FINAL PROJECT REPORT **PERIOD:** 3 year of 3 years

Project Title: **'WA 38': SOP from planting to cropping**

PI: Stefano Musacchi
Organization: WSU -TFREC
Telephone: 509-293-8787
Email: stefano.musacchi@wsu.edu

Co-PI: Sara Serra
Organization: WSU-TFREC
Telephone: 509-293-8769
Email: sara.serra@wsu.edu

Co-PI: Karen Lewis
Organization: WSU-Extension
Telephone: (509) 760-2263
Email: kmlewis@wsu.edu

Co-PI: Bernardita Sallato
Organization: WSU-Extension
Telephone: (509) 760-2263
Email: b.sallato@wsu.edu

Cooperators: Several companies growing 'WA 38' in combination with different rootstocks have been contacted.

Project Request: **Year 1:** $90,860 **Year 2:** $88,523 **Year 3:** $87,292 **(Total $266,675)**

Other funding sources:
Project #AP14-103A: "WA 38 rootstocks and training systems" (2014-2016+1yr NCE) total funds $ 242,519 provided the support to maintain the orchard for this project.

BUDGET
Primary PI: Stefano Musacchi
Organization Name: Washington State University
Contract Administrator: Stacy Mondy/ Kevin Rimes
Telephone: 509-335-6881/ 509-293-8803
Contract administrator email address: arcgrants@wsu.edu/ kevin.rimes@wsu.edu
Station Manager/Supervisor: Chad Kruger
Station manager/supervisor email address: cekruger@wsu.edu

Budget

Musacchi-Serra-Lewis-Sallato			
Costs	Year 1 (2021)	Year 2 (2022)	Year 3 (2023)
Salaries[1]	$ 37,800	$ 39,312	$ 40,884
Benefit[2]	$ 16,760	$ 17,431	$ 18,128
Wages[3]	$ 12,000	$ 12,480	$ 12,980
Supplies[4]	$ 16,800	$ 11,800	$ 7,800
Travel[5]	$ 7,500	$ 7,500	$ 7,500
total	*$ 90,860*	*$ 88,523*	*$ 87,292*

Footnotes:

[1] Salary for a 75% Research assistant ($4,200/month) (Musacchi)

[2] Benefit on salary at 38.98%. Benefits on temporary at 22.4%

[3] Non-student temporary for 20 wks: 40hrs/wk at $15/hr (Musacchi/Lewis/Sallato).

[4] Labware/consumable, tree cost (Musacchi). Supplies include video recording and editing, printing material for outreach. Supply includes software fees for outreach material and translation. Supplies include video recording and editing, printing material for outreach.

[5] 13,043 miles/year for domestic travel ($0.575/mile) to go to the orchard. Travel to visit 10 blocks x 4 visits/year in Columbia Basin and North Central WA (Lewis). Travel to visit 10 blocks x 4 visits/year in south-central WA from Prosser (Sallato)

RECAP-OBJECTIVES:

1. Determine the rootstock effects on flower bud formation, fruit set, and spur extinction from planting to cropping (3rd year).
2. Investigate the 'WA 38' fruit set in the different types of bearing wood and assess the return bloom the following year.
3. Investigate the cultural management practices developed in 'WA 38' private orchards and summarize them in a list of recommended guidelines for growers.

SIGNIFICANT FINDINGS:

1. ***Determine the rootstock effects on flower bud formation, fruit set, and spur extinction from planting to cropping (3rd year) (Musacchi-Serra)***
   - In "No Stub 2022" (unpruned) trees, the smallest proportion of blind wood was reported in 'WA 38'/'G.890' and 'G.11' approximately 11 months after planting, while the largest proportion was in 'M.9-T337', followed by 'Bud10'.
   - 'WA 38'/'Bud9' trees in the "No Stub 2022" treatments presented the highest number of lateral shoots per branch.
   - 'WA 38'/'Bud9' trees for both 2022 pruning scenarios reported the highest average number of Flower Buds/branch (or stubs with shoots).
   - "No Stub'22+Stub3X'23" trees had left the 52% of flower clusters in comparison to "No Stub'22+unpruned'23", whereas "Stub'22+Click(STD)'23" trees only the 26%.
   - No significant difference in fruit set between the three treatments in trial in 2023.
   - Early bearing tendency was observed for 'WA 38'/ 'Bud9', 'M.9-T337', and 'G.935' (regardless of the pruning treatment), while 'G.890' did not produce fruit at harvest in 2023.
   - 'WA 38' grafted on 'Bud9', 'Bud10', 'M9-T337', and 'G.11' reported the lowest TCSA when managed with stub after planting and click pruning in the following year, while 'WA 38'/ 'G.890' showed the highest TCSA at the end of the second year after planting.

2. ***Investigate the 'WA 38' fruit set in the different types of wood and assess the return bloom on the different bearing woods (Musacchi-Serra)***
   - Largest part of 'WA 38' productions in 2021 and 2022, as avg. of 3 sites, was held as single apple/cluster (65% to 73%), followed by double apples/cluster (23% to 32%), and the residual as triple apples/cluster.
   - As average across the 2021 and 2022 scenarios (5 and 3 sites, respectively), 61 to 64% of the 'WA 38' apples were borne on spurs, followed by 12 to 27% on 'Brindilla' and 12% to 24% on 1-year-old shoot lateral buds ('Ramo misto').
   - Apples on 1-year-old shoot lateral buds ('Ramo misto') were confirmed to belong mainly to the small size class; while spurs produced apples with more variable sizes, from small to extra-large.
   - Quality analysis comparing apples from 3 bearing woods did not find consistent trends in 2 years.

3. ***Investigate the cultural management practices developed in 'WA 38' private orchards and summarize them in a list of recommended guidelines for growers (Lewis-Sallato)***
   - Fruit load varied between 63 and 143 fruit per tree, averaging a 70% increase as the trees mature and fill the space, with one site having reduced crop compared to 2021.
   - Crop load was highly variable among sites, ranging from 7.8 to 20 fruit per trunk cross section area (cm^2), influenced more by the year and site (management) than by rootstock.
   - Fruit size vary between 183 g and 304 g, 15% smaller than in 2021, except for one orchard (in both rootstocks), where fruit size was 22% higher.

RESULTS AND DISCUSSION

Objective 1) Determine the rootstock effects on flower bud formation, fruit set, and spur extinction from planting to cropping (3rd year) *(Musacchi-Serra)*

At eight months (8M) after planting (February 2023), the combinations in trial reported significant differences in terms of trunk cross sectional area and growth in 8M within both 2022 treatments (Table 1). For "No Stub 2022", the least vigorous combinations were 'WA 38'/'G.969', 'Bud9', and 'Bud10' and the most vigorous ones were 'WA 38'/'G.890', followed by 'WA 38'/'G.935' (Table 1). The "No Stub 2022" combinations that reported the highest growth in TCSA were grafted on 'G.935', 'G.213', 'G.41' and 'G.890'. For "Stub 2022" trees, a similar trend of vigor was confirmed, with 'WA 38'/'G.890' and 'G.935' being the most vigorous, in contrast to 'WA 38'/''Bud10'' and 'Bud9', the least vigorous combinations (Table 1). 'G.11', 'M.9-T337', 'Bud10', and 'Bud9' showed a low and comparable TCSA growth in 8M, while the most considerable growth was recorded in the graft combination with 'G.41' and 'G.935' (Table 1). In February 2023, only 4 trees in the whole orchard (543 trees total) were deceased by unknown cause: 3 'WA 38'/'G.969' and 1 'WA 38'/'M.9-T337'.

