Rootstock effects on mature Pinot noir growth and productivity under cool climate, dry-farmed conditions – FINAL REPORT

Patricia A. Skinkis and Jeremy D. Schuster

1. Summary

Vine growth, yield, and fruit composition of Pinot noir grafted to 18 rootstocks and own-rooted vines were evaluated during three growing seasons, 2020-2022. The vineyard was >20-years-old, and we hypothesized cumulative impacts on Pinot noir vine growth would be distinguished by rootstock. Specifically, we hypothesized that Riparia Gloire and other vigor-reducing rootstocks, such as 101-14, and 3309C, would have reduced canopy growth compared to other rootstocks not commonly planted in Oregon due to high vigor potential, such as 110R, 140R, 1103P, and 161-49. Results show most rootstocks performed similarly for phenology, vegetative growth, and fruit yield. However, there were some key differences amongst the rootstocks. Riparia Gloire, 44-53, Schwarzmann, and 3309C had the lowest vine vigor and 5BB, 125AA, and 161-49 had the highest vigor based on dormant pruning weights. These differences were visible in the field during the mid-late summer. Of the subset of vines monitored for plant water stress, the most stressed vines were Pinot noir on 101-14 while Pinot noir on 5BB, 140R, and 1103P had less water stress over the two years. The more drought-tolerant rootstocks had less water stress, higher pruning weights and average yields. There were some differences in fruitfulness, with SO4 having the greatest fruitfulness while Riparia Gloire having the lowest. There were yield differences by harvest, with 420A having higher yields and Riparia Gloire and 44-53 having the lowest yields consistently. The impact on yield is mostly explained by differences in cluster weight. Pinot noir fruit ripeness at harvest differed by rootstock, with the most advanced ripeness being in Pinot noir on Riparia Gloire, which had the highest total soluble solids, highest pH, and lowest titratable acidity but also the highest crop load. Crop load was altered by rootstocks and did not correlate well with ripeness parameters. We anticipated that variations in canopy size created by rootstock vigor would affect berry phenolic concentration or content through vine stress and/or differences in light exposure in the cluster zone based on canopy size differences. Pinot noir on Riparia Gloire had the highest total anthocyanin, phenolic, and tannin, but Pinot noir on other rootstocks had similar concentrations despite different levels of plant stress and/or canopy size/exposure. This research shows that rootstock had the greatest impact on vegetative growth and yield, by way of differences in water stress tolerance, thereby causing some differences in vine balance, although those differences in vine balance did not impact fruit composition linearly.

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2. **Project Title and UGMVE proposal number**: Rootstock effects on mature Pinot noir growth and productivity under cool climate, dry-farmed conditions (2022-2409)

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5. Objectives and Experiments Conducted to Meet Stated Objectives:

Objective 1. Determine phenology, vine health, water status, and fruit productivity of Pinot noir grafted to different rootstocks.

This project evaluated vine growth and performance in a mature rootstock trial from 2019-2022. The research block is located at Oregon State University's Woodhall Vineyard in Monroe, OR. It was planted in 1997 to Pinot noir Wädenswil clone (FPS 2A) grafted to 18 different rootstocks of various *Vitis* parentage (*V. cinerea, V. cordifolia, V. rupestris, V. riparia, V. berlandieri, and V. solonis*). Rootstocks included the following: 5BB, 5C, 8B, 110R, 99R, 140R, 125AA, 101-14, 161-49, 420A, 1103P, 3309, 44-53, Böerner, Gravesac, Riparia Gloire, Schwarzmann, and SO4. Own-rooted Pinot noir 2A was also planted in the experimental vineyard as the control. The trial is a randomized complete block design with five-vine plots of each rootstock grafted to Pinot noir (and own-rooted vines) and replicated across five blocks. The vineyard was cane pruned each winter to a bud density of ~13 buds per meter. Vines were balanced pruned based on their vigor level as needed and ranged from 9 to 16 buds per meter. Vines were trained to a bilateral Guyot training system with vertical shoot positioning. Vines are spaced 4' in row and 7' between rows in N-S oriented rows and has been dry-farmed since establishment (year 4 post-planting). Soil mapping within the research block was conducted in 2011, and soils consist of Willakenzie and Jory-Windy Gap complex.

The main purpose of this work is to quantify how the vines have adapted growth over time, so we evaluated vine growth measures in all plots each year. Key phenology stages were determined using the BBCH scale (Lorenz et al. 1994) and attention to date and timing of key phenological stages were noted for bud break, bloom, and veraison. Due to the mid-April 2022 freeze event, some damage was observed to primary buds, so early bud break data were challenging to record. However, effort was made to document the phenology for the key phenological stages listed previously.

