Project Title: WA38 applied research and demonstration block

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Cooperators: Keith Oliver, Garret Henry, Derek Hill, David Gleason, Valent BioScience, Bleyhls Co-op, Burrows tractor Inc, Drape Net, Corsi Consulting.

Report Type: Final report

Project Duration: 3 -Years

Total Project Request for Year 1 Funding: 5,733
Total Project Request for Year 2 Funding: 9,605
Total Project Request for Year 3 Funding: 9,907

Other funding sources: Awarded
Amount: $152,938
Agency Name: Root Growth Management to Reduce Ca Deficiency Disorders in Apples and Cherries. Washington State USDA- Specialty Crop Block Grant. $152,938. P.I. B. Sallato. Co-P.I.s; L. Kalcsits, M. Whiting.
Notes: Costs associated with objective 1 and wages for hourly support during sample collection will be covered by this proposal.

Other funding sources: Awarded
Amount: $50,000
Agency Name: IAREC – WSU
Notes: Funding support for five years (2020 – 2025) provided by Naidu Rayapati, IAREC Director for tree fruit orchards maintenance and plot fees.

Other funding sources: Awarded
Amount: $15,000
Agency Name: Valent BioScience
Notes: Costs associated with ReTain and Pollen spray for fruit set.

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Item	2021	2022	2023
Salaries			
Benefits			
Wages	3,000	6,520	6,781
Benefits	673	1,025	1,066
Equipment			
Supplies[1]	2,060	2,060	2,060
Travel			
Miscellaneous			
Plot Fees			
Total	5,733	9,605	9,907

Footnotes: [1] Wages and benefits to support data collection. Supplies include tissue samples and chemical analyses if peel and fruit for nutrient differences in apples with and without physiological disorders (activity a and b), and fruit quality supplies: sampling bags, iodine, flagging tape, etc.

OBJECTIVES

1. Evaluate horticultural practices on WA 38 grown on G41 and M9-Nic 29 for better production and fruit quality.

We managed, monitored and conducted experiments in the WSU WA 38 Roza orchard. Parallel projects include a heat stress monitoring and mitigation project, led by PIs Khot, and "Ca-related disorders management for vigorous conditions", led by PI Sallato. Information regarding these projects will be reported separately.

2. Utilize the WA 38 Roza farm as a demonstration block for community engagement and outreach.

The WA 38 Roza farm provided a venue for community engagement and outreach. The Roza Farm hosted over 20 field days, workshops and visitors, reaching over 150 people. The workshops were delivered in English and Spanish.

SIGNIFICANT FINDINGS

- At the WA 38 Roza farm, the optimum load per tree, based on fruit load and fruit quality, ranged between 90 and 110 fruits per tree on bi-axis and spindle (1210 trees per acre), and between 65 and 80 fruits per tree on V-trellis (2420 trees per acre)
- WA 38 can overcrop (as seen in 2021) and induce alternate bearing. Thus, there is a need to identify the maximum production potential under each growing condition.
- At the Roza site, WA 38 requires management to prevent excessive vigor, given that the soil is deep, with high water retention and no evidence of limiting conditions. We were able to reduce vigor and increase crop load by implementing summer pruning (between June and August), reducing N and K levels, and controlling water
- G41 exhibited more vigor than M9-nic 29, which was related to higher root growth, root growth rate, and a longer root growth period. Higher root growth translates into higher leaf nutrient uptake, vigor, and green spot incidence
- There is a strong relation between green spot (GS) and nutrient imbalance, specifically between calcium (Ca) and nitrogen (N), an imbalance caused by excessive vigor (Sallato et al., 2021). Green spot severity positively correlated with N and B concentration. Ca was significantly lower in severe GS ++ compared to the control with no symptoms.
- Supplemental pollen at a rate of 30 g per acre via electrostatic application applied at bloom increased fruit set by 36% and final fruit load by 48% compared to the untreated control.
- AVG (ReTain®) applied alone, in combination with pollen or after petal fall, increased fruit per tree between 45% to 85% when compared with the control. However, these treatments did not always lead to increased fruit set or yield.
- While supplemental pollen spray aims to increase the availability and transfer of pollen, ReTain® aims to increase ovule longevity. Thus, when pollen availability, bee activity, or a short pollination period is expected, these tools could improve production, while there is no benefit if these factors are not limiting.
- Summer pruning increased fruiting wood and fruit yield in the second season after the summer prune. There were no differences among the different timings of summer pruning; however, the earliest pruning (May) could induce bud break in the fall (fall blooms). Spring pruning can affect fruit size if done aggressively, as it removes carbohydrate sources; however, it did not induce fruit drop.

METHODS

1. ***Evaluate horticultural practices on WA 38 grown on G41 and M9-Nic 29 for better production and fruit quality.***

The WSU WA 38 block was planted in 2013 in a 0.8-acre block, to evaluate rootstock and training systems. The orchard is divided in three training systems: Spindle 3 x 10 ft (rows 1 to 4), V trellis with spindle training at 1.5 x 12 ft (rows 5 to 8) and bi-axis at 3 x 10 ft spacing (row 9 to 11), on two rootstocks, Geneva 41 (G.41) and M9-NIC29 (Figure 1). Rootstocks are randomly distributed within each training system in blocks of 10 or 22 trees.

