quality", Agricultural Experiment Station, Colorado State University, $26,065.00, Active. (sub: May 12, 2016, start: September 29, 2016, end: June 30, 2018).

Stewart, J. E. (PI), Minas, I. (CoPI), Grant, "Cytospora management in peach orchards through cultural practices, cultivar selection, and stress mitigation", Specialty Block Grants, Colorado Department of Agriculture (CDA) (2017): $91,218 (awarded: May, 2017, start: Feb 1, 2018, end: November 1, 2019).

W. Autio et al. 2018. NC140 Rootstock Research Trial Coordination. International Fruit Tree Association. $12,000 (Peach $2,000).

Minas, I. (PI), Grant, 'Management strategies to maximize Colorado peach orchards productivity and fruit quality potential' Specialty Block Grants, Colorado Department of Agriculture (CDA) (2019): $53,548 (PI). awarded: May, 2019, start: Jan 1, 2020, end: November 1, 2021).

Addendum

Figure 1. Validation data of the non-destructive models created to estimate internal fruit quality of 'Red Haven' peaches (A). Effect of rootstock on 'Red Haven' peach internal fruit quality estimated as dry matter content (DMC) in 2016, 2017 and 2018. Rootstocks are presented from left (large) to right (dwarf) based on tree size.

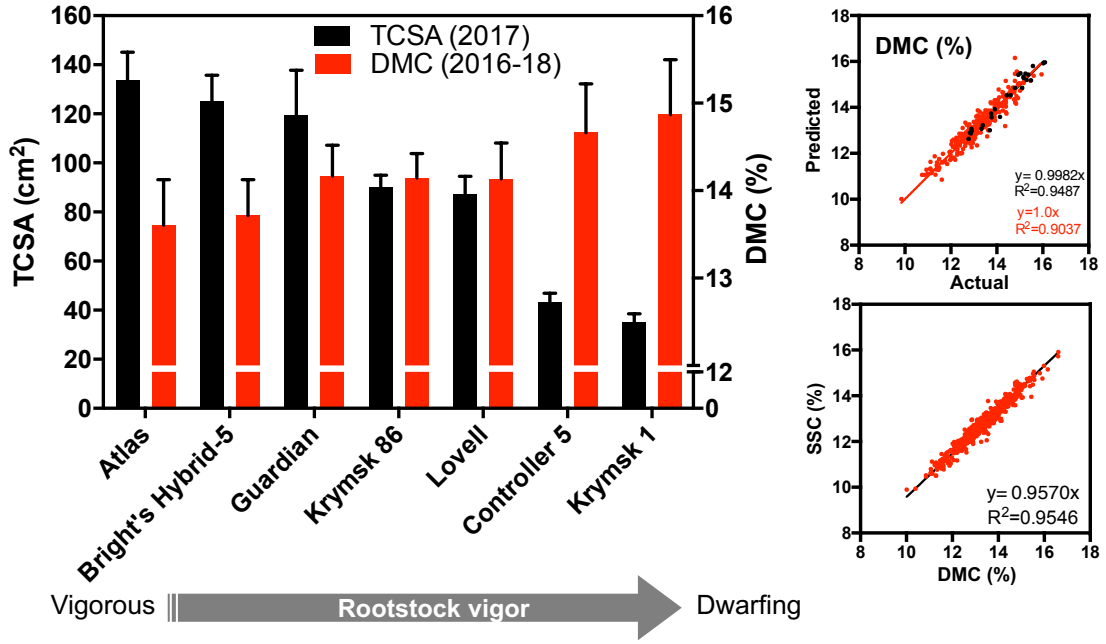

Table 2. Survival, trunk cross-sectional area (TCSA) in fall 2017 and 2018, number of root suckers and percentage of chlorotic trees for the *2017 NC140 Peach Semi-Dwarf Rootstock Evaluation Trial* in WCRC-OM, Grand Junction CO (2018).

