horticulturae

MDPI

Communication

Post-Frost Pruning Does Not Impact Vine Yield and Berry Composition in Young Grapevines

Suraj Kar [1,2], Ricky W. Clark [1,2], Ian T. Ivey [1], Joseph B. DeShields [1,2], Jeremy Cusimano [3] and Alexander D. Levin [1,2,*]

[1] Southern Oregon Research and Extension Center, Oregon State University, 569 Hanley Rd, Central Point, OR 97502, USA; suraj.kar@oregonstate.edu (S.K.); ricky.clark@oregonstate.edu (R.W.C.); ian.ivey@oregonstate.edu (I.T.I.); joseph.deshields@oregonstate.edu (J.B.D.)
[2] Department of Horticulture, Oregon State University, 2750 SW Campus Way, Corvallis, OR 97331, USA
[3] Cascadia Ag Research, P.O. Box 10731, Eugene, OR 97404, USA; jcusimano@cascadiaagresearch.com
* Correspondence: alexander.levin@oregonstate.edu

Abstract: Spring frost is a perennial and widespread problem across many cool climatic and high-elevation winegrowing regions of the world. *Vitis vinifera* L. cv. Pinot noir is an early budding cultivar; thus, it is particularly susceptible to late-spring frost damage. In late April 2022, an advective frost event occurred throughout Western Oregon winegrowing regions and subsequently damaged a substantial number of commercial vineyards. Growers often are unsure of how to manage grapevines after a frost event. Limited research has shown little-to-no effect of pruning vs. non-pruning strategies on vine yield and productivity. In addition, pruning a frost-affected vineyard incurs additional labor costs that may offset the cost–benefit balance for the grower. Therefore, in this experiment, the effect of two different post-frost pruning treatments (cane pruning and spur pruning) on vine yield, berry composition, and vine vegetative growth were tested. No effect of post-frost pruning treatments on vine yield, berry composition, and vine vegetative characteristics was observed. Cluster numbers, cluster weights, and berries per cluster only differed between cane- vs. spur-pruned vines. Therefore, leaving frost-affected vines alone and a scaled-back vineyard management practice could be practical for economic reasons.

Keywords: frost; pruning; canopy management; yield; vine recovery

Citation: Kar, S.; Clark, R.W.; Ivey, I.T.; DeShields, J.B.; Cusimano, J.; Levin, A.D. Post-Frost Pruning Does Not Impact Vine Yield and Berry Composition in Young Grapevines. *Horticulturae* **2024**, *10*, 505. https://doi.org/10.3390/horticulturae10050505

Academic Editors: Arif Atak, Andreia Figueiredo, Inmaculada Pascual and Fermin Morales

Received: 25 April 2024
Revised: 9 May 2024
Accepted: 10 May 2024
Published: 14 May 2024

1. Introduction

In the United States, grape growers endure the greatest economic impact related to crop losses due to cold temperatures compared to any other weather-related damages [1]. Spring frosts are a perennial problem for vineyards in cool climatic or high-elevation regions [2]. Frost is defined as "temperatures less than or equal to 0 °C, at a height between 1.25 and 2 m" from the ground surface [1]. Frost injury in vineyards occurs generally when the air temperature falls below −2 °C post budbreak [3]; however, the extent of damage is dependent on the duration of frost and the phenological stage of the crop [4].

Due to climatic warming trends, the co-occurrence of 'false springs', advancing bud-break, and early shoot development are causing increased frost susceptibility to grapevines, particularly those grown in mid-latitudes [5,6]. Temperatures of −2 to −3 °C can kill young shoots developing from primary buds, and as a result, shoots grow from less fruitful secondary buds [7,8]. Severe frost not only influences the current season's crop, but by negatively affecting flowering and vegetative growth, it can also reduce crop yield in the following seasons [2]. Depending on the extent of damage caused by frost, growers may decide whether to implement any recovery interventions to preserve or stimulate current year's growth or promote adequate fruiting wood for the following season.

Vitis vinifera L. cv. Pinot noir is an early budding cultivar that is especially vulnerable to late-spring frost. In late April 2022, a disastrous advective frost event in Western

Oregon damaged up to 50–100% of all primary shoots in many vineyards [9]. After the frost event, there were numerous questions regarding what to do with damaged vines (if anything) and whether supplementary canopy management practices might help vines recover. In multiple previous reports [10–16], possible post-frost management strategies were discussed, which included taking no action, removing dead shoots, removing all shoots, and light-to-heavy pruning.