Figure 1. WA 38 at WSU Roza Farm with three training systems; spindle (3 x 10 ft), V-trellis (1.5 x 12 ft.) and bi-axis (3 x 10 ft).

Initially the pollinizers were Granny Smith and Chehalis at density approximately of 14% (9% in V-Trellis and 18% in Bi-axis) on M-26 rootstock. In 2017, the Roza Farm was affected by a hail event during bloom accompanied by favorable conditions for fire blight development. Consequently in 2018, 24% of the WA 38 on M9-nic 29 and 11% of the pollinizers died due to fire blight infection and trees were removed. In 2020, we replaced the removed trees with WA 38 on Geneva 11 (G.11) and added missing pollinizers Snowdrift and Evereste crab apple.

Soil conditions: The block is located on a silt loam soil, corresponding to the Warden series over basalt rock. The depth varies slightly between 2.5 feet of effective soil depth to more than 4 ft. Above the basalt rock, some areas have $CaCO_3$ (Caliche), with pH ranging between 7.0 and 7.8. Soil P, S and B levels are usually low.

Training Systems

Spindle; row 1 to 4, with 28 blocks of 10 trees. Initially trained by bending branches, which led to blind wood and low productivity. Since 2018, we been slowly transitioning to traditional spindle. This section is notoriously more vigorous than V-Trellis and bi-axis, providing us the opportunity to learn about green spot and vigor management. Since 2021 we been using these blocks for the PGR trial to evaluate Ca related disorders (Sallato's final report on PGR's for vigor control)

V-Trellis; row 5 to 8, with 28 blocks of 22 trees. This block continues to be managed with winter pruning, summer pruning and hedging. Six trees in this section have a root window (rhizotron) to monitor root growth differences between rootstocks (Obj 1).

Bi-axis; row 9 to 11, with 20 blocks of 10 trees. This section was planted a year later (2014). Since 2018 trees have been pruned lightly during the winter to remove undesired branches; redundant, hanging, and renew wood, followed by summer pruning and hedging. Since 2021, these blocks have been used to evaluated heat monitoring and mitigation practices (Khot's heat stress final report).

General management
Disease and pest management is under advice from Jeff Sample (Blehyl Co-op). Mayor challenges have been fire blight (2018-2019), thrips (2021), and mildew (2019-2022). In 2020, the irrigation system was upgraded and divided for each training system, utilizing Wiseconn Engineering monitoring and controls platform. A set of moisture and temperature sensors were installed on each section, and one weather monitoring system for the entire block. A Venturi system was installed for fertigation in 2021. Additional monitoring systems have been installed in the bi-axis section, associated to the heat stress project (for more details review Khot et al, 2021 report)

Soil and nutrient management
Initial soil analysis (2019) indicated mineral deficiencies of phosphorous (10 mg/kg), sulphur (8 mg/kg), zinc (0.50 mg/kg) and boron (0.12 mg/kg) according to recommended levels (http://treefruit.wsu.edu/orchard-management/soils-nutrition/fruit-tree-nutrition/). In 2019, we applied 100 lbs. per acre of mono ammonium phosphate (MAP), 25 lbs of $ZnSO_4$/acre and 2 lbs of B/acre. Since 2019, we have continued with spring ground application of P (MAP) at 150 lbs/acre and foliar B and Zn (fall and spring). In 2022, we added 23 g of Urea per tree (individually) to all young, replanted trees and new pollinizers.

Research project
1.a. Differences in root growth and nutrient uptake between M9-Nic29 and G41. (Funding source Washington State USDA- Specialty Crop Block Grant. $152,938. Ending 2021). (Sallato)

Root windows (3 x 3 x 3-foot cubes with Plexiglas on one and plywood for other sides) were installed on three random trees per rootstock since 2019. Evaluation of root growth starts prior to bloom and continues every week during spring period when roots are actively growing, and every other week during the summer and fall. Each root window is treated as a replicate unit. Monitoring of root growth is done manually by drawing a quadrant (1.5 x 1.5 ft.) in the middle of the plexiglass and monitoring white roots during the growing season. New growth is recorded and measured on site, then marked with different colors to identify period of growth. At the end of the season, each tree is strip harvested to determine yield, crop load and fruit quality. A detailed explanation of how to develop the root window was shared with the Good Fruit Grower and published in April 2019 (https://www.goodfruit.com/a-window-to-the-roots/)

1.b. Green spot nutrient composition differences, rootstock, and vigor. (Partially funded by Washington State USDA- Specialty Crop Block Grant. $152,938) (Sallato).