Since rootstocks are known to impact carbohydrate and nutrient reserves, we measured early season shoot growth, which may be influenced by reserves. Due to the spring freeze and delay in shoot growth from April through May, and late disbudding/suckering practices, our first measures of shoot growth (3 per plot) did not occur until 7 July 2022. To estimate canopy size and density during the growing season, leaf area index was measured using a ceptometer (AccuPar LP-80, Decagon Devices) at bloom and veraison. Canopy growth relative to vine phenology and date were compared, namely because we hypothesize that some higher vigor rootstocks may grow bigger canopies that may succumb to late season soil moisture deficits.

In 2021 and 2022, a subset of rootstocks within the project were identified to evaluate late season drought response, including 110R, Riparia Gloire, SO4, 101-14, 3309, 140R, 1103P, and own-rooted vines. Water stress, determined through stem water potential, stomatal conductance, and volumetric soil water content were measured. For stem water potential, foil-laminate zip-lock bags were placed on mature, undamaged, sun exposed leaves for an hour before measuring stem water potential with a pressure chamber. It was determined that the largest variation between the plots for stem water potential was during 3:00 to 4:00 pm. These measurements were recorded and repeated weekly from post-fruit set through veraison, as conditions allowed. Leaf stomatal conductance was collected on two mature, undamaged, and sun exposed leaves from each plot using a porometer/fluorometer (LI-600, Li-Cor Biosciences, Lincoln, NE), with three passes through the plots being collected in one sampling period. Measurements were averaged together and repeated weekly or bi-weekly as conditions allowed from post-fruit set through veraison. Volumetric water content was collected using a Delta-T PR2 multi depth soil moisture probe, which collects the volumetric water content at 10 cm, 20 cm, 30 cm, 40 cm, 60 cm, and 100 cm.

To determine impact on potential yield, spring fruitfulness (number of inflorescences per shoot) were quantified after shoot thinning but before bloom. Vines were not cluster-thinned to allow quantification of total yield at harvest. All vines were harvested on the same date at harvest in either September or October each year, and whole vine yields were measured. Dormant pruning weight were measured following each crop year in Jan/Feb. Yield and pruning weight data were used to calculate crop load, a measure of vine balance.

Objective 2. Determine differences in fruit composition of Pinot noir grafted to different rootstocks.

Basic fruit composition was measured at harvest, including total soluble solids (TSS, Brix), pH, and titratable acidity (TA). All experimental plots were harvested on the same date. A ten-cluster sample from each plot was collected at harvest. Five clusters were measured for cluster and berry size metrics, including berry count, cluster weight, and berry weight to determine rootstock influence on yield components. Rachis length and berry count were used to calculate cluster compactness (berries per cluster/rachis length). The other five clusters were frozen at -20°C until analysis. The fresh destemmed berries were pressed to juice and analyzed for TSS, pH, and TA. An aliquot of the juice was frozen at -20°C until analysis for yeast assimilable nitrogen (YAN) using assays for ammonia N (r-Biopharm) and alpha amino acid N (Dukes and Butzke 1998). The frozen clusters were destemmed, mixed, and 50 berries randomly selected from the sample, homogenized, and then extracted using the Australian Wine Research Institute (2017) method. This extract measured for total anthocyanin using the pH-differential method (Lee et al. 2005), total phenolics using the Folin Ciocalteu method

(Waterhouse, 2002), and total tannins using the methyl cellulose precipitation method (Sarneckis et al. 2006). All analyses were run in winter following each crop year.

6. Summary of Major Research Accomplishments and Results by Objective

We completed three field seasons of research by collecting data from bud break through harvest and the post-season dormant pruning weights from each year. We analyzed all fruit for YAN and three phenolic assays. The four-year data have been statistically analyzed as part of a MS thesis by Jeremy Schuster, graduate research assistant in the Skinkis Lab. The results shown here are aggregate for the past four years (2019-2022), although the 2019 season was not funded by this grant (soft start year), but the full data re included herein. Results are currently in two manuscripts to be submitted for review by an academic journal in summer 2023. Below we outline a summary of results by objective.

Objective 1. Determine phenology, vine health, water status, and fruit productivity of Pinot noir grafted to different rootstocks.

Phenology. Detailed assessments of grapevine phenology were conducted using the modified Eichhorn-Lorenz scale (Coombe 1995) on ten to fifteen dates each year and were conducted around budbreak, bloom, and véraison. All nodes on one bilateral cane were quantified at each date, using one vine per plot and returning to the same vines for all observations. Some variation in phenology was observed between blocks in the last year of the trial due to the April 2022 frost event, but there were no differences between rootstocks from bud break to bloom in any of the other years. Likewise, there were no differences in coloration between rootstocks at véraison.