Although there is plenty of published literature discussing the effect of post-frost management on the current year's crop [8,17–19], very little effort has been made to test vine recovery in the season following frost management. In addition, no work has been conducted on young grapevines (<five years old). Therefore, the current study evaluated three different post-frost pruning treatments on young, frost-affected vines in a commercial Pinot noir vineyard, and compared their yield and berry compositional characteristics in 2023.

2. Materials and Methods

2.1. Vineyard Site, Experimental Design, Management, and Pruning Treatments

The study vineyard was planted in 2018 in the Umpqua Valley AVA to *V. vinifera* L. cv. Pinot noir (clone 828) grafted on to 101-14 Mgt. rootstock (*V. riparia* Michx × *V. rupestris* Scheele). Vines were head-trained on a vertical shoot positioning (VSP) trellis system and cane-pruned to two 10-bud canes and two 2-bud renewal spurs per vine. Vines were planted in 1.5 × 2.4 m vine × row spacing in north–south row orientation. Vines were managed according to industrial standards common in the region. The frost event occurred on 15 April 2022, when the low average air temperature fell below −2 °C after a sustained warm period (Supplementary Figure S1). Following the late April frost in 2022, vines were assessed for bud damage. The concerned experimental plots experienced a uniform amount of damage (Supplementary Figure S2). At the time of this frost event, Pinot noir vines were at a 2–3 leaf stage with 2–4 cm shoots, corresponding to the modified Eichhorn–Lorenz (E-L) scale score of 9 [20]. The frost-affected vines were categorized into three treatment groups: (1) DN-CP: do nothing post frost and cane-prune the next dormant season (control); (2) DN-SP: do nothing post frost and spur-prune the next dormant season; (3) CF-CP: cut fruiting canes at the head to two 4-bud spurs post frost, followed by cane-pruning the next dormant season (Figure 1). Treatments were randomly assigned to four-vine plots and were replicated eight times within three rows in the vineyard in a completely randomized design. Treatment plots were separated by one border vine. Vine yield and berry composition were analyzed at harvest in September 2023.

2.2. Yield Components, Fruit Composition, and Vegetative Growth

Yield and yield components were determined by harvesting four whole vines per treatment plot in 2023. All clusters on primary shoots for each data vine were counted and weighed in the field. Cluster weights were determined by dividing the entire plot yield by the number of clusters. Berries per cluster were calculated from the average berry and cluster weight data. To quantify the responses of the fruit composition to pruning treatments, eight whole clusters per treatment plot were collected after harvest in each experimental unit, stored in coolers, and brought back to the lab.

Upon returning to the lab, the clusters were weighed and dissected, the berries were counted, weighed, and pressed, and the resulting juice was collected and centrifuged. The juice total soluble solids (TSS; °Brix) was measured using a digital handheld refractometer (AR200, Reichert, Inc., Depew, NY, USA). The juice pH was determined using a benchtop pH meter (Orion 3-Star Benchtop pH Meter, Thermo Fisher Scientific, Waltham, MA, USA). Titratable acidity (TA) was determined using an auto-titrator (T50 Titrator, Mettler Toledo, Columbus, OH, USA).