From 2018 to 2021, fruit with and without green spot (GS) have been collected from trees on G41 and M9-Nic 29 rootstocks. At harvest, fruit from different rootstocks and training systems were collected to determine fruit per tree, crop load and GS incidence. From each experimental unit and rootstock, fruit from six representative trees with (GS+) and without green spot (GS-) symptoms were collected for quality analysis. Then, each individual fruit were separated into peel, flesh, core and seeds to determine fresh and dry matter proportions. Subsequently, each tissue sample was dried, homogenized and sent to a commercial laboratory for nutrient analysis; nitrogen (N), phosphorous (P), potassium (K), calcium (Ca) magnesium (Mg), iron (Fe), zinc (Zn), cupper (Cu), manganese (Mn) and boron (B) analyses following the method recommended for total tissue analyses (Gavlak et al., 2005). In 2020 and 2021 we added an additional level of GS severity associated to milder symptom (greening), to determine relation with nutrient concentrations.

1.c. Use of AVG (ReTain ®) and artificial pollination to improve fruit set and production (Sallato).

In 2019 to 2021, we studied the effect of an ethylene inhibitor (AVG; ([S]-trans-2-amino-4-(2-aminoethoxy)-3-butenoic acid hydrochloride) (ReTain ®, Valent) and supplemental pollen application on WA 38 fruit set. The trials were conducted in the WA 38 Roza farm and in three commercial orchards; **Buena** 4th and 5th leaf WA 38 trial consisted of five treatments. 1. Pollen, 2. Pollen + ReTain ® at 80% bloom, 3. Pollen + ReTain ® at petal fall, 4. ReTain ® alone at petal fall and 5. Untreated control. All pollen treatments consisted of two applications (approximately at 30 and 80% open flowers) with 15 g of pollen/acre (70% Red Delicious and 30% Granny smith) each provided as in-kind by Firman Pollen. Treatments were applied with electrostatic sprayer provided as in-kind by OnTarget, USA. **Roza WA 38**, 9th leaf consisted of four treatments: 1. Pollen, 2. Pollen + ReTain®, 4. ReTain ® alone and 4. Untreated control. All treatments consisted of one application at 80% bloom of 30 g/acre equivalent. The application was conducted with battery powered backpack sprayer. ReTain® application were all at 333g/acre rate (1 pouch), provided as in-kind by, Valent Bioscience, USA. In all trials we determined the percent of open flowers prior to the application, fruit set (July) and percent of single, double or triple at harvest. Results from this and the other commercial sites have been shared in the pre-harvest field day (2021) and 2022 WSTFA annual meeting.

1.d. Pruning strategies to promote fruiting wood (Sallato).

During the summer, random sections of sets of tree trees throughout the block were selected and pruned at different timings in 2021: June 26th, July 26th and August 25th. In 2022, the same set of trees were left unpruned during the winter, and again pruned during the summer on May 30th, June 16th or September 8th. Fruit yield was monitored during harvest.

In addition, in 2022 and 2023 forty random trees with equivalent bloom density were selected. All trees received a light winter pruning to remove excessively vigorous shoots (thinning cuts) and reduce long hanging shoots. During the growing season a set of 10 trees each were pruned at 0 leaf (0L), five leaf (5L), ten leaf (10L) or left unpruned (control). Total fruit weight, fruit per tree and defects were evaluated at harvest.

1.e. Fruit ripening variability between systems and rootstocks (Sallato, Bolivar).
In 2020 and 2021, three trees per training system and rootstocks were selected during harvest, and each fruit was evaluated for starch content utilizing the WA 38 starch index chart (Hanrahan et al, 2019) http://treefruit.wsu.edu/wa38-starch-scale/.

RESULTS

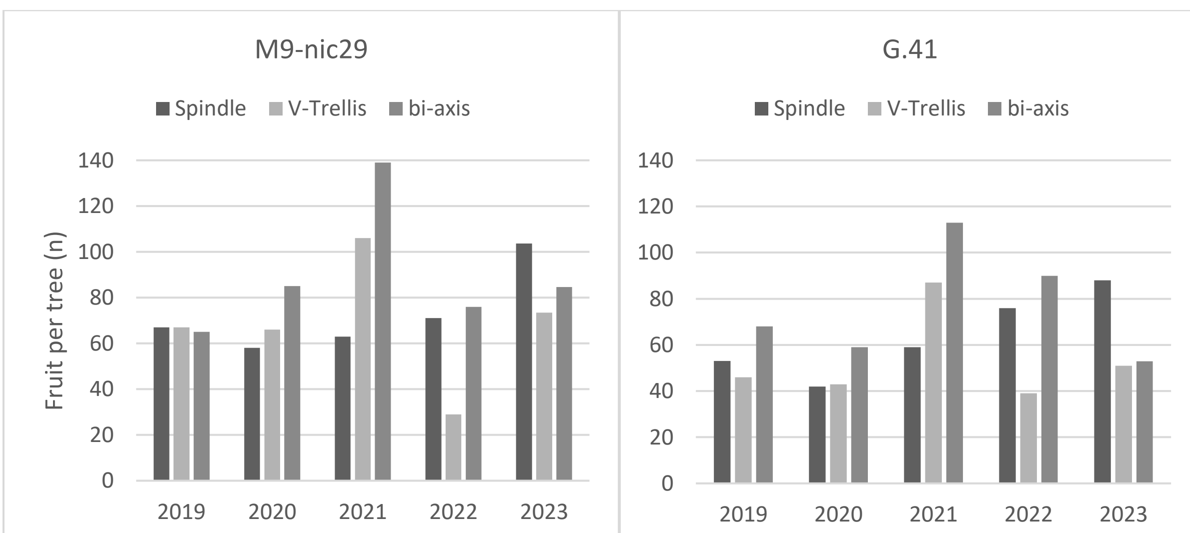
In this report, we provide a summary of key results and focus only on results not reported elsewhere, with focus on final recommendations for WA 38.