Vine growth. There were visible differences in vine growth by rootstock observed during each season. The pruning weights that were gathered as a measure of vine vigor following each growing season showed that Riparia Gloire and 44-53 had the lowest pruning weights at 0.12 and 0.17 lb/ft, respectively (Figure 1). 3309C, own-rooted vines, and Schwarzmann also had low pruning weights with 0.23-0.24 lb/ft, respectively. Since these pruning weights were at or below optimum of 0.2-0.4 lb/ft, we adjusted the number of buds at pruning for these rootstocks, on a plot-by-plot basis. Most of the rootstocks fell within the upper end of optimum pruning weights following with 0.30 to 0.47 lb/ft, with the highest being 5BB. We also quantified canopy density through leaf area index measures taken multiple times from bloom to ripening each year. These measures mirrored the dormant pruning weight data--where there was higher leaf area index, the pruning weight was higher (data not shown).

Water status. Vines had lower water stress during 2022 compared to 2021 (Figure 2) due to greater precipitation in 2022 and higher soil moisture (Figure 3). Pinot noir grafted 1103P, 140R and 5BB had the highest stem water potentials (lowest stress levels) compared to the other rootstocks, particularly 101-14 which experienced the most water stress both years (Figure 2). Similar results were also found for stomatal conductance (data not shown). The average volumetric water content for the 1-meter soil profile depth started at approximately 30% in late June 2022 and dropped to approximately 21% by the beginning of September (Figure 3). Own-rooted vines had consistently lower soil moisture content in the undervine soil profile both years compared to the other rootstocks, suggesting potentially greater root volume in the 1 m depth or more roots at greater depth to draw down the available water.

Fruitfulness and yield. Fruitfulness (number of inflorescences per shoot) was measured after shoot thinning each year. There was an average of 1.6 (±0.05 SE) inflorescences/shoot across all rootstocks over the four years (2019-2022). Mean fruitfulness was highest in 2020 (1.7) and lowest in 2022 (1.5) due to the April frost event that year. Pinot noir on SO4 had the highest fruitfulness (1.7 inflorescences/shoot) and was only different from own-rooted vines (1.5) and Pinot noir on Riparia Gloire Rootstock (1.4). All other rootstocks did not differ from these or each other. The lower vigor of Riparia Gloire had already begun to reduce fruitfulness and yield as a result, creating a naturally smaller vine. Yields varied by rootstock, with Pinot noir on 420A having the highest yield (1.79 lb/ft) and Pinot noir on Riparia Gloire having the lowest (0.87 lb/ft) (Figure 4). Pinot noir on 420A was only higher in yield than Pinot noir on Riparia Gloire, 44-53, own-rooted vines, Schwarzmann, and Gravesac, and Pinot noir on the other rootstocks did not differ from each other in yield.

Vine balance measures. Crop load was calculated from the yield and pruning weight data to reflect the relative amount of vegetative growth and fruit production ratio. As expected, the differences in Pinot noir vegetative growth and yield between the rootstocks resulted in differences in crop load (Figure 5). Pinot noir on Riparia Gloire had the highest crop load at 7.8, which was higher than all other rootstocks except 44-53. The lowest crop load was in 5CTE, 5BB, 125AA, 161-49 and SO4. While crop load is a helpful metric for determining over-cropping in some wine production regions, this study shows that the metric does not work the same in the Willamette Valley. The ripest fruit were obtained from the highest crop load vines while the lowest crop load vines had lower ripeness, suggesting that vines are under-cropped, or the vines are inhibiting ripeness through higher vegetative vigor. We did not crop thin in this trial in any year, and reducing crop in the most vigorous vines would not likely result in an improvement in fruit ripeness, especially with the yields already being low (<1.5 lb/ft on average), which is normal for Pinot noir in the region.

Objective 2. Determine differences in fruit composition of Pinot noir grafted to different rootstocks.

Basic ripeness. All rootstock plots were harvested on the same date each year once commercial ripeness had been attained (~23°Brix). There were differences by rootstock for TSS, pH, and TA each year. Pinot noir on Riparia Gloire was always the most advanced for ripeness with the highest TSS and pH and lowest TA (Table 1) despite having the highest crop load (Figure 5). This may be due to the vines having the lowest yield (Figure 4) but also the lowest vine size (Figure 1). Pinot noir on 420A was always one of the least ripe, with the lowest TSS, pH and highest TA (Table 1) and may be due to the high yields (Figure 4). However, the crop load of Pinot noir on 420A was intermediate and not different from any other rootstock and lower than Pinot noir on Riparia Gloire (Figure 5). In general, the most vigorous, drought tolerant rootstocks had lower TSS and pH and higher TA at harvest. However, ripeness results did not differ for most of the rootstocks in the trial (Table 1).

