

FINAL PROJECT REPORT**YEAR:** 3 of 3 years**Project Title:** Field Evaluation of Pear Cultivars on Cold Hardy Quince Rootstocks**PI:** Todd Einhorn**Organization:** MSU**Telephone:** 517-353-0430**Email:** einhorn@msu.edu**Address:** Plant and Soil Science Building**Address 2:** 1066 Bogue St**City/State/Zip:** East Lansing/MI/48824**Co-PI (2):** Stefano Musacchi**Organization:** WSU-Wenatchee**Telephone:** 509-663-8181 ext. 236**Email:** Stefano.musacchi@wsu.edu**Address:** TFREC**Address 2:** 1100 N. Western Ave.**City/State/Zip:** Wenatchee/WA/98801**Cooperators:** Sara Serra, Kristal Dowell, Mike McCarthy, Dale Goldy**Total Project Request:** Year 1: \$58,110 Year 2: \$70,585 Year 3: \$84,421**Other funding sources**

None.

Budget 1: Todd Einhorn**Organization Name:** OSU-MCAREC**Telephone:** 541 737-4866**Contract Administrator:** Russell Karow**Email address:** Russell.Karow@oregonstate.edu

Item	2018	2019	2020
Salaries	5,536	5,702	8,810
Benefits¹	4,464	4,598	7,104
Wages²	1,300	1,300	1,300
Benefits	130	130	130
Equipment			
Supplies	0	5,500	7,500
Travel³	3,316	3,316	3,316
Miscellaneous			
Plot Fees⁴	5,000	5,000	5,000
Total	19,746	25,546	33,160

Footnotes:¹ Benefits were calculated from actual OPE rates (OSU technician). An annual increase of 3% was applied to years 2 and 3.² Wages are for a part-time employee to help with general maintenance during the season; 100 hours at \$13/hr. Part-time employee benefits are calculated at 10%.³ Travel is to cover mileage to plot for measurements and one trip per year (4 days) for Einhorn to travel to plots to perform pruning and training tasks and meet with S. Musacchi and grower collaborators (airfare was estimated at \$1,000 roundtrip, four nights hotel (\$150/night), car rental (\$500) and per diem (\$54/day).⁴ Plot fees are to compensate growers for land, resources, and fruit.

Budget 2 (Musacchi)**Organization Name: WSU-TFREC****Contract Administrator: Shelli Tompkins****Telephone: 509-293-8803****Email address: shelli.tompkins@wsu.edu**

Item	2018	2019	2020
Salaries	21,000	21,840	22,714
Benefits¹	8,364	8,699	9,047
Wages			
Benefits			
Equipment			
Supplies	0	5,500	10,500
Travel²	4,000	4,000	4,000
Plot Fees³	5,000	5,000	5,000
Miscellaneous			
Total	38,364	45,039	51,261

Footnotes:¹ Benefits were calculated from actual WSU rates. An annual increase of 3% was applied to years 2 and 3.² Travel is to cover mileage to plot for measurements to travel to plots to perform data collection³ Plot fees are to compensate growers for land, resources and fruit.

Objectives:

Evaluate vegetative and fruiting performance of Bartlett and d'Anjou pear trees on promising, cold-hardy quince rootstocks.

Significant Findings:

- Tree survival varied by rootstock and whether or not an interstem was used. At the OR site, 5 of 31 combinations had mortality rates greater than 30% and 13 (approx. 1/3rd) of the combinations had 0% mortality. At the WA site, survivability was higher; only 3 of 24 combinations tested had mortality rates exceeding 20% and 66% of the tested combinations had 0% mortality. Higher mortality in OR was partly due to the site having more direct grafted Bartlett trees and possibly due to gopher damage in the establishment year.
- Sources of mortality will require additional years to determine. Tree mortality was not always associated with a given scion (i.e., incompatibility).
- 8 of 24 combinations had a 20% or more trees struggling to grow in 2020 at WA. A similar scenario occurred in OR. A high proportion of trees with poor growth likely indicates incompatibility. Twelve combinations had no struggling trees.
- There is a wide range of trunk size variation across genotypes (a good overall indication of canopy size and vigor). Genotype and/or combination effects are beginning to show similarly at both sites. The trunk size range is similar from the weakest to most vigorous combinations and these generally agree between sites.
- Pruning weights were recorded at both sites in late winter 2019 and tree height exceeded 8' in 80% of the combinations, with the tallest combinations reaching ~10 ft. The OR site was not pruned after the 2019 season due to COVID and will be pruned in early March 2021. The WA site was pruned in 2020. Pruning weights varied across rootstocks and generally agreed with trunk size data.
- Nearly all quince rootstocks conferred precocity. Bartlett generally had more flower clusters in 2020 than 'd'Anjou'. The fact that the OR had two to three-fold more flower clusters than WA was because trees were not pruned in 2020 and thus had larger canopies with greater bearing potential. OR trees were hand thinned based on trunk size to balance the fruit to canopy ratio. Final fruit numbers per tree were not too dissimilar between sites; 'd'Anjou' trees generally had fewer than 10 fruit per tree and 'Bartlett' had 20 to 40 fruit per tree.
- 'd'Anjou' tree yield in 2020 was minor (1-4 kg/tree [2-9 lbs]). Bartlett yields were roughly double (averaging around 5kg [11 lbs] per tree with maximum yields of 7 kg [15 lbs per tree or 18 bins per acre based on the planting density]. Fruit size was good (typically between 200 and 250 g [80 to 90 fruit per box]).
- To date, three rootstocks appear very promising for dwarfing, precocity and productivity.

Results and Discussion:

Tables 1 and 2 report the percentages of failure trees (tree mortality) for each combination for WA and OR sites, respectively. At both sites, among the combinations with interstems, Anjou/68.002 had the highest mortality rate (Tables 1 and 2). Interestingly, Anjou/99.002 (direct graft) had the highest tree failure incidence in WA but not OR. For Bartlett/Comice, 68.002, 99.002 and 118.001 had the highest mortality in both WA and OR (Tables 1 and 2). However, Bartlett/99.002 direct grafts had 0% mortality at both sites. The highest proportion of trees struggling at the end of the 2020 season were Anjou/Comice/99.002 and Anjou/Comice/118.001 (60% and 36%, respectively) and Bartlett/Comice/118.001 and Bartlett/Comice/68.002 (37% and 31%, respectively). In summary, combinations of both varieties with Comice on CYD 68.002 resulted in the highest proportion of dead trees after more than 3 years from planting. Observed failure for many of these combinations occurred even in the presence of an interstem, indicating that, at least for some CYD accessions, Comice may be incompatible.