Table 1. *'WA 38' trunk cross sectional area (TCSA, cm^2) on 2/6/23 and trunk growth in 8 months (8M) for trees grafted on 9 different popular rootstocks for WA sorted by 2022 imposed treatment: No Stub vs Stub. Significance root: *** = p≤ 0.001). Trees were planted in 2022 at 11 ft x 3ft (1320 trees/A).*

TRT 2022	Rootstock for WA38	N trees '22	TCSA (cm^2) on 02/06/2023		TCSA Growth (cm^2) from June '22 to Feb '23	
No Stub	**Bud9**	33	**3.37**	D	**1.14**	E
	Bud10	34	**3.55**	D	**1.40**	D
	G969	28	**3.62**	D	**1.57**	CD
	G11	35	**4.22**	C	**1.81**	BC
	G213	35	**4.25**	C	**2.20**	A
	G41	34	**4.28**	C	**2.12**	A
	M9T337	33	**4.42**	BC	**1.73**	BC
	G935	34	**4.68**	B	**2.21**	A
	G890	33	**5.79**	A	**1.99**	AB
Significance rootstock			***		***	
Stub	**Bud10**	35	**3.37**	F	**1.29**	D
	Bud9	34	**3.50**	EF	**1.24**	D
	G11	34	**3.75**	DE	**1.39**	D
	G969	32	**3.78**	DE	**1.73**	C
	G213	33	**3.95**	CD	**1.94**	ABC
	M9T337	35	**3.98**	CD	**1.36**	D
	G41	33	**4.29**	BC	**2.09**	A
	G935	34	**4.44**	B	**2.02**	AB
	G890	34	**5.41**	A	**1.80**	BC
Significance rootstock			***		***	

Before imposing new treatments by pruning, at the end of winter 2022-2023 (March 2023), the experimental trees were assessed for branch measurements, blind wood incidence, branching ability and flower buds count. Looking at the proportion of blind wood (as a portion of the branch with no vegetative/flower bud break over the total length of the branch then averaged between the 4 selected branches/tree) in the "No Stub 2022" trees (N=81), some significant differences emerged: the largest proportion of blind wood was found in combination with 'M.9-T337' followed by 'Bud10' (and similar to other 5 combinations, Table 2), while the smallest proportion of blind wood was reported in 'WA 38'/'G.890' and 'G.11' (Table 2) partially confirming some of the results of July 2022 (data not shown). No significant differences in the average internode length in the blind wood portion of the branches (data not shown), but distinctions between original branch lengths in the unpruned trees emerged; this parameter ranged from 77.2 cm (30") in 'WA 38'/'Bud9' to 112.8 cm (44", on average) in 'WA 38'/'G.890' (Table 2). With different levels of significance across the 4 branches, a consistent tendency of 'WA 38'/M9-T337 presenting the highest number of "blind nodes" and 'WA 38'/'G.11' and 'G.41' the lowest number of "blind nodes" emerged, confirming some results already observed in 2022 (data not shown). At the time of branch measurements and blind wood assessment, we also counted the number of 1-year-old shoots longer than 5 cm (~2") inserted in the 4 basal branches. "No Stub 2022" 'WA 38'/Bud9 trees reported the highest number of lateral shoots per branch (2.9), an average significantly superior to the other 8 combinations in trial. Moreover, those lateral shoots (> 5 cm) were

longer on average in 'WA 38'/'G.890' (43 cm, 17") and 'WA 38'/'G.213' (37.3 cm, 15") while shorter in 'WA 38'/'Bud10' (12.3 cm, 5", Table 2).
The scion-rootstock combination impacted the average number of flower buds (FB) per branch in the "No Stub 2022" trees in March 2023. 'G.11', 'Bud9', and 'Bud10' reported the highest average number of FB/branch (16.9-17.7 FB/branch), while 'G.213' was the lowest (9.6 FB/branch).

Table 2. *'WA 38' combinations with 9 different rootstocks before pruning 2023: No Stub (2022) unpruned trees (N=9/combinations with 4 branches/tree) measurements on blind wood carried out in March 2023. Parameters reported are: the proportion of the branch affected by blind wood expressed as % and average of 4 basal branches/tree, the average length unpruned branches (cm), the average length of blind wood per branch (cm), the average number of lateral shoots (1-year-old and >5cm long) emerging from the branches, the average length of lateral shoots (cm), and the average number of flower buds (FB) for branch. Significance: NS= not significant, ** = p≤ 0.01, *** = p≤ 0.001 and letters of separation within each treatment were provided by SNK test. Trees were planted in 2022 at 11 ft x 3ft (1320 trees/A).*

Trt 2022	Rootstock comb. with WA 38 (2023)	N trees (N branches/ tree)	% Blind Wood		Avg. length of unpruned branch (cm)		Avg. length of blind wood in unpruned branch (cm)	Avg. Num 1 yr-old lateral shoots (>5 cm)/branch		Avg. length of 1 yr-old lateral shoots (>5 cm)/branch (cm)		Avg. Num Flower Buds (FB)/branch	
			(average of 4 branches/tree)										
No Stub (= unpruned)	**Bud10**	9 (4)	**17.1**	AB	78.9	B	**12.8**	**2.9**	A	**12.3**	C	**17**	A
	Bud9	9 (4)	**13.4**	ABC	77.2	B	**10.0**	**0.8**	B	**15.9**	BC	**18**	A
	G11	9 (4)	**10.9**	BC	88.9	B	**9.5**	**1.3**	B	**24.7**	B	**18**	A
	G213	9 (4)	**14.3**	ABC	82.7	B	**11.3**	**1.1**	B	**37.3**	A	**10**	C
	G41	9 (4)	**14.0**	ABC	83.6	B	**10.1**	**1.2**	B	**26.4**	B	**14**	ABC
	G890	9 (4)	**10.7**	C	112.8	A	**11.8**	**1.8**	B	**43.0**	A	**13**	ABC
	G935	9 (4)	**14.3**	ABC	86.9	B	**11.7**	**0.8**	B	**27.6**	B	**15**	AB
	G969	9 (4)	**16.4**	ABC	81.7	B	**12.3**	**0.8**	B	**15.5**	BC	**13**	ABC
	M9-T337	9 (4)	**18.1**	A	88.2	B	**14.2**	**1.3**	B	**18.9**	BC	**11**	BC
	Significance		**		***		*NS (0.0504)*	***		***		***	

Similar measurements were carried out in the "Stub 2022" trees (N=81) before pruning them at the end of winter 2022-2023 (Table 3). The 9 combinations that got stubbed after planting in 2022 did not show significant differences in the number of 1-year-old shoots produced from each stubbed branch (=stub), ranging on average between 1.5 ('G.890') and 2.0 ('G.11') per stub, proving that with stub pruning we zeroed the growth and allowed all combinations to start over. On the other hand, significant differences emerged for the average length of 1-year-old shoots, with 'WA 38'/'G.890' presenting the longest shoots (81 cm, 32"), while 'WA 38'/'Bud9', 'M.9-T337', 'Bud10' the shortest ones (37.5 cm, 15", to 41.4 cm, 16", Table 3). Also, the total length of 1-year-old shoots emerging from the stubs showed significant differences, with tendencies reflecting the relationship between rootstock vigor and vegetative growth. 'G.41', 'G.890', and 'G.935' reported the longest total growth of shoots/stub (111.4 cm, 44", to 116.6 cm, 46", on avg.), while 'M.9-T337', 'Bud9', 'Bud10', and 'G.213' had the shortest total lengths (Table 3). Regarding the average number of flower buds per stub, the order of magnitude in the "Stub 2022" trees is lower than in "No Stub 2022"; in fact, the (click)-stubbing approach after planting led to a reduction of flower buds on a tree for the following year. 'WA 38'/'Bud9' presented an average of 2.3 FB/stub, while 'WA 38'/'G.890' presented only 1.3 FB/stub, representing the two average extreme values among the 9 combinations (Table 3).