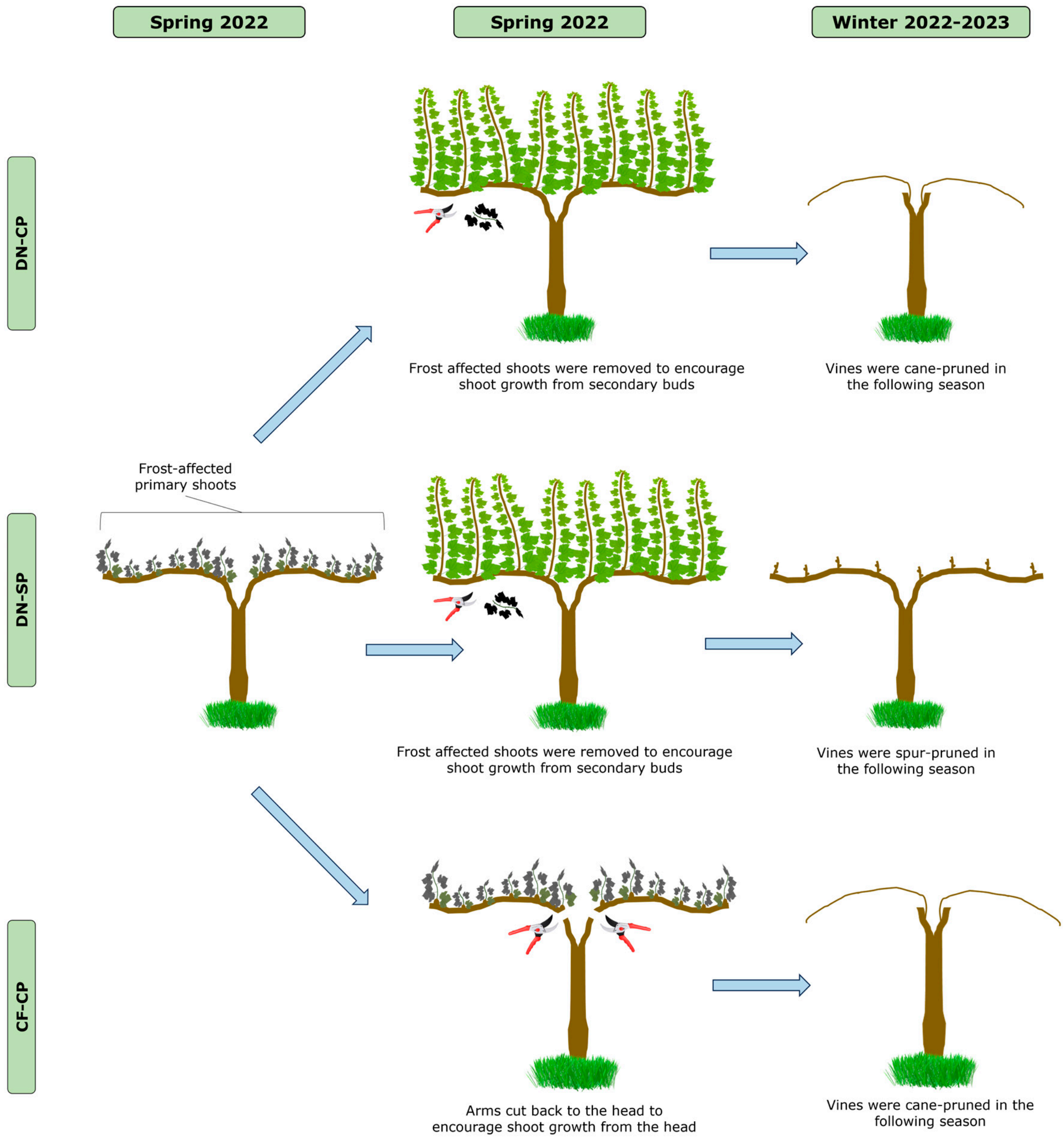

Figure 1. Three different post-frost pruning treatments were used in the study. DN-CP: do nothing post frost and cane-prune the next dormant season; DN-SP: do nothing post frost and spur-prune the next dormant season; CF-CP: cut fruiting canes at the head post frost followed by cane-pruning the next dormant season.

Vegetative growth was measured in terms of trunk cross-sectional area and dormant season pruning weights. Trunk diameters (d; mm) were measured in April 2022 and May 2023 using a digital caliper at 45 cm above the ground surface, just below the graft union. The cross-sectional area of the trunk was calculated using the standard formula for area of a perfect circle: $a = \pi r^2$, where a is the trunk area (mm^2) and r is the trunk radius ($d/2$) (mm). The pruning weights were collected in March 2023.

2.3. Statistical Analysis

All data were analyzed using R software (R 4.3.0) for statistical computing (R Core Team, 2023). Linear models were fitted to data using the *lm()* function from the R base package with statistical significance tested at α = 0.05. The yield components, berry composition, and pruning weight data were analyzed using a one-way ANOVA, with pruning treatment as the main factor. If the treatment effects were found to be significant, the estimated marginal means, followed by a multiple comparison of these means, were computed using Tukey's honest significant difference test using the *emmeans* package. The trunk cross-sectional area was analyzed using a two-way ANOVA with the treatment and year as the main factors, and treatment × year as the interaction factor.