Rootstock	Survival (%)	TCSA (cm^2) fall 2018	% of Lovell	% of Guardian	Suckers	Yield (kg/tree)	Fruit weight (g)	Yield efficiency (kg/cm^2)
Controller™ 6	100	13.3^{bcd}	93	62	0.0^{b}	1.2^{ab}	222.2^{ab}	0.36^{abc}
Controller™ 7	100	7.4^{de}	52	35	0.0^{b}	0.0^{b}	n/a	0.00^{c}
Controller™ 8	100	15.3^{abc}	107	72	0.0^{b}	0.6^{b}	195.6^{ab}	0.19^{abc}
MP-29	100	5.8^{e}	41	27	0.2^{b}	0.4^{b}	148.9^{b}	0.48^{ab}
Rootpac® 20	100	18.4^{ab}	129	86	12.4^{a}	2.3^{a}	232.0^{a}	0.59^{a}
Rootpac® 40	80	11.8^{cde}	83	55	0.3^{b}	0.7^{b}	189.2^{ab}	0.32^{abc}
Guardian®	100	21.4^{a}	150	100	2.5^{b}	1.1^{ab}	186.6^{ab}	0.21^{abc}
Lovell	100	14.3^{ab}	100	67	3.7^{b}	0.5^{b}	221.1^{ab}	0.12^{bc}
Estimated HSD	ns	6.1			8.7	1.6	73.3	0.47

Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.

Table 3. The impact of rootstock on 'Benton' sweet cherry tree survival and TCSA across all training systems in the 2017 NC-140 'Benton' Sweet Cherry Rootstock x Training Systems Trial in WCRC-OM, Grand Junction CO during the season of 2019.

Rootstock	Survival (%)	% Size of MxM14	TCSA (cm^2) at planting	TCSA (cm^2) at fall 2019
Cass	100	56	1.2^{ab}	12.4^{ab}
Clare	100	45	0.9^{b}	10.0^{b}
Clinton	92	72	0.9^{b}	16.0^{ab}
Lake	92	64	1.2^{ab}	14.3^{ab}
Gi3	100	57	3.3^{a}	12.7^{ab}
Gi5	100	76	0.9^{b}	16.9^{ab}
Gi12	100	92	1.2^{ab}	20.5^{a}
MxM14	100	100	1.4^{b}	22.3^{a}
Estimated HSD	ns		0.3	10.5

Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.

Table 4. The impact of training system on 'Benton' sweet cherry tree survival and TCSA across all rootstocks in 2017 NC-140 'Benton' Sweet Cherry Rootstock x Training Systems Trial in WCRC-OM, Grand Junction CO during the season of 2019.

Rootstock	Survival (%)	TCSA (cm^2) at planting	TCSA (cm^2) at fall 2019
TSA	97	1.33	13.8^{b}
Bi-UFO	100	1.38	14.5^{ab}
KGB	97	1.32	18.9^{a}
Estimated HSD	ns	ns	4.4

Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.

Table 5. Tree and yield characteristics in 2019 of Modi® apple trees in the 2015 NC-140 Organic Apple rootstock trial at the CSU's WCRC-OM, Grand Junction, CO.

Rootstock	Survival (%)	TCSA (cm^2) fall 2019	Height (cm)	width (cm)	Yield (kg/tree)	Fruit weight (g)	Suckers
G.11	100	6.3^{bcd}	270.6^{abc}	28.2^{bc}	0.9	163.5	0.0^{b}
G.16	100	2.8^{d}	229.4^{c}	18.9^{d}	1.1	147.3	2.8^{a}
G.202	100	6.8^{abc}	274.5^{abc}	28.8^{abc}	0.6	181.3	0.3^{b}
G.214	100	6.7^{bcd}	274.0^{abc}	28.5^{abc}	1.1	209.8	0.3^{b}
G.222	100	8.9^{ab}	312.1^{ab}	33.2^{ab}	0.3	245.5	0.7^{b}
G.30	100	5.3^{bcd}	262.0^{abc}	25.8^{bcd}	0.5	203.6	0.3^{b}
G.41	100	3.0^{cd}	218.2^{c}	19.2^{d}	0.9	145.7	0.4^{b}
G.890	92	10.7^{a}	333.0^{a}	36.0^{a}	0.8	176.4	0.3^{b}
G.935	83	7.3^{ab}	277.8^{abc}	30.2^{abc}	0.8	135.7	0.1^{b}
G.969	100	5.0^{bcd}	247.9^{bc}	25.0^{cd}	0.8	151.4	0.0^{b}
M9T337	100	6.6^{bcd}	256.9^{abc}	28.8^{abc}	1.2	171.7	0.0^{b}
HSD	ns	3.7	71	7.8	ns	ns	2.1

*Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.

Table 6. Tree characteristics in 2019 of 'Buckeye Gala' apple trees in the 2019 NC-140 Apple rootstock trial at the CSU's WCRC-OM, Grand Junction, CO.

Rootstock	Survival (%)	TCSA (cm^2) at planting	TCSA (cm^2) at fall 2019	Suckers
B.10	100	2.1^{a}	11.8^{ab}	0.0
G.11	100	1.4^{bc}	8.1^{d}	0.3
G.41	100	2.3^{a}	13.2^{a}	0.0
G.4814	100	1.3^{c}	8.4^{cd}	0.3
G.969	100	2.0^{a}	12.7^{ab}	0.1
IFO#2	100	2.4^{a}	12.1^{ab}	0.0
M26	100	2.4^{a}	13.1^{a}	0.5
M9-T337	100	1.9^{ab}	10.5^{bc}	0.2
Estimated HSD	ns	0.6	2.6	ns

*Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.

Table 7. Tree characteristics in 2019 of 'Buckeye Gala' apple trees in the 2019 NC-140 Apple rootstock trial at the CSU's WCRC-OARS, Hotchkiss, CO.

Rootstock	Survival (%)	TCSA (cm^2) at planting	TCSA (cm^2) at fall 2019	Suckers
B.10	100	2.1[a]	3.2[abc]	0.0
G.11	93	1.4[bc]	2.8[bc]	0.0
G.41	100	2.3[a]	3.5[ab]	0.0
G.4814	100	1.3[c]	2.4[c]	0.0
G.969	100	2.0[a]	3.9[a]	0.0
IFO#2	100	2.4[a]	3.6[ab]	0.0
M26	100	2.4[a]	3.6[ab]	0.0
M9-T337	100	1.9[ab]	2.9[bc]	0.0
Estimated HSD	ns	0.6	0.9	ns

*Mean separation in columns by Tuckey's HSD (P=0.05). HSD was calculated based on the number of observations per mean.

