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Review

Conception, Consequences and Design of Cool Climate Viticulture Training Systems

Richard Danko [1,*], Pavel Pavloušek [1], Magdalena Kapłan [2] and Kamila E. Klimek [3]

[1] Department of Viticulture and Enology, Faculty of Horticulture, Mendel University in Brno, 69144 Lednice, Czech Republic; pavel.pavlousek@mendelu.cz
[2] Institute of Horticulture Production, University of Life Sciences in Lublin, 20-612 Lublin, Poland; magdalena.kaplan@up.lublin.pl
[3] Department of Applied Mathematics and Computer Science, University of Life Sciences in Lublin, 20-612 Lublin, Poland; kamila.klimek@up.lublin.pl
* Correspondence: richard.danko@mendelu.cz; Tel.: +420-722920884

Abstract: In this review, the problems, challenges and opportunities of trellis design are dealt with in the conditions of cool climate viticulture influenced by climate changes. Viticulture in so-called cool climate regions faces a number of weather and climatic extremes that directly or indirectly damage the grapes and so the wine. A suitable option is to use the structural and technical implementation of vine trellises—training systems, canopy management, and pruning methods which can help the plant withstand various extremes. At the same time, it is essential to choose trellis design training systems that growers can maintain and that support the appropriate quality of the grapes. Viticultural regions of warmer climate are strengthening the shading potential of training systems. Even so, the central viticultural areas withstand highly variable extremes of previous vintages with numerous shortcomings in the shading potential of trellis design. Meanwhile, the cool climate regions tend to use a trellis design with a simple canopy and easy sunlight exposition to reach the maximum solar contribution.

Keywords: VSP; canopy; SHW; shoot; pruning; grapevine; viticulture; Guyot; cordon; climate change

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1. Introduction

The craft of viticulture is an ever-evolving field that must continuously adapt to diverse climatic conditions, soils, terrain, and geographical features across the globe. Historically, grapevines have thrived as heliophilous plants, spreading out to capture maximum sunlight. This natural adaptation is still reflected in the plant's structure, making its spreading habit an unnecessary feature used for grape-growing.

However, the factors of climate change are dramatically reshaping the landscape of grape production. Most of the growing areas are annually posing the increased frequency and intensity of extreme weather challenges. Spring frosts, heavy rainfall, hail storms, or longer drought periods are occurring with a higher prevalence. In fact, most of these circumstances occur in historically planted areas. As a response to these changes, there are new grape-growing regions arising in cool climate fields, facing extreme conditions and changes year-by-year [1]. Viticulture faces climate adaptations. These changes have a massive impact on ripening, harvest dates, the spreading of new diseases, and water stress. One of the common interceptions is that the grapes are facing a lot of stress factors; the wines are weak in aromatic compounds and there is a lack of freshness with an excessive alcohol content [2]. There is a significant threat of spring frost damage in growing regions with mild and inconsistent winter periods. Massive hail storms and heavy rainfall are actually common extremes that damage the crop, canopy, and the plant's structure. Also, more of the risks associated with new diseases are being detected, particularly with wood-decay fungi, rots, and phytoplasma [3].

The emergence of complex conditions caused by various wood-decay fungi has become a major concern. These diseases spread well with increased rainfall and the humidity driven by extreme weather conditions. Also, the use of improper pruning techniques that leave large wounds on the wood is facilitating infection to enter. To address these challenges, innovative solutions are essential [4]. It is necessary to modify pruning practices with maximal effort for sustainability and compact design. It is really important to reduce the concentration of pruning wounds, to support the natural sap flow and structural archetype with minimized infection risks and wood tissue damage. As a result of these challenges, it will be quite complicated to face all of the specific extremes with unsuitable vine-training styles. The goal is to develop plants of suitable trellis and training, with a significant advantage in evading the stress factors introduced by climate change. It would be appropriate to use the common features offered by the habitus of the plant. With the development of new pruning methods, a new point of view has emerged about how canopy architecture, clear sap-flow, and the structure of the plant can be considered as a game-changing trait of protecting the yield and the plant itself.

As viticulture expands into diverse cool regions, adapting vineyard management systems has become essential. The vertical shoot positioning (VSP) has been widely used to support upward vine growth and to control shading, crucial in a cool climate. However, in warmer regions, or even in the regions of Central Europe, we can observe serious complications with the traditional simple vertical canopy, as the sunlight exposure of previous vintages was really problematic. Therefore, if the climate conditions will continue to change this way for the upcoming years, it will be a serious challenge to face exposure with the low-shading capacity of a canopy. VSP's limitations are prompting a shift toward alternative systems like the single-high wire (SHW). The SHW system already enhances natural shading with improved air circulation and sufficient light distribution. These conditions can be helpful during the hot daily period, but also to face the overexposure to intensive solar radiation that can lead to overheating, premature ripening, and to decreased grape quality. These challenges are driving the development and adoption of different trellis systems, new grape varieties, and innovative cultivation techniques. The evolution of cultivation is inevitable for sustaining high-quality wine production [5]. The integration of biological measurement and disease-resistant varieties further supports the resilience of vineyards. These adaptive strategies can ensure us to thrive across various regions, maintaining exceptional wine quality amidst the shifting climate landscape using a proper growing technique.