Evaluate horticultural practices on WA 38 grown on G41 and M9-Nic 29 for better production and fruit quality.

Since 2018, we have focused our management to reduce excessive vigor, controlling irrigation, reducing fertilizer application based on demand, soil and tissue test, and throughout minimal winter pruning and more intensive summer pruning. Table 1 shows the changes in yield per tree, fruit size and green spot incidence for the last five years, and an estimation of the most frequent box size (based on fruit weight) and bins per acre (based on average fruit weight and a 980 lb, discarding the percent of fruit with green spot). Note that in this estimation, we are considering between 10 to 50 trees per system and rootstock, we are not accounting for other defects such as cracks, thrips or bird picks that were significant in 2021 and 2022.

Overall M9-Nic29 had higher productivity (fruit per tree) compared to G.41 (Figure 1). As shown in Figure 1, in the spindle system, production has been increasing steadily, which has also increased fruit quality and reduced green spot incidence that was very high during 2018 – 2019 (Table 1). In 2023, fruit size averaged 289 g and 272 g for M9-Nic29 and G.41 respectively, and both picked at 81 mm and estimated 64 – 72 box size, the best quality obtained in 2023 across all years.
On the V-trellis, for both rootstocks, the productivity increased dramatically in 2021, to more than 100 fruit per tree in M9nic29 and more than 80 fruit per tree in G.41, leading to smaller fruit in both rootstocks and alternate bearing. In both rootstocks the production dropped to more than half in 2022, and while we didn't see an increase in green spot, there was high level of cracking (apro. 30%). In 2023 fruit yield increased as expected, however to a moderate level of 70 fruit per tree in M9-nic 29 and only about 50 fruit per tree in G.41.

Similarly in 2021, bi-axis trees were also overcropped on M9-nic 29 with almost 140 fruit per tree, leading to small fruit size approx. 237 g average and between 69 and 85 mm diameter, while reduced green spot incidence (below 4%). Consequently, in 2022 we had reduced fruit load, although slightly better fruit size (241 g). In 2023 crop load was slightly increased in M9-nic 29 with no differences in fruit size. In contrast, on G.41 a high crop load in 2021 (average 113 fruit per tree), led to a slight reduction in 2022 (90 fruit per tree). Surprisingly, we observed a greater reduction in 2023 with 53 fruit per tree.



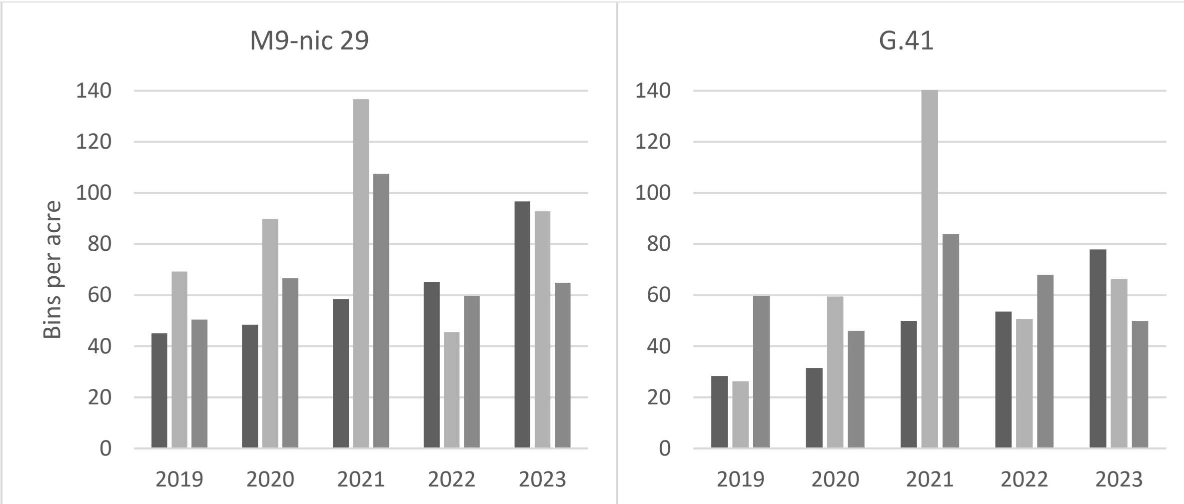


Figure 1. Top; fruit per tree (n) in WA 38 on M9-Nic 29 (a) and G.41 (b) trained as vertical spindle at 3 x 12 ft, on V-trellis at 1.5 x 12 ft and vertical bi-axis at 3 x 12 ft. Bottom; bins per acre in WA 38 on M9-Nic 29 (c) and G.41 (d) estimated based on average fruit weight and a 980 lb bin, accounting for fruit losses associated to green spot only.