Juice Nitrogen (N). Total yeast assimilable nitrogen (YAN) of Pinot noir varied by rootstock each year, and results mirrored vegetative growth, with Pinot noir on Riparia Gloire and Schwarzmann (with the smallest canopies and dormant pruning weights) having the lowest YAN consistently (Table 2). Pinot noir on 5BB and 125AA had the highest YAN concentrations. Dormant pruning weights were positively correlated with YAN concentrations with the highest correlation in 2021, the driest year of the study (Figure 6). This indicates that rootstocks mediated nitrogen uptake and use likely through differences in either rooting depth or moderation through drought tolerance mechanisms.

Berry Phenolics. Whole berry extractions were conducted at harvest to determine the impacts that vine water stress, vine balance, or canopy microclimate differences might have played on berry phenolics, including total anthocyanin, tannin and phenolics. There were differences in Pinot noir composition by rootstock, with Riparia Gloire having the highest anthocyanin, tannins and phenolics (Table 2). However, in most cases, the concentrations were not different from our standard Oregon rootstocks (3309C, 101-14) or other rootstocks in the trial. The differences varied in terms of the phenolic parameter, with Pinot noir on SO4 having lower total phenolics, Pinot noir on 99R had lower tannins, and Pinot noir on 140R having lower anthocyanin that Pinot noir on Riparia Gloire. Differences were not always clear and consistent when it came to phenolic composition despite observed differences in canopy microclimate and plant water stress between the rootstocks.

7. Outside Presentations of Research

Numerous presentations of project results were given to Oregon producers from 2021 to present. These include an annual vineyard field visit to the rootstock block each September, six industry webinars, and two posters at the Oregon Wine Research Institute Grape Day (April 2022 and 2023). The PI kept the industry informed about project status through communications with industry collaborators and advisors and through social media outlets, including the Skinkis Lab Instagram postings @patty.skinkis. The results have also been shared with academic peers at the American Society for Enology and Viticulture National Conference in San Diego, CA in June 2022 and will be presented at GiESCO, an international viticulture conference, in Ithaca, NY in July 2023.

8. Research Success Statements

This project generated regionally important information on grafted Pinot noir performance under dry-farmed conditions. Since this was a mature rootstock trial with multiple years, the data are stronger than most other rootstock trials in the published literature and is providing valuable information on the long-term effects of rootstocks in the unique growing conditions of the Willamette Valley. The information has helped us understand the characteristics of certain rootstocks that may be better suited to dry-farmed sites or those vineyards where there are more water or nutrient stressors related to soil type, reduced herbicide use (weed competition), and no-till systems where there may be increased competition with vineyard floor vegetation. Water and nutrients are managed differently in this region, and this trial has helped provide information for growers to plan for their farming practices in the future. For example, if they plan to use no-till practices for regenerative farming, they may want to consider a more robust rootstock that will have greater drought tolerance such as 1103P or 5BB. However, if they are on a high vigor site and intend to continue with typical farming practices, the standard rootstocks for Oregon will still perform well. Information has already been used by growers to make rootstock selections for the future.

9. Funds Status

Funds for this project were used to support personnel, including salary and benefits of a portion of a faculty research assistant in 2020 and 0.49 FTE graduate research assistant (Jeremy Schuster) in 2021-2023. Funds also covered travel to the research site (vehicle costs), field and lab consumables, reagents and assay kits for fruit composition analyses, and equipment service and calibration.

10. Literature Cited

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Tables

Table 1. Fruit ripeness measures at harvest for Pinot noir grafted to 18 rootstocks and own-rooted (PN2A) vines over four growing seasons at OSU Woodhall Vineyard, Monroe, OR

		Total soluble solids (°Brix)		**pH**		**Titratable acidity (g/L)**	
Rootstock	1103	23.1	cd	3.19	ab	8.8	a
	3309	23.6	abcd	3.17	ab	7.7	cde
	4453	24.0	abc	3.18	ab	7.7	cd
	101-14	23.8	abcd	3.18	ab	7.5	de
	110R	23.9	abc	3.20	ab	7.7	cd
	125AA	22.8	cd	3.16	ab	8.5	a
	140R	23.6	abcd	3.21	ab	8.1	abcd
	161-49	23.7	abcd	3.16	ab	8.5	ab
	420A	22.7	d	3.13	b	8.6	a
	5BB	22.9	cd	3.17	ab	8.7	a
	5CTE	23.2	bcd	3.15	ab	8.2	abcd
	8BTE	23.5	abcd	3.17	ab	8.3	abc
	99R	23.0	cd	3.20	ab	8.2	abcd
	BOER	23.8	abcd	3.15	ab	8.2	abcd
	GRAV	23.5	abcd	3.21	ab	7.8	bcd
	PN2A	23.6	abcd	3.20	ab	7.6	de
	RIPG	24.6	a	3.24	a	6.8	f
	SCHW	24.4	ab	3.25	a	6.9	ef
	SO4	23.8	abcd	3.17	ab	8.2	abcd
	SE	0.2322		0.01949		0.1436	
Year	2019	23.7	a	3.18	b	7.2	c
	2020	23.7	a	3.32	a	6.9	d
	2021	23.6	ab	3.15	b	8.6	b
	2022	23.3	b	3.09	c	9.3	a
	SE	0.1065		0.08942		0.0659	
***p*-values**	*Year*	*0.0122*		*<0.0001*		*<.00001*	
	Rootstock	*<.0001*		*<0.0001*		*<0.0001*	
	*Year * Rootstock*	*0.0002*		*0.0989*		*0.0049*	