In general, the average longest internode in the 1-year-shoots emerging from stubs (from stubs 1 to 4 in "Stub 2022" trees) was found in 'G.890', 'G.41', 'G.969', or 'G.11', while the shortest internode was found in 'M.9-T337' (data not shown). This might confirm that 'M.9-T337' responded well to click pruning after planting to minimize the blind wood with respect to unpruned trees.

***Table 3**. 'WA 38' combinations with 9 different rootstocks before pruning 2023: Stub (2022) or click-pruned trees (N=9/combinations with 4 branches/tree) measurements carried out in March 2023. Parameters reported are: the average number of 1-year-old shoots emerged from the 2022 stubs, the average length of 1-year-old shoots emerged from the 2022 stubs, the total length of 1-year-old shoots emerged from the 2022 stubs, and the average number of flower buds (FB) for branch. Significance: NS= not significant, * = p≤ 0.05, ** = p≤ 0.01, *** = p≤ 0.001 and letters of separation within each treatment were provided by SNK test. Trees were planted in 2022 at 11 ft x 3ft (1320 trees/A).*

Trt 2022	Rootstock comb. with WA 38 (2023)	N trees (N branches/ tree)	Avg. Num 1 yr-old shoots/stub	Avg. length 1-yr-shoots/stub (cm)		Total length 1-yr-shoots/stub (cm)		Avg. Num Flower Buds (FB)/stub (1yr-old shoots included)	
			(average of 4 branches/tree)						
Stub	**Bud10**	9 (4)	**1.8**	**41.4**	D	**72.7**	B	**1.7**	AB
	Bud9	9 (4)	**1.9**	**37.5**	D	**67.6**	B	**2.3**	A
	G11	9 (4)	**2.0**	**45.7**	CD	**88.3**	AB	**1.9**	AB
	G213	9 (4)	**1.6**	**51.2**	BCD	**78.9**	B	**1.8**	AB
	G41	9 (4)	**1.8**	**65.5**	B	**116.6**	A	**1.7**	AB
	G890	9 (4)	**1.5**	**81.0**	A	**115.0**	A	**1.3**	B
	G935	9 (4)	**1.8**	**64.3**	B	**111.4**	A	**1.9**	AB
	G969	9 (4)	**1.6**	**58.9**	BC	**88.2**	AB	**1.4**	AB
	M9T337	9 (4)	**1.8**	**39.7**	D	**67.2**	B	**1.9**	AB
	Significance		*NS*	***		***		*	

In fact, in July 2022 measurements, 'WA 38'/M9-T337 unpruned trees showed the highest number of "blind nodes" (9), but when that combination was click-pruned (stubbed) after planting, the number of blind nodes decreased to one-third (3, -66.7%, data presented in the previous report).

On 03/28/23, we imposed new pruning treatments to the existing trial, dividing the 81 "No Stub 2022" trees into two scenarios: "No Stub'22+unpruned'23" (45 trees=5 trees* 9 rootstocks) and "No Stub'22+Stub3X'23" (36 trees= 4 trees*9 rootstocks). In the first scenario, we only did light branch simplification cuts on top where needed or when too strong branches were competing with the leader. Whereas, in the second case, we pruned the long mid-basal branches (ground to 2nd wire = 4') at a length equal to 3 times the length of the 2022 stub (~11 cm = 4.3") in the "Stub 2022" trees (approx. 33 cm = 1') and the tree-top was handled with regular click pruning, making sure to select the most vertical shoot as leader and remove competitors. On the other hand, the "Stub 2022" trees (81 trees= 9 trees* 9 rootstocks) were all pruned again as: "Stub'22+Click(STD)'23" following the criteria of clicking the 1-year-old shoots emerged from the stubs at a 2X-stub length, so, approx. 22 cm = 8.7", while when branch (shoot or stub) was strong or vertical the click was done at 1X.

On 4/21/23 (12 days before full bloom), flower clusters (FC) number per selected branches (or stubs) was counted in all the experimental trees, and on 6/30/23 (58 DAFB), after the end of the natural fruit shedding, the count of apples per branch and tree was carried out to assess the fruit set by the different 2023 treatments. In early June 2023, each row in the orchard was implemented with peat moss (5 m^3/row=177 ft^3/row=0.05m^3/tree=1.6 ft^3/tree) to conserve water in the hot summer, and 6 applications of 16-16-16 fertilizer (112g/tree/application) were distributed from 5/10 to 7/24/2023. Regardless of the pruning treatments, a highly significant difference emerged when comparing the number of flower clusters/tree among the different rootstock combinations (Figure 1).

The highest averages of flower clusters/tree were reported in combination with 'Bud9' (56 FC/tree), 'G.935' (47 FC/tree), and 'G.11' (46 FC/tree), while 'G.213' (12 FC/tree) and 'G.890' (0 FC/tree) presented the lowest numbers (Figure 1). When comparing the 3 treatments (Figure 1), the effect of the pruning (2022+2023) was very clear on the residual numbers of FC/tree: the "Stub'22+Click(STD)'23" trees presented only 26% of FC in comparison to "No

Stub'22+unpruned'23", while "No Stub'22+Stub3X'23" had a 52% of FC left with respect to "No Stub'22+unpruned'23". The interaction rootstock * treatment resulted significant and revealed some different trends between treatments within some rootstock; one example is 'WA 38'/'G.213', where the highest N FC/tree was recorded in "No Stub'22+unpruned'23", followed by "Stub'22+Click(STD)'23" (statistically similar). At the same time, the lowest number was found in "No Stub'22+Stub3X'23", a different trend than what was reported in Figure 1 (data not shown). At the end of the natural fruitlet shedding, the highest calculated fruit set (%) was reported for 'WA 38'/'Bud9' (2.4%), followed by 'M.9-T337' (1.9%), and 'G.935' (1.3%), while the other combinations were lower and all comparable (data not shown).