Table 1.

Rootstock	System	2019	2020	2021	2022	2023
				Fruit weight (g)		
M9 -Nic29	**Spindle**	290	276	290	287	289
	V-Trellis	221	259	237	289	237
	bi-axis	240	241	237	241	235
G41	**Spindle**	298	316	298	230	272
	V-Trellis	239	284	298	244	241
	bi-axis	328	257	237	241	289
				Green spot (%)		
M9 -Nic29	**Spindle**	29	7.3	2	2	1
	V-Trellis	14	3.4	0	0	2
	bi-axis	1	0.3	0	0	0
G41	**Spindle**	45	27.1	13	6	0.3
	V-Trellis	56	10.4	0	2	1
	bi-axis	18	7	4	4	0
				Box size (n), 40 lb box		
M9 -Nic29	**Spindle**	63	66	63	63	63
	V-Trellis	82	70	77	63	77
	bi-axis	76	75	77	75	77
G41	**Spindle**	61	57	61	79	67
	V-Trellis	76	64	61	74	75
	bi-axis	55	71	77	75	63

Based on our results and growing conditions, we estimate that the optimum load on a bi-axis and spindle systems ranged between 90 to 100 fruit per tree, for both rootstocks. For V-trellis the optimum load ranged between 65 and 80 fruit per tree.

Soil nutrient levels were initially high in potassium (K) while low in phosphorous (P-Olsen), sulfate (SO4), and boron (B) (Table 2). We have been able to reduce the levels of K by not adding any K since 2018. Levels of have increased slowly as a consequence of our annual application of mono ammonium phosphate to the ground (100 – 150 lbs/acre). Levels of S and B remain low.

Table 2. Soil chemical levels from 2020 to 2023.

Parameter	Unit	Optimum	4/4/2020	5/4/2021	3/21/2022	4/17/2023
pH	-	5.0 – 7.0	7	7	7.1	7.3
K	mg/kg	150 - 250	224	271	237	171
	meq/100g	0.5 - 0.65	1.9	2.3	2.0	1.4
Ammonium_N	mg/kg	-	1.8	2.8	9.2	2.1
Nitrate-N	mg/kg	-	0.9	0.6	1.8	1.2
O.M	%	> 1	1.5	1	1	1.9
Ca	meq/100g	4.0 - 20	8.3	8.4	8.7	8.6
Mg	meq/100g	0.5 – 2.5	3.6	2.9	2.9	3.1
CEC	meq/100g	11 - 40	13.9	13.7	13.7	13.2
P Olsen	mg/kg	15 - 40	7.0	7.0	8.0	16.0
Sol.Salts	mmhos/cm		0.1	0.3	0.6	0.1
Sulfate-S	mg/kg	9 - 20	0.9	6.0	6.0	2.3
Na	meq/100g	< 0.5	0.2	0.1	0.1	0.1
Zn	mg/kg	0.6 – 1.0	4.3	1.2	0.9	11.4
Fe	mg/kg	-	14.0	20.0	12.0	103.0
Mn	mg/kg	1 - 4	6.7	1.6	2.2	5.1
Cu	mg/kg	0.6 – 1.0	2.3	2.2	2.2	2.3
B	mg/kg	1.0 – 1.5	0.07	0.13	0.10	0.21

Leaf nutrient levels have remained within normal ranges. Leaf N levels were adequate despite the low N fertilization rate applied since 2019, consisting of one application of 33 lbs/acre during spring. Likewise, all other nutrient levels are within adequate ranges, including Ca, considering the orchard does not receive Ca ground or foliar application.

Table 3. Fruit nutrient concentration from 2021 to 2023. Different letters indicate statistical differences at p value < 0.001 (Tukey test, XSLTAT, Andisoft)

	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
Year	%						ppm				
2021	2.0	0.58	2.20	2.36	0.27	0.18	22.4	742	33.7	9.2	52
2022	2.2	0.39	2.36	1.46	0.29	0.17	12.5	301	28.9	20.3	56
2023	2.2	0.56	1.95	1.66	0.29	0.14	13.8	499	24.7	8.1	54
*	1.7–2.5	0.2-0.3	1.2-1.9	1.5-2.0	0.2-0.3	0-10	15-200	-	25-150	5-12	20-60

* Recommended values for apples leaf samples.

Research projects;

1.a Differences in root growth and nutrient uptake between M9-Nic29 and G41. (Munguia-Sallato)

In all three years of evaluation (2019 – 2022) root growth started when temperatures were above 59 °F in the soil. Consistently G41 has shown higher total root length, root growth rate and longer growth period, compared to M9-nic29. In 2022, after the roots started to growth, soil temperatures got below 44.6 F at 8 inches of soil, delaying root growth on both rootstocks (data not shown, reported in 2022). Increased root growth rate and volume in G.41 contributed to higher vigor and green spot incidence observed in this rootstock between 2018 and 2021, when compared with M9-nic 29. Results from this research objective can be seen in our web page http://treefruit.wsu.edu/videos/rootstock-differences-in-wa-38/.