Table 1: Mortality data expressed as % failure at 17, 29 and 41 months from planting and percentage of trees struggling in November 2020 for both Anjou and Bartlett grafted on 9 different quince accessions in Entiat (WA) (table sorted by cv and CYD acc. #).

Cv	Quince rootstock	Interstem	Count of tree planted (06/06/2017)	Count of tree alive+struggling (11/12/19)	Count of alive +struggling (11/10/20)	Count of dead trees (11/10/20)	Count of struggling trees (11/10/20)	% failure in 17M	% failure in 29 M	% failure in 41 M (2020)	% healthy and alive in 41 M (Nov 2020)	% struggling trees in (Nov 2020)
Anjou	22.001	Comice	22	22	22			0	0	0	100	0
Anjou		None	20	20	20		4	0	0	0	80	20
Anjou	23.001	Comice	12	12	12			0	0	0	100	0
Anjou		None	17	17	17			0	0	0	100	0
Anjou	57.001	Comice	17	17	17			0	0	0	100	0
Anjou		None	11	10	10	1		9	9	9	91	0
Anjou	65.001	Comice	17	17	17			0	0	0	100	0
Anjou		None	12	12	12			0	0	0	100	0
Anjou	68.002	Comice	14	9	8	6	3	0	36	43	36	21
Anjou		None	39	33	33	6	5	13	15	15	72	13
Anjou	70.001	Comice	13	12	12	1	1	8	8	8	85	8
Anjou		None	42	42	42		25	0	0	0	40	60
Anjou	99.002	Comice	12	2	2	10		67	83	83	17	0
Anjou		None	11	10	10	1	4	9	9	9	55	36
Anjou	118.001	Comice	10	10	10			0	0	0	100	0
Anjou		None										
Bartlett	22.001	Comice	24	24	24		1	0	0	0	96	4
Bartlett	23.001	Comice	12	12	12			0	0	0	100	0
Bartlett	57.001	Comice	15	15	15			0	0	0	100	0
Bartlett	65.001	Comice	17	17	17			0	0	0	100	0
Bartlett	67.001	Comice	13	13	13		2	0	0	0	85	15
Bartlett	68.002	Comice	16	12	8	8	5	25	25	50	19	31
Bartlett	70.001	Comice	29	29	28	1	7	0	0	3	72	24
Bartlett	99.002	Comice	54	49	42	12	10	9	9	22	59	19
Bartlett		None	10	10	10			0	0	0	100	0
Bartlett	118.001	Comice	35	35	29	6	13	0	0	17	46	37
Bartlett		None										
		total	477	444	425	52	80	5	7	11	72	17

Table 2: Mortality data from Parkdale (OR) through January 2021 for both Anjou and Bartlett grafted on 9 different quince accessions (table sorted by cv and CYD acc. #).

Cv	quince rootstock (CYD accession)	type of graft	Count of trees planted June 2017	Count of alive trees Jan 2019	Count of alive trees Jan 2020	Count of alive trees Jan 2021	%Mortality 2017-2021	
ANJOU	22.001	Comice	22	22	22	22	0	
		Direct graft	22	22	22	22	0	
	23.001	Comice	12	11	11	11	8	
		Direct graft	10	10	10	10	0	
	57.001	Comice	17	15	14	14	18	
		Direct graft	10	10	10	10	0	
	65.001	Comice	20	20	20	20	0	
		Direct graft	13	12	12	12	8	
	67.001	Comice	12	12	12	12	0	
	68.002	Comice	15	14	10	8	47	
	70.001	Comice	42	42	42	42	0	
		Direct graft	10	9	9	9	10	
	99.002	Comice	56	55	54	53	5	
		Direct graft	12	11	11	11	8	
	118.001	Comice	11	10	10	10	9	
		Direct graft	10	7	7	5	50	
	BARTLETT	22.001	Comice	24	24	24	24	0
			Direct graft	15	15	15	15	0
23.001		Comice	12	12	12	12	0	
		Comice	16	16	16	16	0	
57.001		Direct graft	14	13	13	13	7	
		Comice	19	19	19	19	0	
65.001		Direct graft	11	9	9	9	18	
		Comice	14	13	13	13	7	
67.001		Comice	16	15	15	11	31	
70.001		Comice	43	41	41	41	5	
		Direct graft	16	15	14	14	12	
99.002		Comice	57	37	34	30	47	
		Direct graft	12	12	12	12	0	
118.001		Comice	48	41	39	29	40	
		Direct graft	12	11	11	11	8	

Table 3: 2019-2020 winter pruning (kg/tree) and cumulative pruning weights (2018-2020) in Entiat (WA) for Anjou and Bartlett with Comice interstems grafted on 9 different quince accessions (table sorted by cv and CYD acc. #).