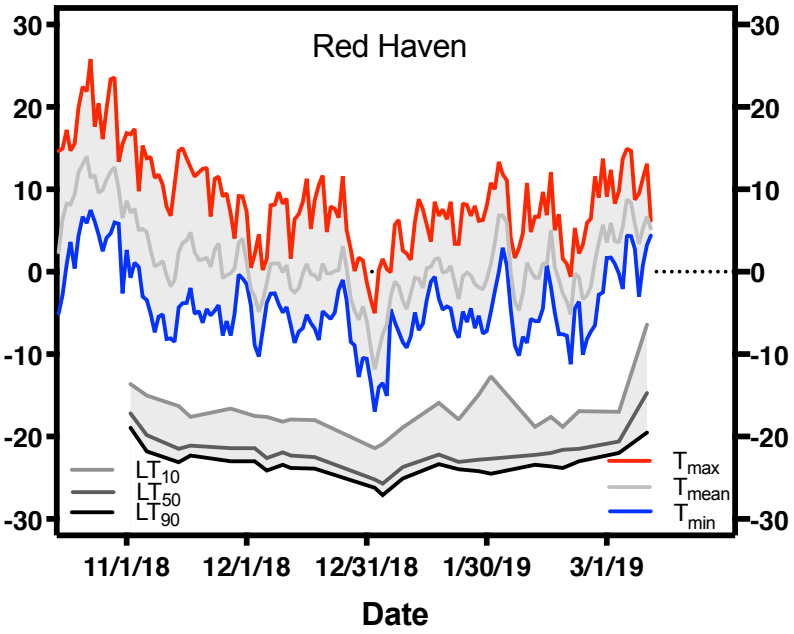

Figure 2. Seasonal patterns of temperature and cold hardiness, expressed as lethal temperature for 10, 50 and 90% of the total flower buds killed (LT_{10}, LT_{50}, LT_{90}, respectively), for peach flower buds of 'Red Haven' peaches grafted on 'Lovell' peach seedling cultivar rootstock that is planted within the *NC-140 2009 'Red Haven' Peach Rootstock Evaluation Trial*. Daily maximum, mean, and minimum temperatures recorded at the CSU Western Colorado Research Center at Orchard Mesa near Grand Junction, CO, 2018/19*.
*Temperature data for various locations within the Grand Valley can be found at: http://www.winecolorado.org/colorado-grape-growing/weather-station-network./
Meteorological data from other locations throughout Colorado may also be available from the Colorado Agricultural Meteorological network - CoAgMet.

Table 8. Lethal temperatures (LT) in Celsius (ºC) for 10 (LT_{10}), 50 (LT_{50}) and 90% (LT_{90}) flower buds killed, for 'Red Haven' peaches grafted on Atlas, Bright's Hybrid-5, Guardian®, Krymsk®86, Lovell, and Krymsk®1 rootstocks during the dormant season 2018/19. All the above rootstocks were planted within the *NC-140 2009 'Red Haven' Peach Rootstock Evaluation Trial* in the experimental orchard of the Colorado State University's WCRC-OM, Grand Junction, CO.

	Atlas	Bright's Hybrid-5	Guardian®	Krymsk®86	Lovell	Krymsk®1	Date
LT_{10}	-15.4	-14.2	-15.4	-14.3	-16.6	-14.2	**11/7/18**
	-16.5	-16.5	-16.8	-16.2	-18.6	-16.8	**11/20/18**
	-16.3	-16.5	-18.4	-17.4	-17.7	-17.7	**12/3/18**
	-21.1	-20.7	-23.8	-23.0	-21.4	-20.5	**1/3/19**
	-11.4	-14.4	-18.1	-15.3	-17.6	-9.3	**1/22/19**
	-10.5	-11.6	-12.5	-12.4	-10.9	-11.3	**2/5/19**
	-14.0	-10.8	-17.0	-17.2	-16.1	-10.2	**2/20/19**
LT_{50}	-19.0	-18.5	-18.8	-18.7	-19.4	-18.7	**11/7/18**
	-20.5	-20.6	-21.0	-21.1	-21.2	-20.1	**11/20/18**
	-20.5	-21.3	-21.7	-21.9	-21.2	-20.9	**12/3/18**
	-25.5	-25.4	-26.3	-26.3	-25.1	-25.8	**1/3/19**
	-22.1	-21.6	-22.4	-22.6	-21.6	-21.3	**1/22/19**
	-21.7	-21.2	-22.9	-22.0	-21.8	-21.5	**2/5/19**
	-22.0	-22.0	-22.5	-22.8	-21.8	-21.7	**2/20/19**
LT_{90}	-20.9	-20.5	-20.5	-20.7	-21.2	-20.6	**11/7/18**
	-22.6	-22.2	-22.4	-22.6	-22.6	-22.3	**11/20/18**
	-22.8	-23.1	-22.9	-22.9	-22.8	-22.4	**12/3/18**
	-26.8	-26.8	-27.6	-27.4	-26.3	-26.9	**1/3/19**
	-23.4	-23.5	-24.3	-23.7	-23.3	-23.4	**1/22/19**
	-23.7	-23.9	-24.3	-24.1	-23.5	-23.9	**2/5/19**
	-23.7	-24.1	-24.6	-24.3	-24.1	-23.7	**2/20/19**