3. Results and Discussion

Due to the severity of damage during the frost year (2022), the plot-by-plot yield and berry composition data were not collected in that year. However, the average yield per vine across the entire frost-affected experimental block was 1.6 kg. At harvest in 2023, no impact of post-frost pruning treatments on vine yield was observed (Table 1). The vines produced an average of 5.4 kg per vine across treatments, a ~250% increase compared to 2022. Although no statistically significant differences were observed in the yield response, there were statistically significant differences among treatments for clusters per vine, cluster weights, and berries per cluster. Treatment DN-SP resulted in a significantly higher number of clusters per vine compared to the other two treatments. Conversely, DN-SP resulted in fewer berries per cluster and lower cluster weight compared to the rest of the treatments. Berry weights did not differ significantly among treatments, with an average across-treatment berry weight of 0.91 g/berry. Accordingly, the cluster weight was mainly influenced by the number of berries per cluster as apparent from the strong and significant correlation between the two parameters (r = 0.88, $p < 0.0001$) (Supplementary Table S1).

Table 1. Yield and yield components in response to post-frost pruning treatments in field-grown Pinot noir vines in Umpqua Valley AVA. Data are the means ± SE ($n = 8$). Different letters besides the values for a particular variable indicate statistically significant differences among the treatment means ($p < 0.05$). Treatment descriptions are provided in Figure 1.

Treatment	Yield (kg/vine)	Clusters per Vine	Cluster Weight (g)	Berries Per Cluster	Berry Weight (g)
DN-CP	5.20 ± 0.24	33 ± 1 b	156 ± 5.43 a	175 ± 4.11 a	0.90 ± 0.03
DN-SP	5.37 ± 0.35	48 ± 2 a	112 ± 3.47 b	124 ± 3.69 b	0.90 ± 0.03
CF-CP	5.57 ± 0.25	36 ± 2 b	158 ± 5.66 a	168 ± 8.22 a	0.95 ± 0.02
ANOVA			***p*-values**		
Treatment	0.67	<0.0001	<0.0001	<0.0001	0.48

The higher number of berries per cluster observed in cane-pruned vines was likely the result of a greater number of flowers per inflorescence in the larger flower primordia in cane-pruned vines compared to spur-pruned vines. In a study conducted on Pinot noir in Oregon, Ulmer and Skinkis (2020) [21] observed 24–33% more berries per cluster in cane-pruned vines than spur-pruned vines, which was closely matched in this study (37%). In addition, they observed lighter yet more numerous clusters per vine in spur-pruned compared to cane-pruned vines. The cluster weights in their study were similarly more strongly influenced by berries per cluster than berry weights. Similar findings were reported by Skinkis and Gregory (2017) [22] and Jones et al. (2018) [23] in *V. vinifera* L. cvs. Pinot noir and Chardonnay, respectively. Thus, the results of our study are in accordance with their findings.

Like the vine yield, berry composition parameters did not differ significantly among the treatments (Table 2). All vines produced an average juice TSS of 22 °Brix, pH of 3.24, and TA of 6.3 g/L, indicating a technologically mature Pinot noir berry status for Oregon [24].

Table 2. Berry composition in response to different post-frost pruning treatments in field-grown Pinot noir vines in Umpqua Valley AVA. Data are the means ± SE (n = 8). Treatment descriptions are provided in Figure 1.

Treatment	TSS (°Brix)	pH	TA (g/L)
DN-CP	22.3 ± 0.9	3.24 ± 0.05	6.54 ± 0.30
DN-SP	22.0 ± 0.7	3.25 ± 0.03	6.27 ± 0.13
CF-CP	21.9 ± 1.0	3.25 ± 0.03	5.98 ± 0.13
ANOVA		***p*-values**	
Treatment	0.94	0.99	0.20

The trunk cross-sectional areas measured during May 2022 and 2023 did not show a significant difference among treatments in either year (Table 3). Averaged across treatments, the trunk areas were 358 mm^2 and 549 mm^2 in 2022 and 2023, respectively, representing a 54% year-over-year increase ($p < 0.0001$). The lack of an interaction effect ($p = 0.90$) between the treatment and year indicated that pruning treatments did not influence year-over-year trunk growth. Similarly, the vine vegetative growth measured in terms of pruning weights in March 2023 did not significantly differ ($p = 0.07$) across treatments, with a grand mean of 1.1 kg of pruning weight per vine.

Table 3. Trunk cross-sectional area in response to different post-frost pruning treatments in field-grown Pinot noir vines in Umpqua Valley AVA. Data are the means ± SE (n = 8). Treatment descriptions are provided in Figure 1.