Cultivar	Rootstock	Interstem	Pruned Weight (kg/tree) 2019		Count of reps 2020	Pruned Weight (kg/tree) 2020		Pruned weight in 3 years 2018-2020 (kg/tree)	
d'Anjou	22.001	Comice	0.34	ab	3	0.49		0.91	ab
	23.001	Comice	0.44	a	3	0.50		1.04	a
	57.001	Comice	0.39	a	4	0.50		1.02	a
	65.001	Comice	0.42	a	3	0.62		1.15	a
	67.001	Comice	0.27	ab	3	0.51		0.80	ab
	68.002	Comice	0.11	b	3	0.23		0.36	b
	70.001	Comice	0.21	ab	7	0.31		0.54	ab
	99.002	Comice	0.28	ab	4	0.33		0.66	ab
	118.001	Comice	0.19	ab	3	0.32		0.52	ab
Significance			**			NS (0.0597)		**	
Bartlett	22.001	Comice	0.58	ab	8	0.67	ab	1.37	ab
	23.001	Comice	0.57	ab	3	0.70	ab	1.38	ab
	57.001	Comice	0.58	ab	3	0.70	ab	1.44	ab
	65.001	Comice	0.68	a	3	0.84	a	1.67	a
	67.001	Comice	0.32	bc	4	0.47	abc	0.83	bc
	68.002	Comice	0.19	c	3	0.16	c	0.37	c
	70.001	Comice	0.37	bc	4	0.52	abc	0.91	abc
	99.002	Comice	0.42	abc	10	0.52	abc	1.00	abc
	118.001	Comice	0.18	c	6	0.27	bc	0.46	c
Significance			***			**		***	
Combinations on direct graft (interstem= none) have been excluded from statistical analysis. Significance: *, p<0.05, **, p<0.01, ***, p<0.001, NS= not significant. Letters separate means in combination with interstem by SNK for (alpha=0.05).									

Pruning weights were calculated as the total weight of wood removed per plot, then divided by the number of trees pruned in the plot to account for differences in tree numbers. Data are presented as wood removed in kg/tree. Pruning data for 2020 are only provided for WA; OR trees were not pruned due to travel restrictions that prohibited the scheduled pruning in late March. Previous pruning data from OR can was reported in earlier 2018 and 2019 reports. Relatively little wood was removed in 2020 on a tree basis in WA. However, significance was detected for Bartlett combinations with interstems (Table 3). The most vigorous combinations were Bartlett/Comice/65.001, and the least vigorous combination was Bartlett/Comice/68.002. There were no differences in 2020 pruning weights for 'd'Anjou' combinations. Three-year-cumulative weight data, however, did reveal differences in vigor across the 9 rootstock-interstem combinations (Table 3). Overall, the most vigorous combinations were Anjou/Comice/23.001, Anjou/Comice/57.001, Anjou/Comice/65.001. Anjou/Comice/68.002 was the least vigorous. Because some combinations had a high portion of their total trees categorized as failing on direct graft, these were not included in the analysis.

Trunk cross sectional areas (TCSA) of scions measured in November 2020 at 10 cm above the graft union (always on the scion) are reported in Figures 1 and 2.

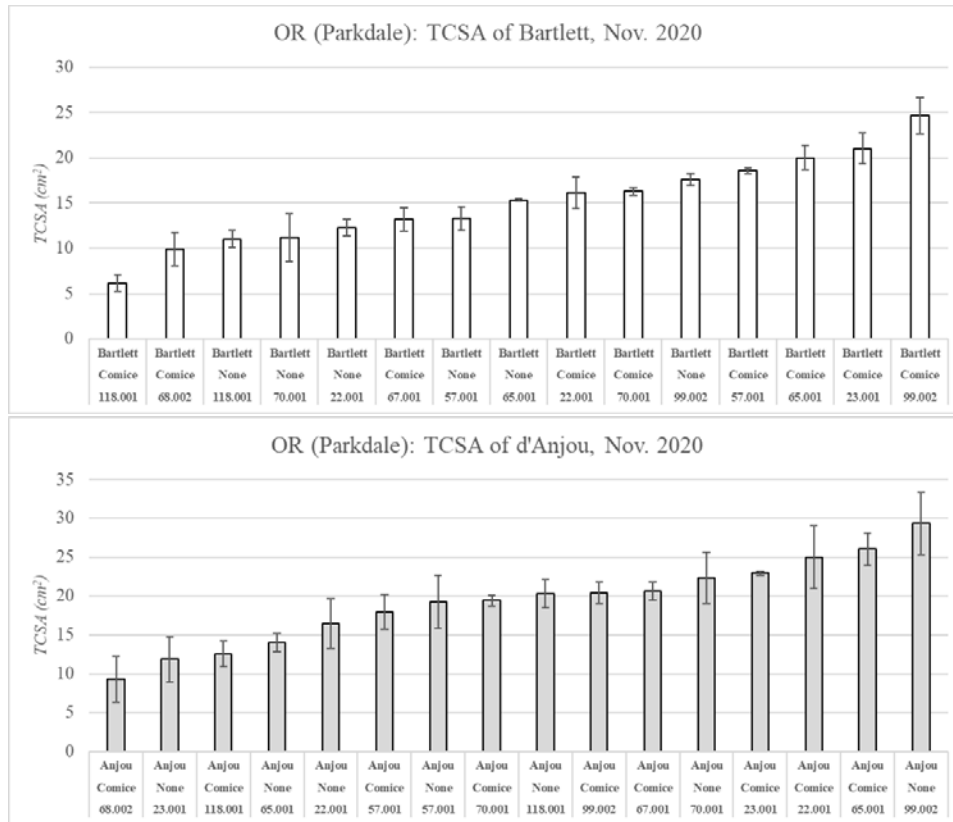


Figure 1: Trunk cross sectional area (TCSA) measured November 2020 with for Bartlett (A) and d'Anjou (B) grafted with Comice interstem on 9 different quince accessions in Parkdale (OR). Data are sorted by ascending TCSA for each variety. Bars are $\pm 1SE$.

There was roughly a three-fold difference in tree sizes across the 9 rootstock combinations at each site (Figs. 1 and 2). For a given genotype, trees in OR were generally much larger than WA and this was especially true for vigorous combinations (Figs. 1 and 2). We attribute this difference to climate and soil differences between sites (more precipitation and higher organic matter content in Parkdale than Entiat). The more vigorous and less vigorous combinations were similar between sites with some exceptions. For OR, 99.002 produced the largest trees and 65.001 and 23.001 were similarly vigorous between cultivars. 118.001 and 68.002 were the weakest trees. In WA, the largest trees were on Comice/65.001 and Comice/57.001, and the smallest trees were on Comice/68.002 and Comice/118.001, irrespective of the scion cultivar (Figure 2). The low vigor of Anjou/Comice/68.002 was similarly shown by pruning weight data (Table 3). In November 2020, a vigor evaluation was conducted in WA, assigning a score from 1 to 5 to trees still alive (a score of 1 equates to very low vigor/struggling and 5 equals high vigor). This evaluation confirmed results from other vegetative parameter data: Anjou/Comice/65.001 and Anjou/Comice/57.001 were the strongest trees and Anjou/Comice/99.002, 118.001, and 68.002 were the weakest (data not shown). A very similar trend was reported for Bartlett with Comice interstem (data not shown).