1.b. Green spot nutrient composition differences, rootstock, and vigor. (Sallato-Munguia-Whiting)

Our previous work suggested that there is a strong relation between GS and nutrient imbalance, specifically between calcium (Ca) and nitrogen (N), an imbalance caused by excessive vigor (Sallato et al., 2021). In 2021 we evaluated different levels of GS to incorporate an intermediate level of severity. We observed a positive correlation between N and B concentration and GS severity (Table 4). Ca was significantly lower in severe GS ++ compared to the control with no symptoms. Nutrient concentration of P and K were higher in GS fruit, irrespective of the severity.

Note that Ca related disorders and the nutrient imbalances extensively reported for bitter pit, green spot and other physiological disorders do not imply a deficiency of Ca, the need of additional Ca application nor the causal factor. Nutrient imbalances have been useful as indicators, however the causes have been associated more strongly to excessive vigor.

Table 4. Nutrient concentration in the peel of WA 38 fruit on G41 without green spot (GS -) and two levels of GS: flecking (GS +) and spots (GS ++).

Nutrient	GS -	GS +	GS ++	Pr > F(Model)
N %	0.40 c	0.48 b	0.54 a	<0.0001
P %	0.08 b	0.09 a	0.09 a	0.001
K %	0.83 b	0.95 a	0.94 a	0.007
Ca %	0.09 b	0.10 a	0.08 c	<0.0001
Mg %	0.11 b	0.12 a	0.13 a	<0.0001
B mg/kg	32.5 b	38.1 ab	43.5 a	0.038

1.c. Use of AVG (ReTain ®) and artificial pollination to improve fruit set and production. (Sallato-Whiting)

Between 2020 and 2021, we evaluated the impact of supplemental pollen spray and AVG ([S]-trans-2-amino-4-(2-aminoethoxy)-3-butenoic acid hydrochloride; ReTain®, Valent Bioscience Inc) on WA 38 fruit set and yield. The treatments included supplemental pollen application with or without ReTain® in six different trials, two at the WSU Roza WA 38 orchard. The supplemental pollen was always applied at a rate of 30 g per acre (70% ‘Red Delicious’ and 30% ‘Granny Smith’, Firman Pollen Inc., Yakima, USA) suspended in a proprietary suspension media. In all trials except at the WSU Roza farm (Prosser, WA), the treatments were applied with a commercial electrostatic sprayer, while at the Roza farm we used an electrostatic backpack sprayer (OnTarget Spray Systems, Mt. Angel, OR). The AVG treatment consisted of one pouch (333g) of ReTain® formula.

In 2020, in a commercial ‘WA 38’ orchard near Buena, WA, fruit set varied between 60.0 ± 9.3 and 82.5 ± 9.3 fruitlets, being 36% higher with supplemental pollen spray treatment compared to the untreated control and ReTain®. At harvest total fruit per trees were 85%, 80% and 48% higher in the ReTain®, ReTain®+ pollen, and pollen treatments respectively, when compared with the control

(Figure 2). The following year, we added two treatments: ReTain® at petal fall (PF) and pollen at bloom +ReTain® at PF. Again, supplemental pollen, pollen + ReTain® at bloom and ReTain® alone at petal fall increased the number of fruit per tree by 66.5%, 58.5% and 45.4% respectively, when compared with the control (Figure 1).

Similar results were observed at the WSU Roza experimental station on 'WA 38' on M9-Nic 29 rootstock, where fruit set was 74% higher with supplemental pollen application, followed by ReTain® and ReTain® + pollen spray. At harvest, yield per tree was 29% higher with ReTain® + pollen, when compared with the control, while the other treatments were not different (data not shown). The same treatments were imposed on 'WA 38' on G.41 rootstock, with no differences among treatments, however, crop load (fruit number per trunk cross sectional area) was the lowest in the control (4.7 ± 0.7 fruit/TCSA cm2) and 25.5% higher in the supplemental pollen spray treatment (5.9 ± 0.7). In two commercial trials conducted on a 4th leaf 'WA 38' in 2021, the application of ReTain®, supplemental pollen or the combination of both led to no differences in fruit set or yield. However, the grower reported 37% more bins per acre in the pollen and the ReTain® treated blocks, when compared with the untreated control.