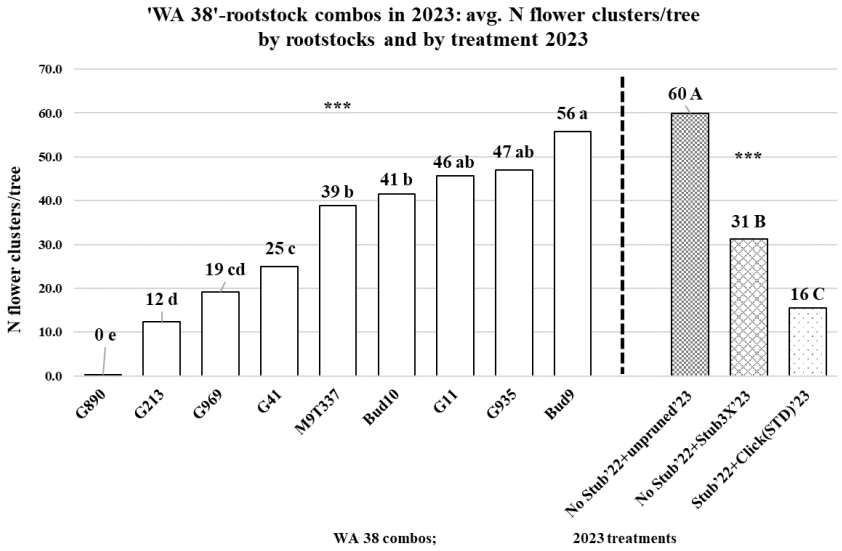

Figure 1. *'WA 38' scion-rootstock combination in trial in 2023 in Rock Island (WA). On the left of the bar chart, the avg. N of flower clusters/tree is reported by rootstocks regardless of the trt (N=18/combo), and, on the right, the same parameter displayed by pruning treatments in 2023 (N=45, 36, 79 respectively). Significance: ***=p<0.001 and letter of separations discriminate means for p=0.05; in lower case letters for the 9 combos and capital letters for the three treatments 2023. Trees were planted in 2022 at 11 ft x 3ft (1320 trees/A).*

On 9/28/23, the first crop was harvested, but not all 162 experimental trees were bearing fruit. Therefore, the proportion of bearing trees versus not-bearing trees was surveyed by rootstock*treatment combination, and the combinations with less than 3 trees were excluded by statistical analysis (Figure 2). In general, 'Bud9', 'M.9-T337', and 'G.935' showed an early bearing tendency, with 78 to 72% of trees bearing fruit, while, on the opposite side, 'G.890' did not bear fruit until harvest (Figure 2).
Comparing the three treatments in 2023, yield per tree was higher in "No Stub'22+unpruned'23" (2.0 kg/tree) and "No Stub'22+Stub3X'23" (1.6 kg/tree) in comparison to "Stub'22+Click(STD)'23" trees (0.5 kg/tree, data not shown). The different 2023 treatments showed to have impacted the average fruit mass, with the lowest apple weight found in "Stub'22+Click(STD)'23" (224 g, 80 apples/box size) and the highest in "No Stub'22+Stub3X'23" (289 g, 72-64 apples/box size, data not shown).
Only 8 combinations of scion-rootstock-treatment were statistically analyzed (Figure 3), and the most productive one, in the first cropping season, was 'WA 38'/'Bud9'_No Stub'22+unpruned'23 (avg. 3.8 kg/tree =8.4 lb/tree), followed by 'WA 38'/'Bud9'_No Stub'22+Stub3X'23 (2.3 kg/tree =5.1 lb/tree), and 'M.9-T337'_No Stub'22+unpruned'23 (2.1 kg/tree=4.6 lb/tree); all the other combinations produced less than 2 kg/tree (4.4 lb/tree). On average, the apple weight fluctuated from 203 g to 288 g without significant differences between the combinations (Figure 3).

In fall 2023, tree dimensions (height, widths, trunk circumference) were measured, and trunk cross sectional area, trunk growth, and canopy volume, were calculated for all experimental trees.
'WA 38'/'G.890' was the combination that, in general, regardless of the pruning treatment imposed, showed the highest tree height, widths (S-N and E-W), canopy volume and TCSA and growth, while, on the opposite side of the range, we had 'WA 38'/'Bud9' and 'WA 38'/'Bud10' (similar) with the shortest tree height, the narrowest canopies (smaller widths), the smallest TCSA and canopy volume,

and the lowest trunk growth in 2023 season (Table 4). These results confirmed the expected effect of different rootstocks in controlling tree size.

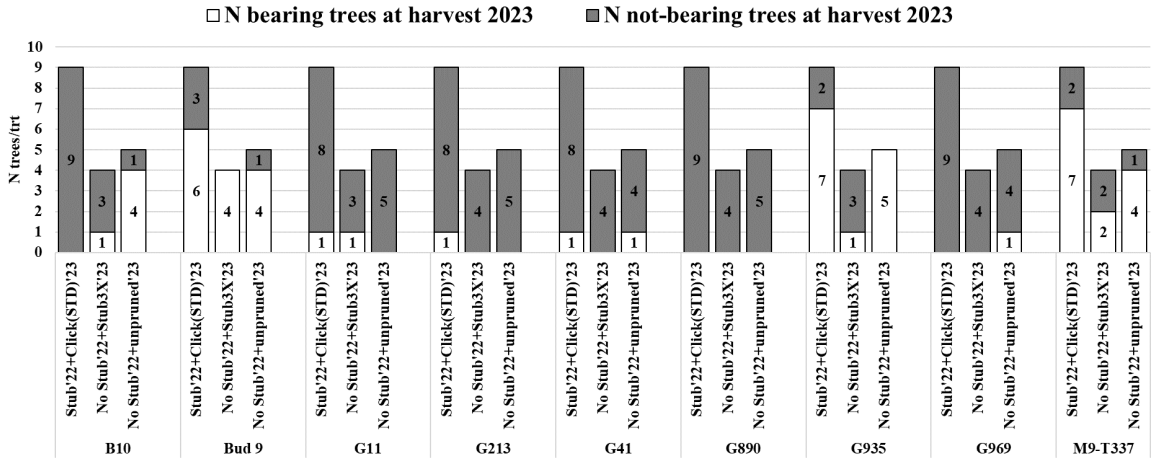

Figure 2. *'WA 38' scion-rootstock-pruning treatment combinations in trial in 2023 in Rock Island (WA). The combinations with less than 3 trees/combo were excluded from statistical analysis by combinations on yield 2023 data set.*

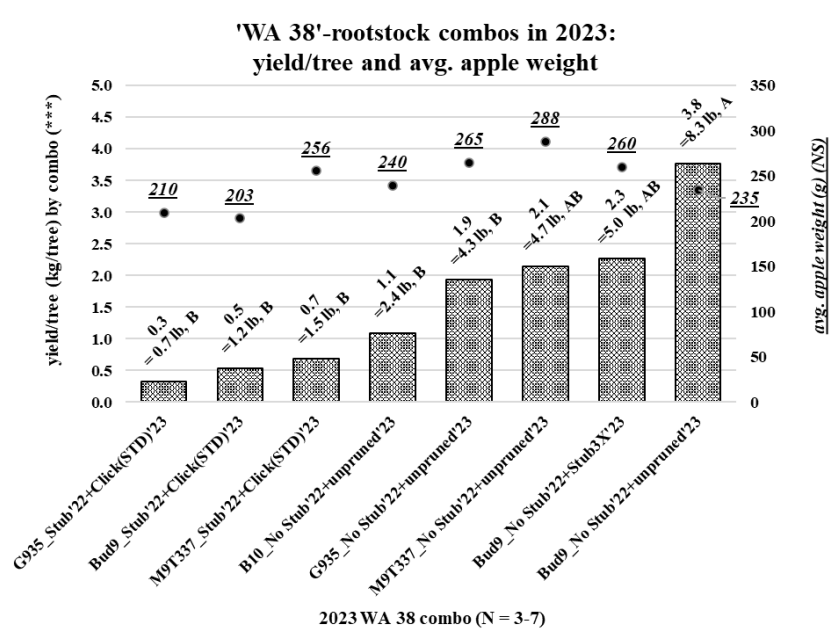

Figure 3. *Productive data for 'WA 38' scion-rootstock-pruning treatment by combinations in trial in 2023 in Rock Island (WA). Parameters reported are: on the primary Y-axis, the yield as kg/tree (on top of each bar kg are also converted in lb/tree), and on the secondary Y-axis, the average apple weight (g). Significance: NS= not significant, ***=p<0.001. Trees were planted in 2022 at 11 ft x 3ft (1320 trees/A).*