Suckering was observed in nearly all combinations with Comice interstem in WA, although ~78% of combinations (with interstems) had only 3 or fewer suckers/tree. Comice/67.001 had the highest number of suckers (approximately 10/tree), significantly higher than all the other combinations and Comice/23.001, 70.001, and 118.001 had the fewest. Similar results were documented in OR (data not shown here but was included in earlier reports).

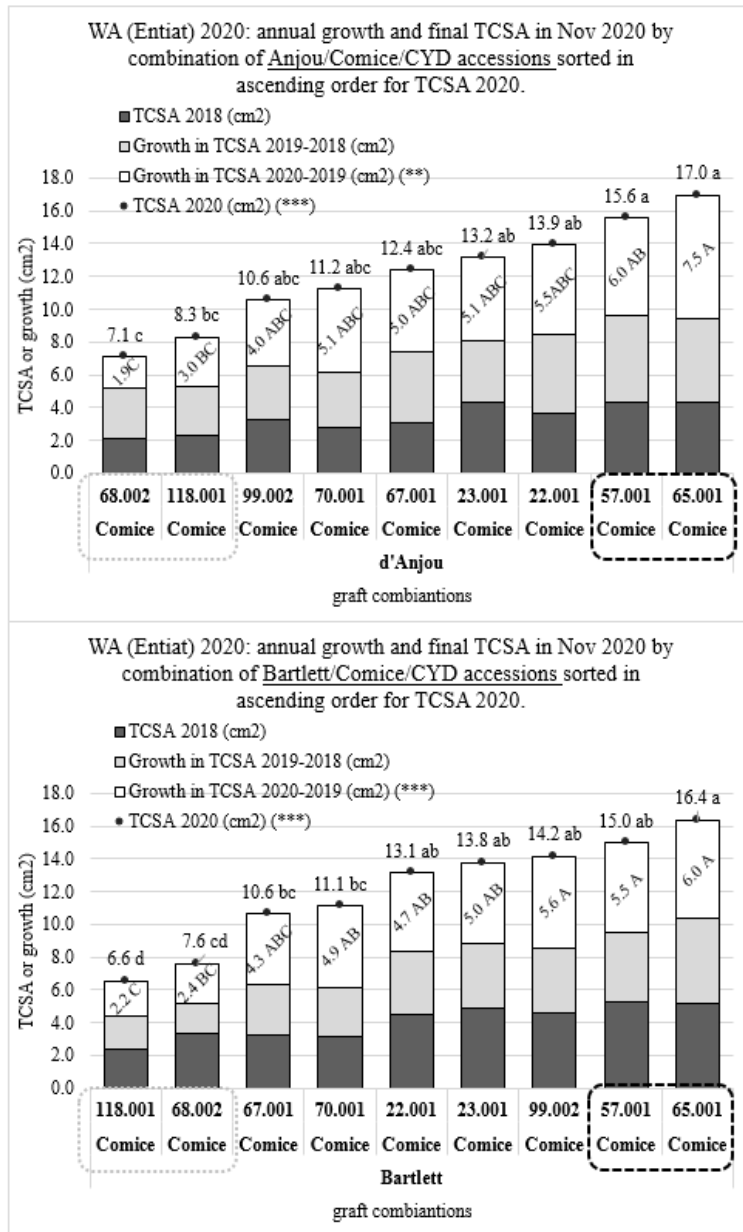


Figure 2: Annual growth and trunk cross sectional area (TCSA) in 2020 with historical data for 2018 and 2019 for Anjou (A) and Bartlett (B) grafted with Comice interstems on 9 different quince accessions in Entiat (WA). The chart is sorted by ascending TCSA 2020 for each variety. Accessions with the highest (57.001 and 65.001) and lowest (118.001 and 68.002) TCA were the same for each cultivar .

In spring of 2020, we counted flower clusters to estimate the precocity of the 9 rootstocks. Flower cluster counts were performed at both sites. No statistically significant differences emerged from the assessment across the 9 CYD accessions given high variability between young trees, however, cultivar differences were clear. The average number of clusters was between 23 and 82 for Anjou and 48 to 280 for Bartlett (Tables 4 and 5). The markedly higher number of flower clusters for Bartlett was observed at both sites, but >100 clusters per tree were only observed in OR since those trees had not been pruned and thus had significantly greater fruiting wood (Table 5). The amount of wood did not necessarily correlate to the number of clusters (Table 5). Hand thinning was performed in OR to balance

the crop load thereby resulting in a similar number of fruit per tree as WA (Tables 4 and 5). On 17-April 2020, the percentage of clusters in full bloom was higher in Anjou than in Bartlett (81% and 15% respectively on average) but there was no difference found among combinations in bloom timing for a given cultivar. In general, Bartlett fruit set was more than 4-fold higher than Anjou (6.9% and 1.6%, respectively). No tendency of a specific rootstock having an effect on fruit set was observed. Secondary (late) bloom was also assessed in WA given its relationship with fire blight infection. Despite the lack of statistically significant differences, some combinations tended to show a higher secondary bloom at the end of May (for example, Bartlett/Comice/23.001, 65.001, 118.001). Another period of secondary bloom was observed in August 2020, with the combination Bartlett/Comice/118.001 having the highest average number of secondary blooms per tree (Table 4).

Table 4: Bloom, fruit set, bloom timing and secondary bloom characteristics in spring 2020 in Entiat (WA) for Anjou and Bartlett with Comice interstem grafted on 9 different quince accessions (table sorted by cv and CYD acc. #).