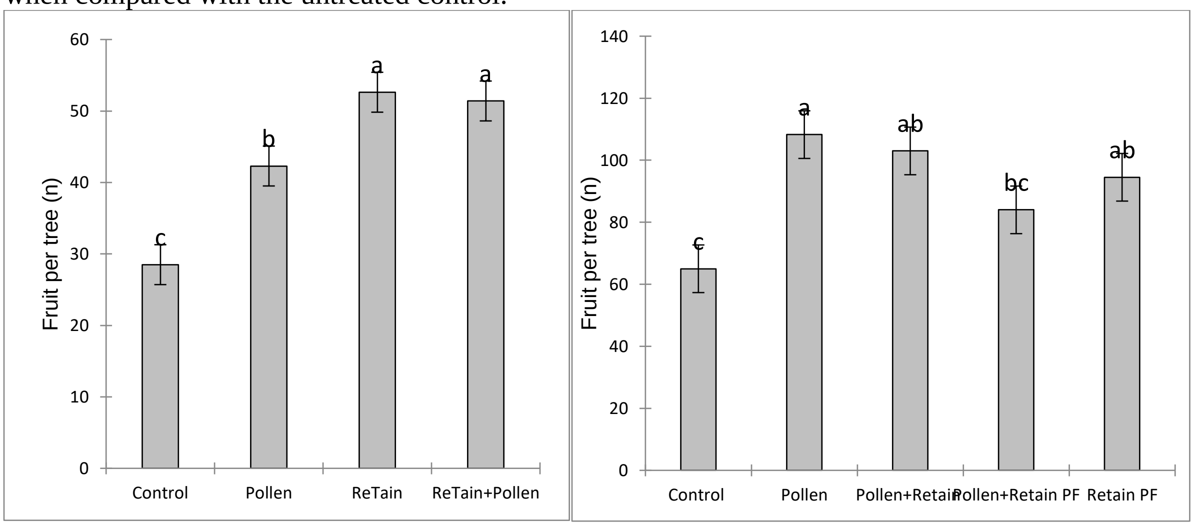


Figure 2. Total fruit (n) per tree at harvest in 2020 (left) and 2021 (right) commercial 'WA 38' orchard near Buena, WA. Treatments included an untreated control, pollen (at bloom), ReTain® at bloom, ReTain®+Pollen, Pollen + ReTain PF (at petal fall) and ReTain® PF (at petal fall). Bars indicate mean values and error bars correspond to the standard error (n=10). Different letters indicate significant differences between treatments ($p < 0.001$).

The outcomes of supplemental pollen application and ReTain® varied across the orchards, possibly due to different limiting factors. While supplemental pollen spray aims to increase the availability and transfer of pollen, ReTain® aims to increase ovule longevity. Thus, when pollen availability, bee activity or short pollination period is expected, these tools could improve production, while there is no benefit if these factors are not limiting. Results for this objective were reported in detail in 2021 and shared with WA industry at the WSU WA 38 pre harvest field days (2021, 2022 and 2023), pollination field days (April 19th and April 21, 2022) in Spanish with infographics "*Mejora de la cuaja en 'WA 38' (*Improving fruit set in 'WA 38'). And at the WSTFA annual meeting Dec 6, 2022 newsflash.

1.d. Pruning strategies to promote fruiting wood (Sallato)

Summer pruning response varied depending on the year. In 2021, early summer pruning (between May and June 16th) led to current season regrowth and in a few cases, induced flower buds to break during the fall. These late blooms can increase the risk of fire blight infection while losing the bud for the following season. Later summer pruning (after June 16^{th}) did not induce fall bloom and the regrowth varied depending on the vigor and angle of the shoot being pruned. The later the pruning, the lesser the regrowth. However, in 2022 we did not induce flowering in the fall, regardless of the timing of pruning, and regrowth shoots were shorter than those in 2021.

In all regrowth cases, the new shoots were weaker, and, in most cases, we observed symptoms of iron or zinc deficiency (chlorosis), likely due to fast regrowth rate and reduced mobility of these elements in the plant. Regardless, the following year, there were no signs of deficiency.

By the end of the second-year, summer pruned trees had higher crop load compared to those that were only pruned in the winter. There were no differences among the different timings of summer pruning. This higher crop load in 2022 led to a dramatic reduction in fruit set in 2023, thus we couldn't isolate the impact of consecutive summer pruning.

Regarding the summer pruning trial, based on pruning levels, the early and more aggressive summer pruning led to higher fruit per tree compared with the pruning trial at 5 leaf or 10 leaf stage, however it was not different from the unpruned control. These intensive pruning treatments led to small fruit at harvest. In 2023, there were no differences among treatments in regards of fruit yield, size or defects (data not shown).

Table X. Total fruit yield, fruit per tree and average fruit weight by pruning intensity.

	Yield (lbs/tree)	Fruit per tree	Fruit weight (g)
Control	19.6 a	39.0 ab	243.9 ab
10 L	11.4 ab	20.4 b	237.3 ab
5 L	9.2 b	14.6 b	293.7 a
0 L	20.2 a	48.2 a	198.8 b
Pr > F(Model)	0.030	0.011	0.021

Summer pruning helped reduce excessive shoot growth and helped increase tree productivity by two main effects; 1. Reducing vigorous upright shoots that can become blind wood or further increase vegetative growth with winter pruning. 2. Increased fruiting wood for the following and subsequent season. A later summer pruning (August) seemed more appropriate and with lesser risk in inducing fall blooms, however, summer pruning did expose fruit that were previously shaded, leading to increased sunburn risk. To prevent this higher risk, we applied sunburn protectants to the individual trees, however growers can utilize other mitigation practices, or avoid summer pruning when temperatures and sun exposure is expected to be high.