In the comparison of the 3 pruning treatments in 2023 for tree dimensions and volume, regardless of the rootstock, it became evident how the "No Stub'22+unpruned'23" trees are significantly wider (data not shown) and with a larger canopy volume than "No Stub'22+Stub3X'23" and "Stub'22+Click(STD)'23" (Table 4). These last two treatments showed a 20% canopy volume reduction compared to unpruned trees (Table 4). When looking at TCSA by treatments, no significant differences emerged, but the interaction rootstock * treatment showed a trend for 'WA 38'/'G.213' and 'WA 38'/'G.890', opposite to the majority of the other combinations. In fact, for those combinations, the trees subjected to No Stub'22+Stub3X'23 reported the highest TCSA than the other two treatments (data not shown).

Table 4. *'WA 38' combinations with 9 different rootstocks in October 2023: tree dimensions (height, widths, trunk circumference) were measured, and canopy volume, trunk cross sectional area, and trunk growth were calculated for all experimental trees. Significance: NS= not significant, * = p≤ 0.05, *** = p≤ 0.001 and letters of separation within each treatment were provided by SNK test. Trees were planted in 2022 at 11 ft x 3ft (1320 trees/A). TCSA = trunk cross sectional area, Growth 8 M= TCSA growth in 8 months, Canopy volume was calculated as a cone. Canopy widths were not reported.*

October 2023 measurements									
WA 38 rootstocks	**N=**	**TCSA (cm^2)**		**Growth 8M (cm^2)**		**Tree height (cm)**		**Canopy volume (m^3)**	
Bud9	18	7.0	D	3.4	D	278	F	1.1	F
B10	18	7.8	CD	4.3	C	290	EF	1.0	F
G11	18	8.7	C	4.7	C	303	DE	1.7	CDE
M9T337	18	8.7	C	4.5	C	311	CDE	1.4	E
G969	18	9.9	B	5.9	B	326	BCD	1.6	DE
G41	18	10.3	B	5.9	B	345	B	2.1	B
G935	18	10.3	B	5.7	B	332	BC	1.9	BC
G213	18	10.5	B	6.4	B	323	BCD	1.9	BCD
G890	18	12.8	A	7.3	A	375	A	3.0	A
Significance by root		***		***		***		***	
trt 2023									
No Stub'22+unpruned'23	45	9.6		5.3		327.6		2.0	A
No Stub'22+Stub3X'23	36	9.6		5.3		323.1		1.6	B
Stub'22+Click(STD)'23	81	9.5		5.3		315.1		1.6	B
Significance by trt23		*NS*		*NS*		*NS*		***	
*Significance rootstock*trt23*		*		** (p=0.0408)*		*NS*		*NS*	

Objective 2) Investigate the 'WA 38' fruit set in the different types of wood and assess the return bloom on the different bearing woods *(Musacchi-Serra)*

From harvest 2022, samples for quality analysis from the two sites where 'WA 38' was trained at spindle were stored for 3.5 months in RA storage. The different quality parameters across the locations were I_{AD}, firmness, and titratable acidity (Table 5). The first two parameters confirmed the same behavior as the previous year. Apples harvested from 'WA 38'/M9337-GS_Spindle_SRO site – regardless of the bearing wood – showed to be riper with lower firmness, lower $I_{AD,}$ and TA than apples from 'WA 38'/NIC29_Spindle _Quincy orchard (Table 5). Despite the lack of significance for yield and average apple mass in 2022 between the two sites (N apples/tree and kg/tree), SRO site showed a slightly lighter crop than Quincy (data not shown).

When comparing the 3 bearing woods – major interest for this analysis – firmness, SSC, and DM% did not differ in 2022, while they did in 2021. On the other hand, apples harvested from spur had a larger diameter and mass, higher N of healthy and mature seeds, and higher TA compared to apples from 'Ramo misto' and/or 'Brindilla' (Table 5). While in 2021 crop, apples borne on 'Brindilla' were smaller and had lower SSC and DM% than the other bearing woods, in 2022, this wood formation showed a lower apple mass and higher I_{AD} (less ripe). Regarding mature-healthy seeds/fruit, apples harvested from spurs showed an average of 8.7 good seeds/fruit, significantly higher than 7.8 good seeds in apples borne on 'Ramo misto' (Table 5). The latter bearing wood showed a delay in bloom compared to inflorescences on spurs and 'Brindilla' that can cause a slightly lower number of healthy and enduring seeds. In the two years of quality analysis comparing bearing woods, consistent trends for the internal parameters were not found. In the last year of data, DM% did not show differences among the 3 bearing woods, suggesting apples with a similar consumer eating quality. Further investigation would be needed in the future to test this hypothesis.

Table 5. *'WA 38' quality analysis after 3.5 months (M) of regular air 34°F storage from harvest 2022 for the locations 'WA 38'/NIC29_Spindle_QUINCY and 'WA 38'/M9337-GS_Spindle_SRO investigated in the 2021-2022 survey for objective 2. Sorting criteria for those apples were: only single (S) apples in the cluster, all best color, absence of defects and size range 216-339 g (80-64 apples/box). Significance: *= p≤ 0.05, ** = p≤ 0.01, *** = p≤ 0.001, NS= not significant and letters of separation within each treatment were provided by SNK test. DM% and TA have a different number of replications not corresponding to N apples reported.*