Cultivar	Interstem	Rootstock	Rep N (for cluster count)	Num flower clusters/tree (4/17/20)	% Clusters in full bloom/tree (04/17/20)	Num fruit/tree (05/28/20)	% Fruit set on total flowers (05/28/20)	Num secondary bloom clusters/tree (5/28/2020)	Num secondary bloom clusters/tree (8/19/2020)
d'Anjou	Comice	22.001	3	73	90.7	6	1.7	0.3	1.3
	Comice	23.001	3	36	69.4	5	1.5	0.3	0.0
	Comice	57.001	3	26	61.8	7	3.6	0.7	0.0
	Comice	65.001	3	26	73.2	3	1.9	0.0	0.0
	Comice	67.001	3	62	91.2	6	1.1	0.7	0.0
	Comice	68.002	3	56	84.0	5	1.6	0.7	0.3
	Comice	70.001	3	25	88.2	1	0.8	0.0	2.0
	Comice	99.002	3	34	89.3	2	1.0	0.0	0.0
	Comice	118.001	3	60	78.6	5	1.4	1.0	0.0
Significance				NS	NS	NS	NS	NS	NS
Bartlett	Comice	22.001	3	59	15.2	22	6.3	1.3	0.3
	Comice	23.001	3	96	15.7	21	5.4	2.0	0.0
	Comice	57.001	3	74	16.6	26	6.5	1.3	1.0
	Comice	65.001	3	66	26.1	23	6.7	2.0	0.0
	Comice	67.001	3	74	25.3	21	5.3	1.7	0.3
	Comice	68.002	3	61	6.0	19	7.7	0.7	0.0
	Comice	70.001	3	50	8.7	22	6.0	1.0	1.0
	Comice	99.002	3	48	13.6	18	9.2	0.7	0.0
	Comice	118.001	3	48	10.1	25	8.8	2.0	2.3
Significance				NS	NS	NS	NS	NS	NS

Fruit set did not differ among the rootstocks and fruit numbers per tree ranged between 1-17 for Anjou and 16-44 for Bartlett when averaging across sites (Tables 4 and 5). Further observations and assessments on return bloom, rootstock induced precocity and fruit set will require further investigation in the following years.

The 2020 harvest represented the first crop for both cultivars since blocks were established in 2017. Although this is the 4th leaf, trees were restarted in their second leaf due to poor uniformity and small tree size; thus, trees were easily one year behind. Bartlett were harvested 20-Aug and 3-Sep in WA and OR, respectively and Anjou were harvested 3-Sep and 6-Oct in WA and OR, respectively. Harvests were performed at commercial timings for the farms they were located. Tree yield was markedly lower for Anjou than Bartlett at both sites (Figs. 3 and 4), as would have been predicted from bloom and fruit set data as well as the inherent differences in precocity between the two cultivars. Trees have largely filled the orchard space and are expected to achieve high yield potential in 2021. Fruit size was very good for both cultivars and sites, particularly for first-crop fruit (~200-250 g) and supports the well-known benefit of quince rootstocks for imparting large fruit size to pear. Statistical differences

among rootstocks was not detected within cultivar in WA, likely due to the variability associated with young trees. Similar variability was also observed in OR (see error bars, Figure 4). In WA, the combinations that produced greater than 1.5 kg/tree of Anjou were Comice/118.001 (despite producing the smallest trees) and Comice/57.001. Tree yields were ~double in OR but these two rootstocks also produced the highest yield (~4kg per tree; Fig 4). In WA, Comice/70.001 resulted in the least productive of all 9 combinations, with below 1 kg/tree on average and was similarly low in OR, though not the lowest (Figs. 3 and 4).

Table 5: Vegetative growth, bloom, fruit set, number of fruit thinned and fruit per tree in spring 2020 in Parkdale (OR) for Anjou and Bartlett with Comice interstem grafted on 9 different quince accessions (table sorted by Total length of 1 yr shoots in meters). Trees were not pruned after 2019 harvest due to covid restrictions that limited the PI from traveling to OR, hence the larger canopies and greater bloom compared with WA.

Scion	Rootstock	Interstem	No. of 1yr old	Total length 1yr	No. clusters	No.	% Fruit Set	No.Fruit per tree
			Shoots	shoots (m)		Fruit Thinned		
			3/15/2020	3/15/2020	5/13/2020	6/17/2020	6/17/2020	6/17/2020
d'Anjou	23.001	None	26.7	3.4	72.0	1.0	10.9	5.2
	68.002	Comice	29.0	7.4	39.7	2.3	23.8	12.3
	65.001	None	30.6	7.8	54.0	1.0	4.5	2.0
	118.001	Comice	27.3	9.0	34.3	1.0	24.8	11.8
	22.001	None	42.6	10.8	46.5	2.0	10.2	6.1
	118.001	None	41.3	11.8	69.0	19.0	21.9	14.8
	57.001	Comice	50.0	16.2	59.0	3.0	8.5	5.7
	57.001	None	67.3	17.6	73.8	2.3	19.2	12.8
	67.001	Comice	55.0	17.9	82.3	3.8	16.5	17.8
	23.001	Comice	63.2	18.7	33.6	0.0	6.8	3.0
	70.001	Comice	54.5	19.5	38.2	1.9	11.9	4.7
	65.001	Comice	67.3	20.3	46.7	0.0	4.7	1.8
	70.001	None	64.7	20.9	23.2	0.0	11.0	6.5
	22.001	Comice	67.6	22.2	59.0	1.0	9.0	3.7
	99.002	Comice	62.4	24.7	46.1	2.0	13.0	4.5
	99.002	None	78.5	27.0	69.8	2.3	11.5	8.8
Bartlett	118.001	Comice	11.8	4.1	66.3	7.8	28.9	16.3
	68.002	Comice	30.9	9.0	137.1	7.4	15.3	17.4
	22.001	None	42.8	12.5	212.2	19.4	16.0	22.9
	118.001	None	40.8	12.5	211.8	25.0	24.9	28.2
	67.001	Comice	38.0	13.7	126.4	7.9	22.8	19.3
	70.001	None	51.4	14.6	169.9	25.6	36.4	33.9
	99.002	None	54.4	15.9	272.9	17.8	20.5	32.2
	22.001	Comice	44.3	16.5	220.7	12.7	19.7	27.8
	70.001	Comice	52.9	19.9	128.7	11.7	35.2	30.6
	57.001	Comice	50.4	20.4	204.7	10.9	22.1	31.1
	23.001	Comice	50.0	20.7	199.4	11.3	27.1	38.1
	57.001	None	63.2	23.4	281.2	31.4	23.7	32.4
	65.001	Comice	57.7	24.0	225.6	16.6	23.7	35.3
	65.001	None	61.8	24.1	285.5	21.5	22.3	25.2
	99.002	Comice	61.0	28.2	209.8	17.5	27.2	44.0