Year	Treatment	Trunk Cross-Sectional Area (mm^2)	Increase (%)
2022	DN-CP	356.85 ± 19.66	--
	DN-SP	360.36 ± 14.61	--
	CF-CP	356.27 ± 15.41	--
2023	DN-CP	540.42 ± 30.57	51.95 ± 4.18
	DN-SP	556.40 ± 27.05	54.47 ± 3.95
	CF-CP	549.74 ± 30.13	54.29 ± 4.23
ANOVA		***p*-values**	
Treatment		0.80	0.82
Year		<0.0001	--
Treatment × Year		0.90	--

This study did not find a yield difference in the second year between treatments that removed (CF-CP) or did not remove (DN-CP and DN-SP) frost-affected shoots in the first year. Lider et al. (1975) [25] suggested that a potential difference might be expected due to the vines' young age and the associated lower levels of stored carbohydrate reserves. Indeed, Friend et al. (2011) [17] and Dami et al. (2012) [11] reported that the removal of frost-affected shoots can result in the depletion of storage carbohydrate reserves, and suggested that this may lead to yield reduction. However, the post-frost treatments applied to the young vines in this study had no effect like in many other earlier studies on post-frost pruning or shoot removal treatments. In an early study on multiple frost-damaged *V. vinifera* L. cultivars in California, Lider (1965) [13] showed that the removal of frost-injured shoots in either spur- or cane-pruned vines had very little effect on the yield. Subsequent work by Kasimatis and Kissler (1974) [26] revealed that shoot removal treatments following frost damage did not increase yield or affect berry quality in *V. vinifera* L. cvs. Tokay, Carignane, Zinfandel, Chenin blanc, and Grenache. More recently, Keller and Mills (2007) [27] observed no effect of pruning treatments on the fruit composition of *V. vinifera* L. cv. Merlot in Washington following cold injury to the vine trunk. In a study conducted on *V. vinifera* L. cv. Pinot noir in New Zealand, Jones et al.

(2010) [12] observed no effect of pruning treatments on the current year or subsequent year's crop. Lastly, McGourty et al. (2010) [28] found that the removal of frost-damaged shoots and associated tissues had no effect on return yield in *V. vinifera* L. cv. Cabernet Sauvignon, though it did significantly increase the yield of *V. vinifera* L. cv. Chardonnay. However, there was no influence on berry quality in either cultivar. In summary, numerous previous studies conducted in various parts of the world and the United States on numerous *V. vinifera* L. cultivars have indicated little-to-no effect of post-frost pruning treatments on vine productivity and/or fruit quality.

The uniform recovery of vines in the second year, irrespective of post-frost management during the first year, could be attributed to the vine's ability to compensate for frost-injured primary growth with more photosynthetically efficient secondary growth. In a frost-simulation field trial, Montague et al. (2020) [8] reported significantly greater mid-day photosynthetic carbon assimilation and gas exchange rates in the leaves growing from secondary buds compared to leaves from primary buds for two consecutive years in *V. vinifera* L. cvs. Grenache and Cabernet Sauvignon. Even though pruning weights were not measured during the 2024 dormant season, similar studies conducted by Jones et al. (2010) [12], Jones et al. (2018) [23], and Ulmer and Skinkis (2020) [21] did not find an effect of pruning methods on vine vegetative growth. Pruning treatments also lacked any significant physiological impact on vine recovery during subsequent growing seasons [11]. This lack of influence of pruning method on vegetative growth could be attributed to spur-pruned vines having numerous yet smaller shoots, while cane-pruned vines have fewer but larger shoots.

4. Conclusions

The results of this study demonstrate that post-frost pruning treatments do not affect the vine yield or berry composition in the following season, even when conducted on severely frost-impacted, young grapevines. These findings corroborate numerous studies across various wine regions and grapevine cultivars all over the world. Therefore, doing no additional pruning or shoot removal on frost-affected vines may be the best practice depending on the extent of damage.

Given the low fruit yield and added labor cost, post-frost vineyard management needs to take into consideration the best potential cost–benefit outcome. Many basic agricultural inputs (e.g., pesticides, fertilizer, water) can be reduced to match the significantly lower crop level and altered farming objectives. On the other hand, if a vineyard is completely unmanaged post frost, it will lead to inoculum build-up that will increase disease pressure in neighboring blocks and future years. Thus, it is worth emphasizing that frost-affected vines should still be maintained at a minimum level to ensure long-term vineyard productivity and economic viability.