Means are presented with standard errors (SE) and p-values from analysis of variance. Different letter following means indicates a difference in means based on Tukey's mean separation (p<0.05).

Table 2. Berry composition at harvest for Pinot noir grafted to 18 rootstocks and own-rooted (PN2A) at OSU Woodhall Vineyard over three years.

		Yeast assimilable nitrogen (mg/L)		**Total anthocyanin (mg/g)**		**Total phenolics (mg/g)**		**Total tannin (mg/g)**	
Rootstock	1103	98.6	abcde	0.59	bc	6.2	ab	4.7	ab
	3309	76.7	cde	0.68	abc	6.2	ab	4.9	ab
	4453	66.5	e	0.71	ab	5.8	ab	4.5	ab
	101-14	69.9	de	0.72	ab	6.6	a	4.6	ab
	110R	90.0	bcde	0.63	abc	6.2	ab	4.1	b
	125AA	119.3	a	0.59	bc	5.4	ab	3.9	b
	140R	118.8	ab	0.53	c	5.6	ab	4.4	ab
	161-49	109.3	abc	0.58	bc	5.6	ab	4.4	ab
	420A	101.6	abcde	0.59	bc	6.0	ab	4.8	ab
	5BB	132.3	a	0.57	bc	5.9	ab	4.5	ab
	5CTE	98.8	abcde	0.64	abc	5.7	ab	4.4	ab
	8BTE	107.3	abcd	0.64	abc	6.5	a	5.0	ab
	99R	113.7	abc	0.58	bc	6.1	ab	4.1	b
	BOER	108.3	abc	0.61	abc	5.9	ab	4.5	ab
	GRAV	92.2	bcde	0.60	abc	5.8	ab	4.6	ab
	PN2A	76.2	cde	0.71	ab	6.0	ab	4.7	ab
	RIPG	66.7	e	0.76	a	6.7	a	5.7	a
	SCHW	68.2	e	0.69	abc	5.9	ab	4.9	ab
	SO4	103.1	abcde	0.68	abc	5.1	b	4.5	ab
	SE	7.5215		0.03329		0.2603		0.2758	
Year	2020	85.9	b	0.81	a	6.2	a	3.8	b
	2021	106.2	a	0.67	b	5.5	b	3.9	b
	2022	94.8	b	0.44	c	6.2	a	6.0	a
	SE	2.9887		0.01323		0.1034		0.1096	
p-values	*Year*	*<.0001*		*<.0001*		*<.0001*		*<.0001*	
	Rootstock	*<.0001*		*<.0001*		*0.0014*		*0.0151*	
	*Year * Rootstock*	*0.3668*		*0.4621*		*<.0001*		*0.5653*	

Means are presented with standard errors (SE) and p-values from analysis of variance. Different letter following means indicates a difference in means based on Tukey's mean separation (p<0.05).