WA 38 harvest 2022 (obj. 2 survey)	*N apples*	Apple maximum diameter (mm)		Apple mass (g)		I_{AD} at 3.5M		Firmness (lb)		N mature-healthy seeds/tree		N underdeveloped seeds/tree		SSC (°Brix)	DM%	TA (% malic ac.)	
QUINCY	*90*	75.9		209		0.75	A	15.47	A	8.3		1.6		12.9	13.49	0.41	A
SRO	*78*	76.3		218		0.36	B	14.58	B	8.1		1.7		12.9	13.39	0.35	B
Significance location		NS		NS		***		***		NS		NS		NS	NS	***	
Brindilla	*55*	73.8	C	194	C	0.67	A	15.11		8.1	AB	1.6		12.8	13.24	0.36	B
Ramo Misto	*55*	75.9	B	212	B	0.54	B	15.05		7.8	B	1.9		13.1	13.45	0.36	B
Spur	*58*	78.4	A	233	A	0.50	B	15.01		8.7	A	1.4		12.8	13.62	0.40	A
Significance wood		***		***		***		NS		*		NS		NS	NS	**	
Significance location*wood		NS		NS		NS		NS		**		**		NS	NS	***	
QUINCY_B_S	*30*	74.2	c	191	c	0.85	a	15.34	a	8.67	a	1.27	b	12.8	13.28	0.37	b
QUINCY_RM_S	*30*	76.0	bc	212	bc	0.73	b	15.43	a	7.57	b	2.30	a	13.2	13.52	0.38	b
QUINCY_S_S	*30*	77.6	ab	224	ab	0.67	b	15.64	a	8.67	a	1.23	b	12.7	13.66	0.46	a
SRO_B_S	*25*	73.3	c	197	c	0.46	c	14.83	b	7.52	b	2.08	ab	12.9	13.20	0.36	b
SRO_RM_S	*25*	75.8	bc	212	bc	0.32	d	14.59	b	8.16	ab	1.36	b	13.0	13.38	0.34	b
SRO_S_S	*28*	79.3	a	242	a	0.31	d	14.34	b	8.68	a	1.61	ab	12.9	13.58	0.34	b
Significance combo		***		***		***		***		**		**		NS	NS	NS	

Objective 3) Investigate the cultural management practices developed in 'WA 38' private orchards and summarize them in a list of recommended guidelines for growers *(Lewis-Sallato)*

A total of nine commercial 'WA 38' blocks were selected in 2021 (Table 6). The selection considered the industry standard rootstocks; 'G.41', 'M.9, 'G.890', 'G.11' and 'Bud10' and prioritized locations with more than one rootstock for comparative analysis. Sites were monitored during bloom to rate bloom density and date, by the end of the growing season to measure max shoot growth, and at harvest to determine fruit yield, estimate crop load, and trunk cross sectional area. We collected photos and videos on each site/stage to develop a comprehensive database to share with WA growers and extension and outreach products. In addition, we interviewed 31 growers to understand the most common practices utilized in 'WA 38' orchards and continue assessing challenges and knowledge gaps to guide future efforts.

Table 6. *Sites of 'WA 38' monitored for Objective 3 in 2022-2023. Single Drip + Sprinklers =SD+S, Single Drip =SD, double drip=DD, overhead cooling =OC. All sites were planted at 12 ft row spacing and two leaders (Bi-Axis) training system.*

Site	Rootstock	Planting year	Year of first crop	Soil History	Training	Leader spacing (inches)	Irrigation	Heat mitigation
1	G41	2018	3rd	Replanted	Vertical – Bi-axis	30	SD+S	OC
2	M9-NIC29	2018	3rd	Replanted	Vertical – Bi-axis	30	SD+S	OC
3	G890	2018	3rd	Replanted	Vertical – Bi-axis	30	SD	Netting
4	M9-NIC29	2018	3rd	Replanted	Vertical – Bi-axis	30	SD	Netting
5	Bud10	2018	3rd	Replanted	Y Angle – Bi-axis	24	DD	Sprays
6	G.11	2017	3rd	New	Vertical-Bi-axis	30	SD+S	OC
7	M9-NIC29	2018	3rd	New	Vertical-Bi-axis	30	SD+S	OC
8	G41	2019	2nd	Replanted	Vertical- Bi-axis	30	SD+S	Sprays
9	M9-NIC29	2019	2nd	Replanted	Vertical- Bi-axis	30	SD+S	Sprays

Overall bloom density increased over the tree years, being generally high in 2022 and 2023, ranging between 68 and 244, higher than in 2022. However, fruit yield (number per tree) was more than 30% lower in three blocks (1, 2 'G.41' and 2 'M.9'), equivalent to the previous year, and only orchard 5 ('M.9-NIC29') was 30% higher, overall, it ranged between 37 and 141 fruit per tree (Figure 4). Note that growers were expecting higher crops as the trees filled the space. The changes in relation to the previous year appear to be more associated with the orchard than the rootstock, thus a response to environmental conditions or management. For example, in orchard 1, both 'G.41' and 'M.9' had lower fruit per tree, while in orchard 5, both 'G.41' and 'M.9-NIC29' slightly increased fruit yield.
In contrast, as a measure of fruit per trunk cross sectional area, crop load ranged between 3.8 and 6.9 was reduced in all combinations but orchard 5 (Figure 5).

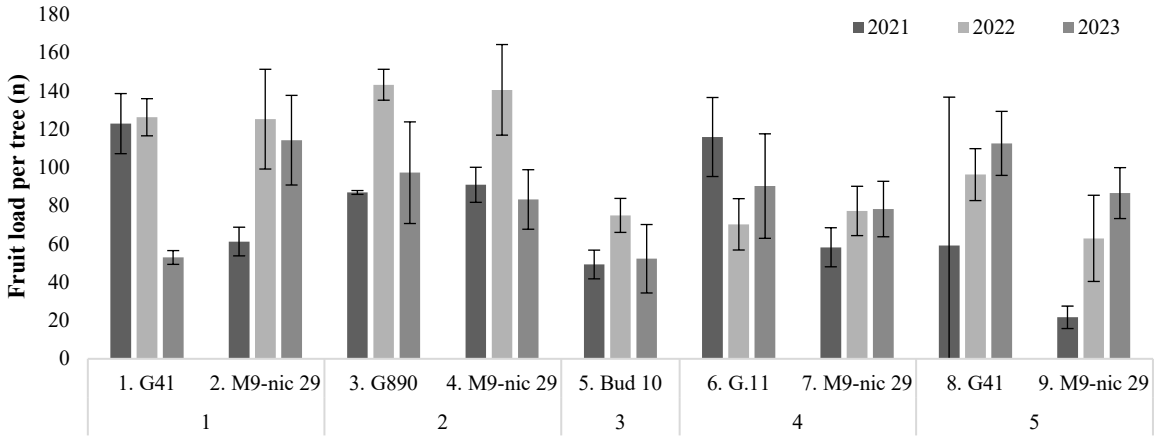

Figure 4. *Fruit load per tree for 2021, 2022, and 2023 by orchard (number) and rootstock. Bars indicate the mean value of 6 representative trees; error bars indicate standard deviation.*

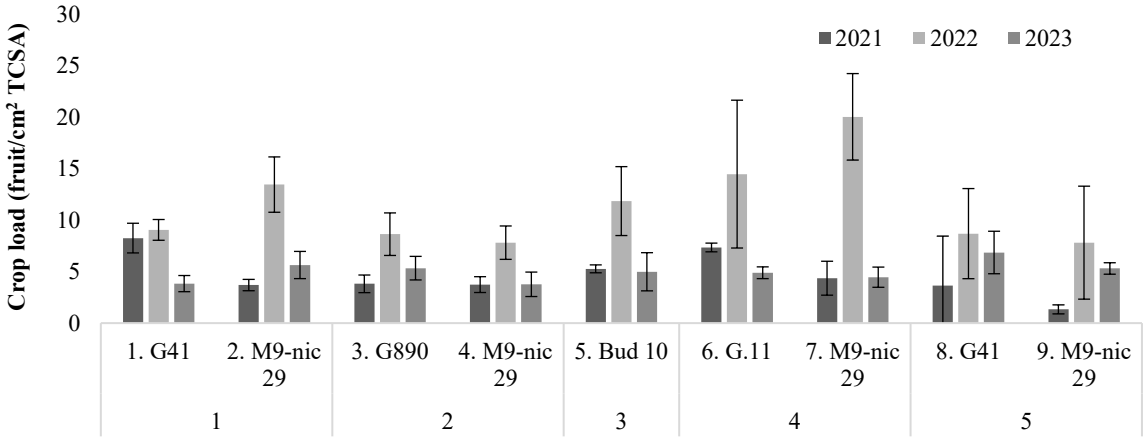

Figure 5. *Crop load (N fruit per trunk cross sectional area in cm^2) for 2021, 2022, and 2023 by orchard (number) and rootstock. Bars indicate the mean value of 6 representative trees, error bars indicate standard deviation.*