Other more expensive labor inputs might be eschewed altogether. For example, canopy management practices such as shoot thinning and leaf removal may not be warranted for the same reasons. This would allow for reallocation of precious labor resources to other non-affected and/or higher-value blocks. In conclusion, leaving frost-affected vines alone does not weaken the vines in the following season and can save post-frost management costs.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae10050505/s1, Figure S1: Average daily maximum (tmax) and minimum (tmin) air temperatures during 2022. The grey shaded area indicates the daily temperature ranges throughout the year. The black arrow indicates the frost event that initiated the study. "Frost line" is drawn at −2 °C according to Barlow, 2010 *; Figure S2: Injury to the experimental vines recorded after the 15 April 2022 frost event. Table S1: Pearson's correlation (r) between the yield and berry composition parameters. Variables with significant correlation ($p < 0.05$) are shown.

Author Contributions: Conceptualization, A.D.L.; methodology, A.D.L.; formal analysis, S.K.; investigation, S.K., R.W.C., I.T.I., J.B.D. and J.C.; resources, A.D.L., J.C.; data curation, S.K.; writing—original draft preparation, S.K.; writing—review and editing, S.K., R.W.C., I.T.I., J.B.D. and J.C.; visualization, S.K.; supervision, A.D.L.; project administration, A.D.L.; funding acquisition, A.D.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article and Supplementary Material.

Acknowledgments: The authors thank Mesa Vineyard Management for managing the research block and the Oregon Wine Research Institute for their continuous support.

Conflicts of Interest: Author J.C. was employed by the company Cascadia Ag Research. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Snyder, R.L.; Melo-Abreu, J. *Frost Protection: Fundamentals, Practice and Economics*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2005; Volume 1, pp. 1–240.
2. Trought, M.C.T.; Howell, G.S.; Cherry, N. *Practical Considerations for Reducing Frost Damage in Vineyards*; Report to New Zealand Winegrowers; Lincoln University Press: Lincoln, New Zealand, 1999; pp. 1–43.
3. Barlow, S. *Improved Frost Management in the Goulburn & Yarra Valleys*; Final Report to Grape and Wine Research and Development Corporation, Project Number RT 06/04-1; The University of Melbourne: Victoria, Australia, 2010.
4. Rieger, M. Freeze Protection for Horticultural Crops. In *Horticultural Reviews*; Janick, J., Ed.; Wiley Online Library: Hoboken, NJ, USA, 1989; Volume 11, pp. 45–109.
5. van Leeuwen, C.; Sgubin, G.; Bois, B.; Ollat, N.; Swingedouw, D.; Zito, S.; Gambetta, G.A. Climate Change Impacts and Adaptations of Wine Production. *Nat. Rev. Earth Environ.* **2024**, *5*, 258–275. [CrossRef]
6. Peterson, A.G.; Abatzoglou, J.T. Observed Changes in False Springs over the Contiguous United States. *Geophys. Res. Lett.* **2014**, *41*, 2156–2162. [CrossRef]
7. Keller, M. *The Science of Grapevines*, 3rd ed.; Academic Press: Cambridge, MA, USA, 2020; ISBN 978-0-12-816365-8.
8. Montague, T.; Graff, E.; Kar, S. Secondary Bud Gas Exchange, Growth, and Fruitfulness of Vitis Vinifera L. Cultivars, 'Grenache' and 'Cabernet Sauvignon' Grown on the Texas High Plains. *Vitic. Data J.* **2020**, *2*, e60430. [CrossRef]
9. Alberty, M. *Willamette Valley Could Lose Half Its Grape Crop after Frost Hits Oregon Vineyards*; The Oregonian: Portland, OR, USA, 2022.
10. Creasy, G.L.; Trought, M.C.T.; Wells, G. Moderate and Severe Frost Recovery Options for Grapevines. In Proceedings of the 11th Australian Wine Industry Technical Conference', Adelaide, South Australia, 7–11 October 2001; Blair, R.J., Williams, P.J., Høj, P.J., Eds.; The Australian Wine Research Institute and the Australian Society of Viticulture and Oenology: Adelaide, Australia, 2002.
11. Dami, I.E.; Ennahli, S.; Zhang, Y. Assessment of Winter Injury in Grape Cultivars and Pruning Strategies Following a Freezing Stress Event. *Am. J. Enol. Vitic.* **2012**, *63*, 106–111. [CrossRef]
12. Jones, J.E.; Wilson, S.J.; Lee, G.; Smith, A.M. Effect of Frost Damage and Pruning on Current Crop and Return Crop of Pinot Noir. *N. Z. J. Crop Hortic. Sci.* **2010**, *38*, 209–216. [CrossRef]
13. Lider, J.V. Some Responses of Grapevines to Treatment for Frost in Napa Valley. *Am. J. Enol. Vitic.* **1965**, *16*, 231–236. [CrossRef]
14. Trought, M.; Arnst, B.; Bartleet, G.; McCartney, S.; Friend, A. Romeo Bragato Frost Workshop. In Proceedings of the Romeo Bragato Conference, Wellington, New Zealand, 27–30 August 2003.
15. Winkler, A.J. Why Treatment of Frosted Vines Sometimes Fails. *Wines Vines* **1961**, *42*, 27.
16. Winkler, A.J. *General Viticulture*, 2nd ed.; Cerruti, L., Ed.; University of California Press: Berkeley, CA, USA, 1974; ISBN 9780520025912.
17. Friend, A.P.; Trought, M.C.T.; Stushnoff, C.; Wells, G.H. Effect of Delaying Budburst on Shoot Development and Yield of Vitis Vinifera L. Chardonnay "Mendoza" after a Spring Freeze Event. *Aust. J. Grape Wine Res.* **2011**, *17*, 378–382. [CrossRef]
18. Graff, E.; Montague, T.; Kar, S. Secondary Bud Growth and Fruitfulness of *Vitis Vinifera* L. 'Grenache' Grafted to Three Different Rootstocks and Grown within the Texas High Plains AVA. *Int. J. Fruit Sci.* **2022**, *22*, 64–77. [CrossRef]
19. Del Zozzo, F.; Canavera, G.; Pagani, S.; Gatti, M.; Poni, S.; Frioni, T. Post-Spring Frost Canopy Recovery, Vine Balance, and Fruit Composition in Cv. Barbera Grapevines. *Aust. J. Grape Wine Res.* **2022**, *2022*, 6596021. [CrossRef]
20. Coombe, B.G. Growth Stages of the Grapevine: Adoption of a System for Identifying Grapevine Growth Stages. *Aust. J. Grape Wine Res.* **1995**, *1*, 104–110. [CrossRef]
21. Ulmer, M.R.; Skinkis, P.A. Cane- and Spur-Pruned Pinot Noir Results in Similar Fruitfulness, Yield, and Grape Ripeness under Cool Climate Conditions. *Catal. Discov. Pract.* **2020**, *4*, 10–20. [CrossRef]
22. Skinkis, P.A.; Gregory, K.M. Spur Pruning May Be a Viable Option for Oregon Pinot Noir Producers Despite Industry Fears of Lower Productivity. *Catal. Discov. Pract.* **2017**, *1*, 62–72. [CrossRef]