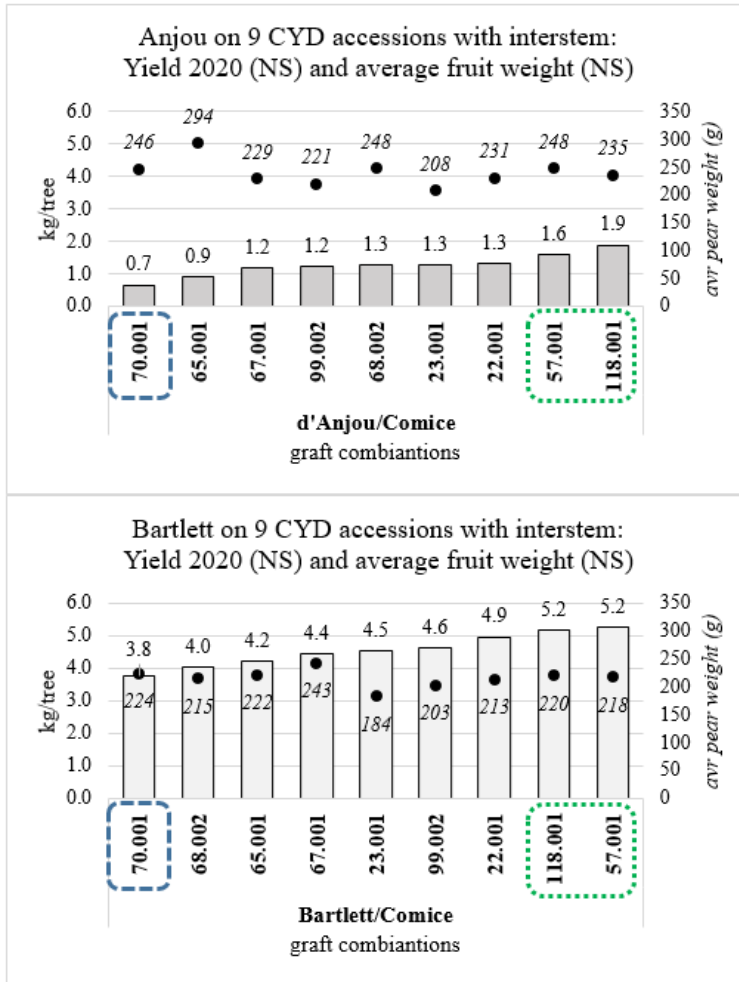


Figure 3: First crop yield data 2020: kg fruit/tree and average pear weight (g) for Anjou (A) and Bartlett (B) grafted on 9 different quince accessions in Entiat (WA). The chart is sorted by ascending yield/tree for each variety. Within a cultivar differences in either measure were not significant (NS). Dashed boxes on the x-axes show consistency in rootstock performance between cultivars.

As previously stated, Bartlett yields were markedly higher than Anjou. In WA, similar rootstock-yield trends were evident for Bartlett as observed with Anjou (Comice/57.001 and Comice/118.001 produced the highest yields) but this was not observed in OR. Again variability in young trees, relatively few trees and replicates, and the fact that this was the first crop made it difficult to determine treatment (rootstock) effects. Despite the relatively low first-crop yields, a yield of 30 Bartlett pears per tree (average across rootstocks in OR) produced ~15 lbs per tree, or 18 bins per acre at the tree density of the plantings (Fig. 4). The large fruit sizes reported were not affected by crop loads across the nine rootstocks, however a few rootstocks did produce small fruit size (<200 g), and this may be an indicator of future issues. In OR, 118.001 had both the lowest yield and fruit weight (for Bartlett). In WA, combinations with Comice/23.001 had the lowest numerical average fruit weight (Fig. 3).