Survey results

With more than 20 million trees ordered, 'WA 38' on 'G.41' remains the most planted **scion-rootstock** combination (23%), followed by M9-337 (20%) and M9-Nic 29 (12%). In the last two years, 'G.969' and G11 were the second and third most ordered trees. Over half of the surveyed growers planted their 'WA 38' orchards at 3 x 12 ft (20%). Regarding **training system**, trees with two leaders (bi-axis) are the most popular (50%), trained vertically. Spindle trees were the second most popular choice, with

half of the trees trained on a V trellis. Only a quarter of the sites were three or more leader trees. Regarding the **pollinizers**, the density varied between 5 to 11%. The most popular are crabapple pollinizers: Everette, Snowdrift, and Indian Summer. Due to low crop load, several growers added more pollinizers after the third or fourth year. Most growers use double drip **irrigation** plus sprinklers (38%). Only 9 out of 31 blocks had drip only (29%). Four indicated the intention to add sprinklers (S) for better water coverage or sunburn or frost protection. Many growers started with no **sunburn mitigation strategies**; however, after 2021 heat events, 67% started using overhead cooling (OC). Two of the surveyed sites installed netting at planting. Most growers complemented these strategies with sunburn protectants (sprays) starting in June when temperatures are expected to be over 90 °F. **Summer pruning** is used by 34% of the surveyed sites. The timing varies among growers, but preferred time is during active shoot growth (end of May to end of July). Apogee® was used by 10% of the respondents. Among those adopting summer pruning, spraying sunburn protectants (i.e., Eclipse, Surround) was indicated as a practice after summer pruning. Except for two sites, all orchards have **cover crops** in the inter- row. One of 29 respondents thinned their 'WA 38' during bloom, but only for one year. Regarding challenges currently relevant for 'WA 38', the most mentioned is the low productivity (low fruit set, high drop). Among the practices adopted to increase set, 54% used supplemental pollen, either dusted, sprayed in solution, or placed in the beehives. Ten of them also sprayed ReTain® during bloom or after ten days. And 20% of them are using both Pollen + ReTain® as a standard practice.

New challenges in 2023 field days are bird damage control and identifying the best rootstock combinations.

Outreach/extension activities

A) Nine field days were organized: five in Spanish and four in English.

- October 13th, 2023: Covering vigor management, heat mitigation and harvest maturity (Sallato, Khot, Torres) (35 attendees)
- September 13th, 2023: 'WA 38' Pre-Harvest Field Day hosted by Musacchi, Serra, Lewis, Sallato (estimated 29 attendees). Looking at rootstock differences and pruning response, fruit set and bee exclusion by netting.
- July 20th, 2023: Dia de Campo en la Roza (Spanish). Field day in the WSU Experimental orchard Roza farm in Prosser in Spanish (16 attendees).
- October 19th, 2022: Actualización de conocimientos en 'WA 38' (Spanish), hosted by Sallato. We had 33 attendees and 23 responses to the survey. 81.6% indicated increased knowledge, and 83.3% intention to apply some of the learnings during the session. E.g., means for vigor control, summer pruning and irrigation, when to apply calcium. The highest-rated topics are soils-root-tree and general characteristics of 'WA 38'.
- September 15th, 2022: 'WA 38' Pre-harvest Field Day hosted by Musacchi, Serra, Lewis, Sallato. Invited presenter: Kalcsits. At the preharvest field day, we had 89 attendees. Of 22 respondents, over 93.4% indicated they were satisfied with the content. Learnings included: pruning, harvest timing, and maintaining vigor.
- July 5th, 2022: Día de campo en 'WA 38': Nutrición, vigor y estrés por calor. Sallato presenter (Spanish). WSU- Huerta la Roza, IAREC (10 attendees). Topics: Nutrition, vigor and heat stress).
- April 21st, 2022: Día de Campo 'WA 38'- Polinización y cuaja de fruta Sallato presenter (Spanish). Quincy and Royal City, (14 attendees). Topics: Pollination and fruit set.
- April 19th, 2022: Día de Campo 'WA 38'- Polinización y cuaja de fruta. Sallato presenter (Spanish). WSU Experimental orchard Roza farm in Prosser (16 attendees). Topics: Pollination and fruit set.
- Sept 17th, 2021: 'WA 38' research and harvest management update (attendees 115 in Sunrise and 95 in Quincy) hosted by Musacchi, Serra, Lewis, Sallato. A survey was conducted, and we obtained 30 responses (26%). The most interesting topics were associated with improving fruit set and the farm manager interview. Forty percent of the respondents indicated gained knowledge, and 27% indicated an intention to implement changes in their operation based on the information reported during the field day.

B) A "*'WA 38' SOP manual*" made of 8 independent chapters is currently in preparation, and it is forecasted to become available as a WSU Extension publication (each chapter independent from others) in Summer 2024.

GLOSSARY (Figure 6)**:**

A. 1X stub = residual portion of a pruning cut made on lateral branches, 1X stands for length of the remaining wood = 11 cm/4.3". Approach utilized after planting the first year in the "Stub" trt.
B. 3X stub = residual portion of a pruning cut made on lateral branches during the second year after planting, specifically stubbed at 3X length (33 cm/~1ft) as a "recovery approach."
C. Spur = 2+ year-old short and compact fruiting formation.
D. Brindilla = tip bearing 1-year-old shoot with vegetative lateral buds.
E. Ramo Misto = 1-year-old shoot bearing on lateral buds and on tip bud.