Figures

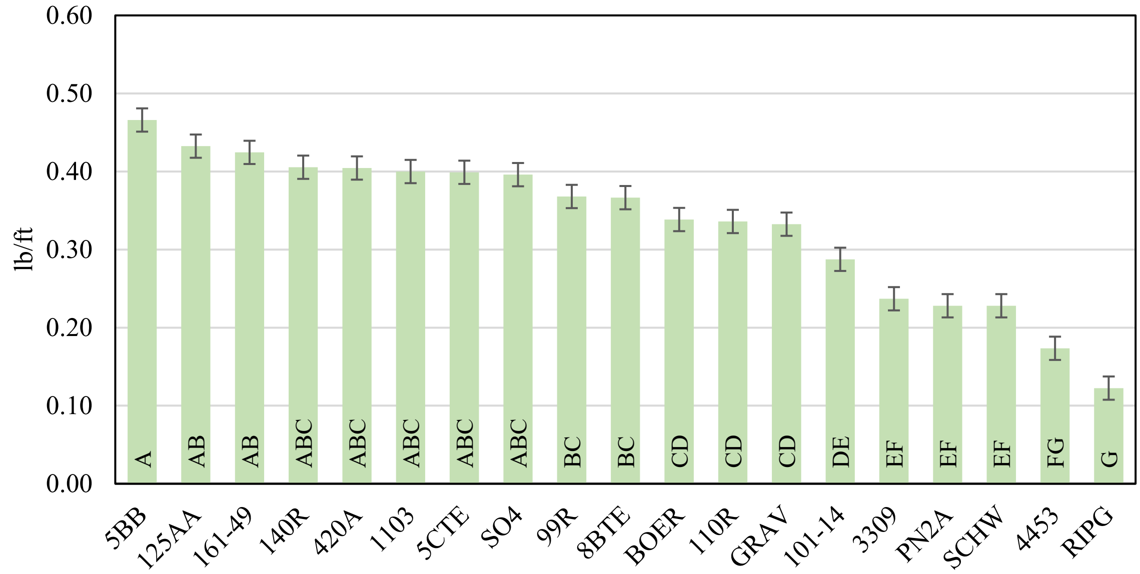

Figure 1. Dormant pruning weight (in lb/ft of linear row) of Pinot noir grafted to 18 rootstocks and own rooted. Data represents four-year means (2019-2022) with standard errors. Different letters indicate a difference in means at $p<0.05$. Analysis of variance of the data show that year and rootstock are statistically significant (both $p<0.0001$).

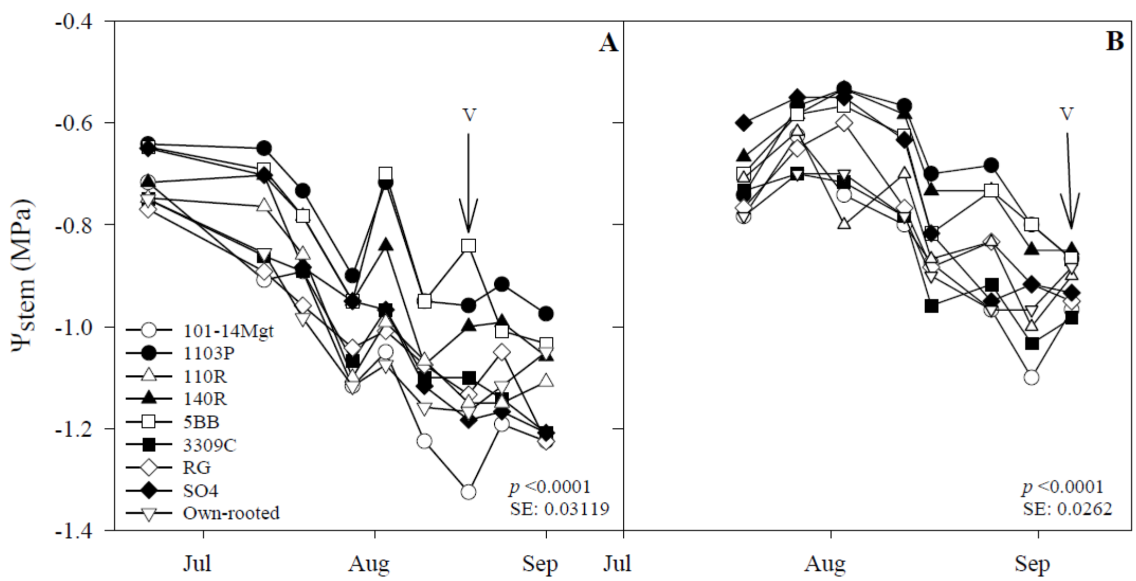

Figure 2. Stem water potential of Pinot noir grafted onto different rootstocks and own-rooted vines over two growing seasons, 2021 (A) and 2022 (B). Arrows indicate véraison (V). Data were analyzed with repeated measures analysis of variance (ANOVA) and *p*-values and standard errors are shown.