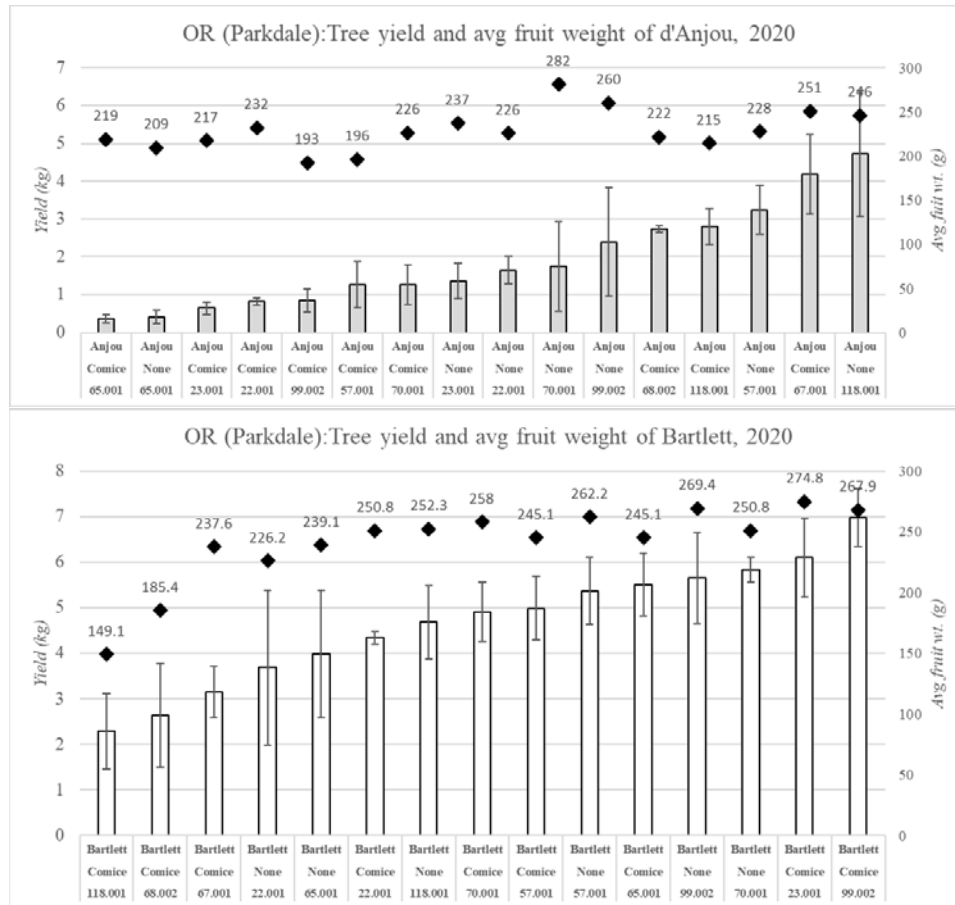


Figure 4: First crop yield data 2020: kg fruit/tree and average pear weight (g) for Anjou (A) and Bartlett (B) grafted on 9 different quince accessions in Parkdale (OR). The chart is sorted by ascending yield/tree for each variety. Bars on tree yield data are $\pm 1SE$.

In WA, fruit quality was analyzed for Bartlett combinations following 2.5 months of regular air (RA) cold storage and a 7-day (room temperature) ripening treatment; Anjou were not evaluated due to an insufficient number of fruit. In OR, Bartlett fruit quality was evaluated at harvest and after 1 month RA postharvest cold storage and a 7-day ripening period and Anjou fruit analysis only occurred following 3 months RA cold storage and a 7-day ripening period, again due to lower Anjou yield. A minimum of 14 days and 60 days cold storage is necessary to induce ripening capacity of Bartlett and Anjou, respectively, following exposure to room temperatures. Bartlett fruit quality data from WA are summarized in Table 6, for the most interesting parameters: average pear weight at harvest, pear weight drop during cold storage, pear weight drop during the 7 days of ripening at room temperature, I_{AD} (by DA meter) at harvest, I_{AD} drop during cold storage, I_{AD} drop during the 7 days of ripening at room temperature, firmness, soluble solids content (SSC), titratable acidity (TA), and pH. Despite the narrower range of pear size selected for instrumental quality analysis (in order to eliminate the confounding effects of fruit size on fruit quality attributes), significant differences in terms of weight and weight drop emerged. In particular, Bartlett/Comice/70.001 pears had the highest average fruit weight, and the greater losses in weight in both intervals (up to 5% of their initial weight; Table 6). The other combinations did not differ with respect to fruit weight loss. Differences in fruit maturity were observed across the rootstocks with Bartlett/Comice/68.002 and 70.001 appearing riper (1.90 and 1.94 I_{AD} respectively) than others (which averaged 2.03 to 2.13) based on the non-destructive DA meter

assessment (Table 6). After 7 days of ripening, Bartlett/Comice/68.002 and 70.001 pears showed the lowest drop in I_{AD}, probably reflecting their more advanced maturity stage at the time of harvest with respect to Bartlett/Comice/118.001, which had the highest I_{AD} drop in 7 days, and one of the highest value at harvest (Table 6). Bartlett/Comice/118.001 also had the lowest SSC among the 9 combinations (11.7 °Brix) and Bartlett/Comice/65.001 had the highest SSC (15.3 °Brix) which was similar to Bartlett/Comice/68.002 (14.9 °Brix). The wide range of SSC needs to be confirmed in the future to determine if specific CYD accessions have an impact on fruit quality. Titratable acidity (TA) and pH between were statistically similar among the 9 combinations evaluated in WA (Table 6).

Table 6: Bartlett fruit quality carried out October 2020 (2.5 months after harvest and RA storage) for all 9 combinations with Comice interstem. Fruit (N=15) were selected in size range 70-75 mm for Entiat WA.

CV/interstem	CYD	N=	Avr. pear weight (g) at harvest		Weight drop (g) harvest-T0 day1		Weight drop (g) in 7 days RT		I _{AD} at harvest		I _{AD} drop harvest-T0 day1		I _{AD} drop in 7 days RT		Firmness (kg) (day7)		SSC (Brix) (day7)		TA (% ac. malic) (day7)	pH (day7)
			232	ABC	3.6	B	10.6	AB	2.13	A	0.52	AB	1.43	ABC	0.89	A	13.7	B	0.59	3.70
Bartlett/Comice	22.001	15	232	ABC	3.6	B	10.6	AB	2.13	A	0.52	AB	1.43	ABC	0.89	A	13.7	B	0.59	3.70
Bartlett/Comice	23.001	15	213	C	3.5	B	10.3	B	2.11	A	0.55	AB	1.43	ABC	0.92	A	13.7	B	0.48	3.84
Bartlett/Comice	57.001	15	238	AB	3.6	B	9.9	B	2.03	AB	0.57	AB	1.33	BCD	0.95	A	13.4	B	0.52	3.73
Bartlett/Comice	65.001	15	242	AB	4.1	B	11.7	AB	2.05	A	0.59	A	1.36	ABCD	0.89	A	15.3	A	0.46	3.79
Bartlett/Comice	67.001	15	237	ABC	3.6	B	10.1	B	2.07	A	0.58	A	1.39	ABCD	0.81	A	13.2	B	0.47	3.79
Bartlett/Comice	68.002	15	236	ABC	4.0	B	10.1	B	1.90	C	0.57	AB	1.27	CD	0.91	A	14.9	A	0.47	3.75
Bartlett/Comice	70.001	15	250	A	5.1	A	12.4	A	1.94	BC	0.62	A	1.24	D	0.85	A	13.9	B	0.50	3.71
Bartlett/Comice	99.002	15	222	BC	3.8	B	11.2	AB	2.11	A	0.47	B	1.48	AB	0.89	A	14.1	B	0.51	3.77
Bartlett/Comice	118.001	15	236	ABC	4.3	B	11.4	AB	2.11	A	0.46	B	1.51	A	0.64	B	11.7	C	0.47	3.77
<i>Significance</i>			**		***		**		***		***		***		***		***		NS	NS

Bartlett harvest: 08/20/20. Harvest-T0 day1=2.5 month in storage at 33F RA. Destructive analyses were done after ripening for 7 days at room temperature (RT). Firmness as avr. of 2 cheeks in the more external pear cortex layer. SSC= soluble solids content in Brix degree. TA and pH means are averages of 3 juices/combo (N=3, not single fruit).
Significance: **= $p < 0.01$, ***= $p < 0.001$, NS=not significant. Post doc letters separation by SNK for alpha=0.05. Same letters identify similar means for each parameter and column.