1.c. Fruit ripening variability between systems and rootstocks (Bolivar – Sallato)

Detailed information was shared in previous report and at the Jan 2022, Pom Club meeting (Sallato), and in the Spanish field days led by CoPI Bolivar, "Perfil de maduración de WA38 en dos portainjertos y tres sistemas de producción- Año 2020. Jenny Bolivar-Medina, Bernardita Sallato. (WA38 maturation profile on three production systems and 2 rootstock types- 2020). An infographic of the results can be found http://treefruit.wsu.edu/perfil-de-maduracion-de-wa-38-en-dos-portainjertos-y-tres-sistemas-de-produccion-2020/

Utilize the WA 38 Roza farm as a demonstration block for community engagement and outreach.

The WA 38 Roza farm provided a venue for community engagement and outreach in multiple field days, workshops, group visits, etc. In 2022, Sallato led a full day workshop for the WSTFA – WSDA and WSU collaborative “Agricultural Leadership Program”, where we covered the areas of “plant physiology” (M. Whiting), Crop load management (D. Gleason), Irrigation (A. Moreno), IPM (T. DuPont) and Soil and Nutrient management (B.Sallato), in English and Spanish, for 33 students. Co PI Bolivar hosted 3 field days in Spanish in 2022 and Sallato has hosted a pre-harvest WA 38 every year.

In 2021 we reached over 60 people during the field days, in 2022 we reached over 80 people and in 2023 we reached over 100 people including a Spanish and English speaking growers, three international visits (Italy, Chile, Brasil), K-12, Yakima Community College students among others.

A survey conducted after the field days reported 80% increase of knowledge and 50% of the participants, indicated intention to change their management practice for pollination and nutrient management. At the pre harvest WA 38 field day (Spanish), we had 33 attendees and 24 responded to our survey. A 100% of the respondent indicated they see value in the WA 38 demonstration site and field days, which had led to changes in practices including training systems, rootstock selection, fruit set management strategy, pruning, among others.

EXECUTIVE SUMMARY

Project Title: WA38 applied research and demonstration block.
Keywords: Cosmic crisp, vigor, green spot, supplemental pollen

With the development of new varieties and rootstocks, numerous challenges emerge before achieving enhanced growing practices. With over 20 million WA 38 plants, growers face various unanswered questions. The Roza WA38 block, established in 2013 at the Washington State University Irrigated Agriculture Research and Extension Center in Prosser, serves as a unique research and extension hub in the heart of the Yakima Valley. The planting design has three training systems; vertical spindle at 1210 trees per acre, V trellis at 2420 trees per acre and a vertical wall bi-axis at 1210 trees per acre, and two rootstocks; G 41 and M-9 Nic 29, arranged in a randomized design, creating a distinctive experimental setting for targeted inquiries and validation. The project objectives were to 1. Evaluate horticultural practices on WA 38 grown on G41 and M9-Nic 29 for better production and fruit quality and 2. Utilize the WA 38 Roza farm as a demonstration block for community engagement and outreach.

Over the three-year period, insights revealed that at the WA 38 Roza farm, the optimal fruit load per tree, based on fruit load and quality, ranged between 90 and 110 fruit per tree on bi-axis and spindle (1210 trees per acre) and between 65 and 80 fruit per tree on V-trellis (2420 trees per acre). These findings underscored that WA 38 can experience overcropping (as seen in 2021), leading to alternate bearing, necessitating the identification of maximum production potential under each growing condition. Managing excessive vigor at the Roza farm, achieved through summer pruning (June to August), reduced N and K levels, and water control, resulted in increased fruiting wood and fruit yield in the second season post-summer prune. Although no differences were observed among various summer pruning timings, the earliest pruning in May could induce bud break in the fall (fall blooms). Spring pruning, if done aggressively, could impact fruit size by removing carbohydrate sources, but it did not induce fruit drop. Despite this, G41 exhibited more vigor than M9-nic 29, correlated with higher root growth, root growth rate, and a longer root growth period. Higher root growth translated into increased leaf nutrient uptake, vigor, and higher green spot incidence during the initial two study years. In 2022 and 2023, green spot levels significantly decreased in both rootstocks, strongly linked to nutrient imbalance, particularly between calcium (Ca) and nitrogen (N), a result of excessive vigor.

Another significant limitation of WA 38, as reported by surveyed growers, is low productivity (low fruit set). The evaluation of supplemental pollen application via electrostatic, with and without AVG (ReTain®, Valent), yielded varied results across orchards and years. However, it seems that when weather conditions limit natural pollen availability or transfer, supplemental pollen can boost yield by 48%. Similarly, AVG (333 g, ReTain®) applied alone, in combination with pollen, or after petal fall also increased fruit per tree compared to an untreated control.

In summary, the Roza WA38 project provided valuable insights into tailoring horticultural practices, managing vigor, and addressing productivity challenges, contributing to the ongoing enhancement of WA 38 cultivation.