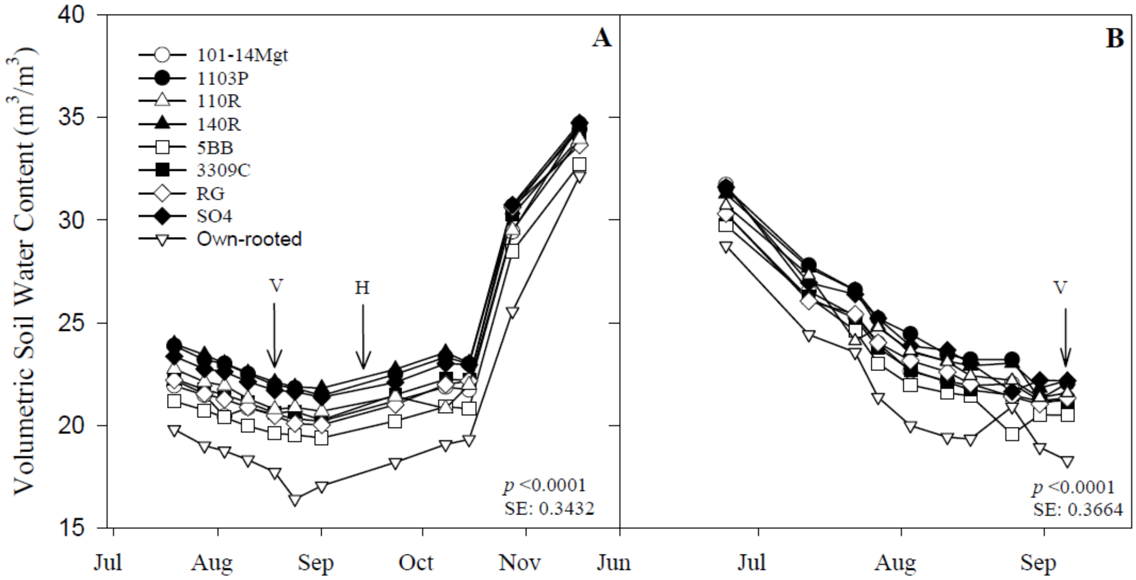

Figure 3. Volumetric soil water content measured in the vine row of Pinot noir grafted to different rootstocks and own-rooted at OSU's Woodhall Vineyard over two growing seasons, 2021 (A) and 2022 (B). Data were analyzed for the entire season with repeated measures analysis of variance (ANOVA) and the *p*-value and standard errors are shown. Arrows indicate veraison (V) and harvest (H).

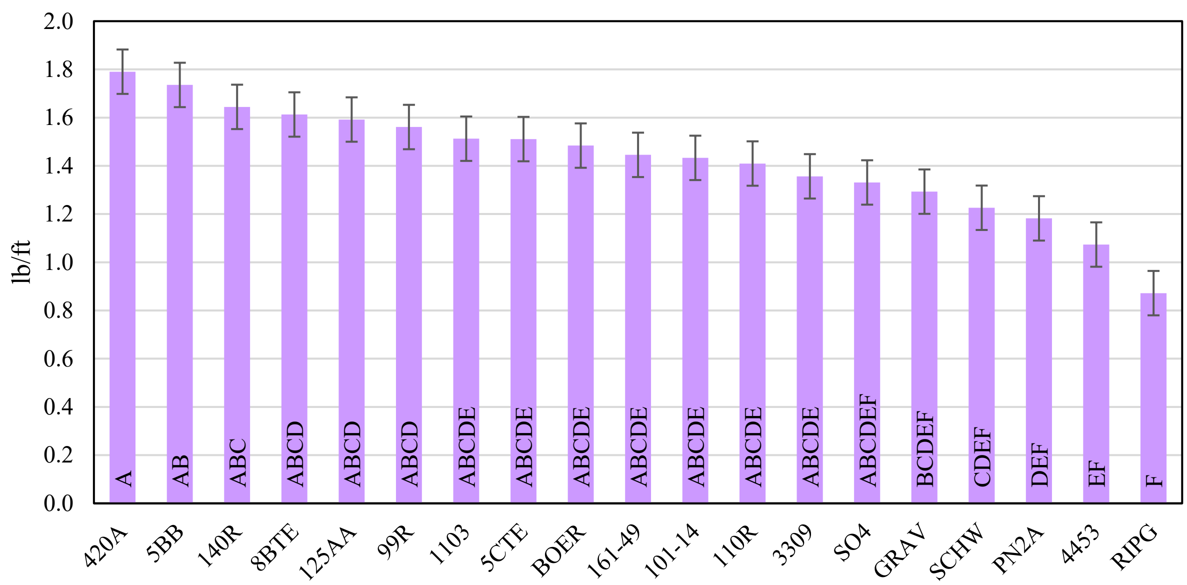

Figure 4. Harvest yield (in lb/ft of linear row) of Pinot noir grafted to 18 rootstocks and own rooted vines (PN2A). Data are four-year means (2019-2022) with standard errors. Different letters at the base indicates a difference in means at $p<0.05$. Analysis of variance show that year and rootstock are statistically significant (both at $p<0.0001$).