In OR, there were only minor differences among rootstocks for fruit quality attributes of Anjou (data not shown to conserve space). These were deemed unimportant given the relatively low yields. For Bartlett, fruit were harvested at the appropriate commercial maturity range (i.e., ~19 lbs FF). Maturity did not appear to be affected by rootstock and all fruit ripened to acceptable eating quality (<4 lbs FF), though direct grafted Bartlett to 22.001 was numerically more firm than other treatments (Table 7). The range in SSC was 11.7 to 14.2 with most fruit having a SSC of ~12.5. TA levels were not affected by treatment and remained relatively high following cold storage and ripening, though this would be expected from the short PH storage period.

Table 7: 2020 Anjou fruit quality attributes measured after a postharvest (PH) cold storage period of 3 months and a 7-day ripening period and Bartlett fruit quality carried out at harvest and again following 1 month of cold storage and a 7-day ripening period, Parkdale (OR).

Scion	Rootstock	Interstem	2020	2020	2020	2020	2020	2020
			Harvest FF (lb)	Harvest SS (%)	Harvest TA (%)	PH FF (lb)	PH SS (%)	PH TA (%)
	22.001	Comice	19.3	12.1	0.41	2.3	12.7	0.37
	22.001	None	20.3	13.8	0.41	4.4	15.2	0.37
	23.001	Comice	19.1	11.7	0.37	2.2	12.8	0.39
	57.001	Comice	19.3	11.9	0.44	2.1	13.1	0.37
	57.001	None	19.9	13.2	0.39	2.2	14.2	0.40
	65.001	Comice	19.2	12.4	0.42	2.3	13.1	0.44
	65.001	None	21.4	13.3	0.38	2.4	14.2	0.39
Bartlett	67.001	Comice	20.6	12.4	0.40	2.4	13.6	0.38
	68.002	Comice	18.3	14.2	0.47	2.3	15.2	0.44
	70.001	Comice	20.0	12.0	0.37	2.1	12.8	0.36
	70.001	None	20.0	13.5	0.32	2.5	14.3	0.39
	99.002	Comice	19.6	12.7	0.39	2.3	13.8	0.38
	99.002	None	20.2	12.6	0.40	2.2	13.2	0.41
	118.001	Comice	20.2	12.5	0.40	2.2	13.0	0.40
	118.001	None	20.1	12.7	0.37	2.3	13.4	0.38

Executive Summary

Project title: Field Evaluation of Pear Cultivars on Cold Hardy Quince Rootstocks

Keywords: Pear rootstocks, dwarfing, cold hardy, quince, efficiency

Abstract: Quince is the preferred rootstock for intensive pear production, facilitating high-density, efficient orchards that are amenable to mechanization. Quince rootstocks are highly dwarfing, precocious, and confer high productivity and large fruit size to pear; however, they often have insufficient cold hardiness for cold regions like the PNW. With previous funding from the NW Pear Committee, we identified 20 quince accessions from the germplasm repository at the USDA-NCGR, in Corvallis, Oregon that were as hardy or hardier than the commercial pear rootstocks, Old Home X Farmingdale (OH × F) 87 and 97. Nine of the 20 accessions were micropropagated and budded to the scions ‘d’Anjou and ‘Bartlett’ (with and without a ‘Comice’ interstem) and planted in two high-density (3 ft × 12 ft., 1210 trees per acre) field performance trials in 2017 with industry collaboration (Entiat, WA and Parkdale, OR). Trees were trained to a spindle architecture and vegetative and fruiting data were recorded over a three-year period. At the completion of this project (2020, 4th leaf), tree survival varied markedly by rootstock; in OR, 13 (approx. 1/3rd) of the combinations had 0% mortality and 5 of 31 combinations had mortality rates greater than 30%. In WA, survivability was higher; only 3 of 24 combinations tested had mortality rates exceeding 20% and two-thirds of the combinations had 0% mortality. Annual vegetative growth data indicated that 8 of 24 combinations had 20% or more trees struggling at the completion of 2020. A rootstock with a high proportion of struggling trees suggests incompatibility between the quince rootstock and either the interstem (Comice) or the scions. Twelve combinations had no struggling trees. Quince rootstocks conferred significant dwarfing to d’Anjou and Bartlett. Similar genotype and/or combination effects are beginning to show after the fourth-leaf at both sites with the most vigorous or weakest trees belonging to the same rootstock. Eighty percent of the combinations filled the orchard space (in height and spread) by the fourth leaf. Annual pruning weight data across the rootstocks generally agreed with trunk size data. Nearly all quince rootstocks conferred precocity to the scions with significantly more flower clusters for Bartlett compared to ‘d’Anjou in 2020. Final fruit numbers per tree were not too dissimilar between sites; ‘d’Anjou’ trees generally had fewer than 10 fruit per tree and ‘Bartlett’ had 20 to 40 fruit per tree. Differences among rootstocks were relatively minor in the first cropping year. ‘d’Anjou’ tree yield was insignificant (2-9 lbs per tree) but Bartlett yields averaged around 11 lbs and reached as high as 15 lbs per tree or 18 bins per acre [based on the planting density]. Fruit size was very good for rootstocks (typically between 200 and 250 g [80 to 90 fruit per box]), a common benefit of quince rootstocks. To date, three to four rootstocks appear very promising for their overall effects on dwarfing, precocity and productivity for either Bartlett and/or ‘d’Anjou. Future work has been proposed to continue evaluated cropping in the 5th leaf and beyond with the aim of advancing one or more dwarfing and yield efficient quince rootstocks for PNW pear producers.