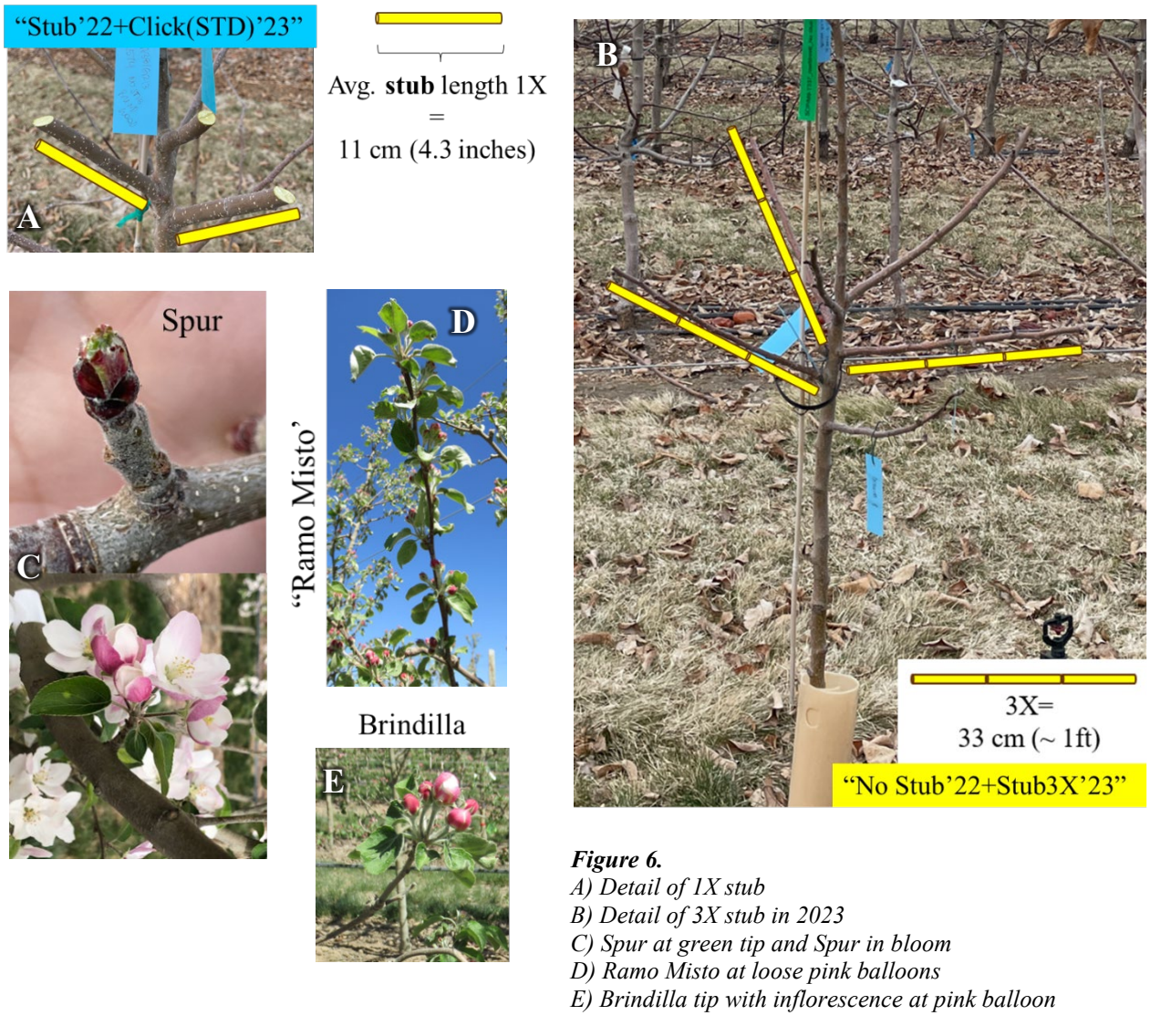

Figure 6.
A) Detail of 1X stub
B) Detail of 3X stub in 2023
C) Spur at green tip and Spur in bloom
D) Ramo Misto at loose pink balloons
E) Brindilla tip with inflorescence at pink balloon

Executive Summary

Project Title: **"WA 38: SOP from planting to cropping"**

Keywords: *blind wood, rootstocks, click pruning, bearing woods*

The overall goal of the project was to develop a protocol from orchard establishment to cropping for 'WA 38' in combination with 9 of the most popular and adopted rootstocks in WA: 'Bud9', 'Bud10', 'G.11', 'G.213', 'G.41', 'G.935', 'G.969', 'G.890', 'M.9-T337'. Due to poor quality trees originally planted and the severe heat waves that hit the PNW in June 2021, the orchard was replanted with well-feathered trees in April 2022, allowing us to plant 2 additional combinations.

With the first objective, we aimed to characterize the rootstock effect on blind wood, vegetative growth, flower buds formation, fruit set, and yield by comparing two contrasting scenarios: A) "No Stub" at planting and, B) "Stub" at planting; being the latter the recommended approach to minimize the blind wood for this variety. During the first season, the incidence of the blind wood (% blind portion of a branch over the total length of it) on unpruned basal branches of "No Stub" trees was significantly higher in combination with 'G.213', 'M.9-T337' and 'G.969', while smaller with 'G.11'. The effect of clicking or stubbing immediately after harvest allowed an overall reduction in the length of blind wood from 15.3 cm in the unpruned trees to 5.6 cm in the stubbed branches. Moreover, 64 to 85% of the nodes in the stubbed branch vegetated after the cut. Before the imposition of pruning at the end of March 2023, vegetative measures revealed that the smallest proportion of blind wood in the unpruned trees was found in combination with 'G.890' and 'G.11', while the largest incidence in M9-T337 and 'Bud10'. Regarding the flower bud (FB) formation, 'WA 38'/'Bud9' trees registered the highest average number of FB/branch (or stub with shoots) in both 2022 pruning scenarios, suggesting a specific trait of conferring early bearing for this rootstock. During pruning, a third treatment was added to the comparison between "No Stub 2022+2023" and "Stub2022+click2023"; this additional pruning approach had the purpose of following the evolution of not stubbed trees at planting but stubbed at 3X length during the second season as a sort of "recovery approach". Both pruning approaches in 2023 showed an impact on the number of flower clusters/trees in comparison to unpruned trees, but, at the end of the natural abscission window, the fruit set was not different between them. At harvest 2023, not all the combinations had bearing trees. In fact, 'WA 38'/'G.890' did not bear fruit at harvest, confirming the effect of a vigorous rootstock in delaying cropping. At the end of the 2023 season, trunk cross sectional areas across combinations allowed us to build our own WA tree vigor/size scale for 'WA 38' on the 9 rootstocks in trial, mimicking Cornell's one widely adopted for the Geneva series rootstocks. 'WA 38' vigor scale based on "Stub'22+Click'23" approach lists in ascending order of vigor the following rootstocks: 'Bud9'='Bud10'='G.11'='M.9-T337' < 'G.213'='G.935'='G.969'='G.41' < 'G.890'.

With the second objective, we investigated the different types of fruiting wood, and we surveyed that the 61-64% of the crop of 2 years was held on spurs (2+ year-old short fruiting formations), followed by 'Brindilla' (tip bearing 1-year-old shoots), and 'Ramo misto' (1-year-old shoots bearing on lateral buds). 'WA 38' as a natural fruiting habit is a type 4 variety characterized by an inclination to set fruit on 'Brindilla' in addition to spurs. Training systems and pruning styles are key factors in impacting the proportion of the different types of wood in the tree.

With the third objective, we explored the cultural management practices adopted and developed in 'WA 38' private orchards and summarized them in this report. Moreover, nine 'WA 38' field days were organized in 3 years. "'WA 38': SOP from planting to cropping" will become part of a WSU extension article collection made of 8 independent chapters with a forecasted publication in Summer 2024.

Future prospective:

The three treatments imposed in March 2023 ("No Stub'22+unpruned'23", "No Stub'22+Stub3X'23", "Stub'22+Click(STD)'23") will be further investigated with the goal of collecting information about the effectiveness of the "recovery approach" as a potential tool to rescue a 'WA 38' block and convert it to click pruning.