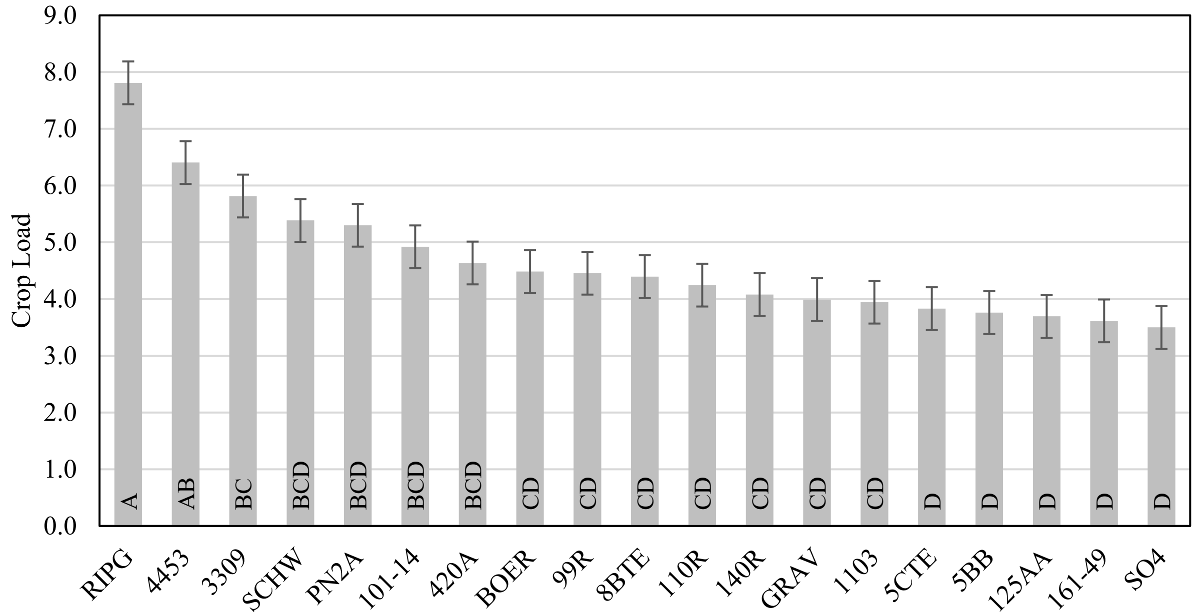

Figure 5. Crop load (yield/pruning weight) of Pinot noir grafted to 18 rootstocks and own-rooted vines (PN2A). Data represent four-year means (2019-2022) with standard errors. Different letters at the base indicate a difference in means at p<0.05. Analysis of variance of the data show that year and rootstock are statistically significant (both p<0.0001).

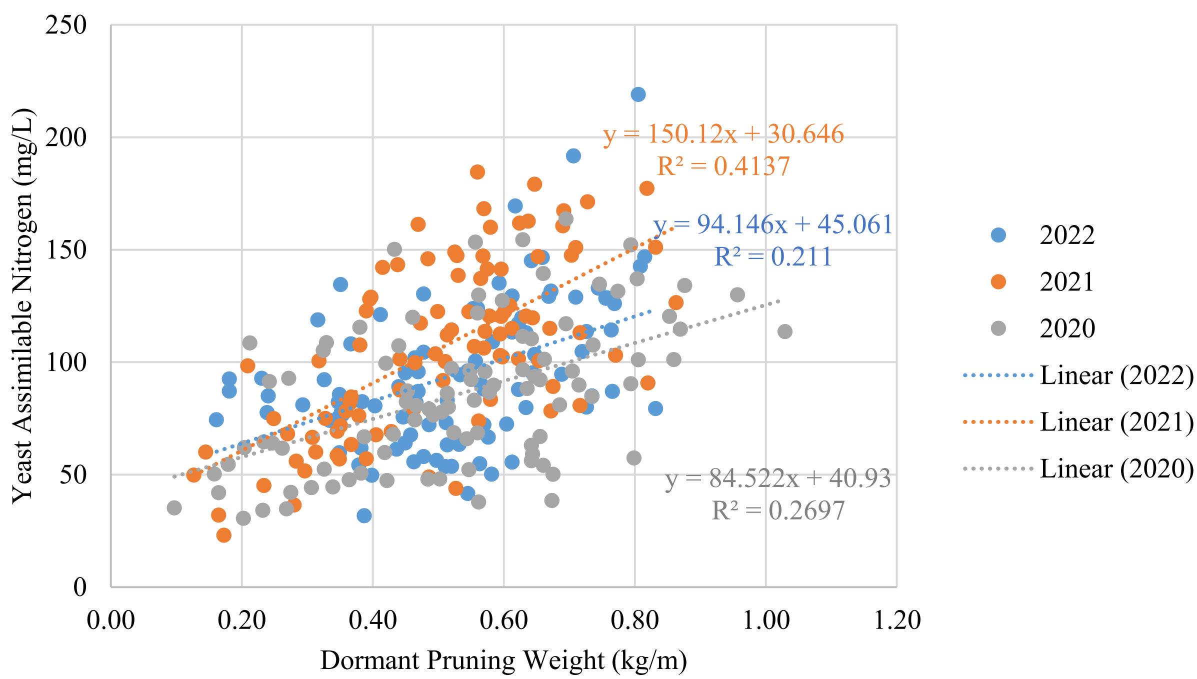

Figure 6. Comparison of dormant pruning weight and yeast assimilable nitrogen of Pinot noir grafted onto 18 rootstocks and own-rooted during three growing seasons.