23. Jones, J.E.; Kerslake, F.L.; Dambergs, R.G.; Close, D.C. Spur Pruning Leads to Distinctly Different Phenolic Profiles of Base Sparkling Wines than Cane Pruning. *Vitis-J. Grapevine Res.* **2018**, *57*, 103–109. [CrossRef]
24. Castagnoli, S.P.; Vasconcelos, M.C. Field Performance of 20 "Pinot Noir" Clones in the Willamette Valley of Oregon. *Horttechnology* **2006**, *16*, 153–161. [CrossRef]
25. Lider, L.A.; Kasimatis, A.N.; Kliewer, W.M. Effect of Pruning Severity on the Growth and Fruit Production of "Thompson Seedless" Grapevines. *Am. J. Enol. Vitic.* **1975**, *26*, 2–5. [CrossRef]
26. Kasimatis, A.N.; Kissler, J.J. Responses of Grapevines to Shoot Break-Out Following Injury by Spring Frost. *Am. J. Enol. Vitic.* **1974**, *25*, 17–20. [CrossRef]
27. Keller, M.; Mills, L.J. Effect of Pruning on Recovery and Productivity of Cold-Injured Merlot Grapevines. *Am. J. Enol. Vitic.* **2007**, *58*, 351–357. [CrossRef]
28. McGourty, G.; Nosara, J.; Papper, P.; Koball, D.; Bordman, C. Managing Frost-Damaged Vines. 2010. Available online: https://cemendocino.ucanr.edu/files/17619.pdf (accessed on 9 May 2024).