2. Grapevine, the Modifications of the Liana in Modern Viticulture

Until now, the original non-domesticated *Vitis vinifera* spp. *silvestris* was still located in the range of the Middle East and in the large woods of the Mediterranean basin. However, the origin of grapevine domestication starts in the regions of the Lesser Caucasus. As is known, the first cultivation of the vine was without any harassment or canopy modification. A really important step in vine modification was the natural selection of plants bearing the largest crop load [6,7]. Another important step in the domestication timeline was when pruning was implemented as a means of obtaining a stable and loaded yield, and to manage and facilitate the vegetative growth [8].

Grapevines, *Vitis vinifera* L., have the characteristics of perennial lianas that combine the morphology of herbaceous and woody plants. Molecular biology with use of specific SSR Markers with geographical location has proven the evolution of a growing repertoire of grapevine genes [9]. However, not every gene donor tends to clear clustering. According to the gene analysis included in this study, most of the taxonomy of the grapevine is described as perennial liana with characteristics of both herbaceous and woody plants [10]. Moreover, several biological and morphological mechanisms are responsible for the sustainability and perennial plant cycle, supported by lignified tissues, bark cover protection, and the cambial development of the vascular system [11].

Vitis vinifera L., the Eurasian grapevine, remains as one of the main fruit crops worldwide. The determination of phylloxera (*Daktulosphaira vitifoliae*) in European vineyards during the 19th century forced the producers to use the American *Vitis* species with habitats similar to the wild grapevine as rootstocks. On the other hand, it was essential to not interrupt the natural tension of bud differentiation and primary meristematic activities [12].

Modern Limitations

The viticulture sector faces a large scale of challenges—strategies of sustainable production, water availability, or weather extremes. Many of the viticulturists have set a goal of balanced berry and wine composition, the yield optimization, or the collection of functional rootstocks. However, the impact of climate change is expected to transform the grapevine breeding market over Europe, as all of the regions face the increased intensity of extreme conditions. According to the study of [13], one of the suitable strategies would be to use different varieties to adapt in warmer climates, than to lose the suitability over the traditional regions. The distribution of suitable rootstocks and varieties is crucial for climate variability and the bioclimatic overlap. According to the study of [14], there are various consequences of changing the vegetation, significantly disrupting the dormant period and advanced phenological events [14]. Therefore, the berry composition is changing, twisting the wine parameters. When the overall impact of conditions becomes unbearable, berries ripen unproperly and wines tend to become unbalanced with higher alcohol and poor flavors [15]. According to the study of [16,17], one of the worst scenarios is that former traditional warm viticulture regions may become unsuitable for grapevines, as there are more vulnerable areas over the world, such as the Mediterranean area.

As the scenarios find out, wild grapevines provide a valuable gene pool for adapting viticulture to the improved management of the natural grapevine habitat. There is also a variability to counteract the relatives of future climate limitations, as it stands in countries like Poland, Latvia, or Sweden. In particular, there is a specific strategy that makes grapevine propagation and reproduction a different level of breeding—the management of biomass production and regulation of shoot system development [18,19]. Canopy management has been an underestimated aspect of viticulture. However, in recent years, it has become evident how much working with the plant's physiology can help to facilitate grape cultivation.

3. Grapevine Wood Morphology

3.1. Green Shoots

As a perennial higher plant, the grapevine tends to grow primarily from winter buds, well-protected vegetative postpone organs. The bud includes a primordial apical meristem, the green shoot. Organogenesis appears after budburst with new growing units for the primary stem. The buds remain unbalanced in production, vigor, and shape, as its fertility depends on the position and character of the wood from which they originally burst [20,21].

Grapevines feature a specific structure of primary and secondary growing tissues, the specific meristems. All of them are considered as a narrative of specific cell pools, the morphogenetic meristems with particular behaviors [22].

Many of those attributes result in specific vigor and require cultivation management to control the vegetative overgrowth. Due to this and many other reasons, the grapevine became one of the most suspicious plants when it comes to controlling the quantitative and qualitative development by pruning and thinning [23,24].

The grapevine structure is a precisely organized system with several stages of plant tissues ranging from cell development to branching. With years of progress, the shape of the shoot system has diverged, evolved, and now it leads to adapt for the mechanization of pruning, shoot positioning, spraying, and harvest [25].

As we observe a lignified cane, which was a green shoot even before, there is a morphologic signature typical of lianas—nodes and internodes. Described in an article as phytomers and dedicated to metamers, they grow in length when the apical dominance is present. After decapitation, the shoots and nodes of the main axis establish in length, growing in thickness, and giving a signal to burst the side shoots, also known as lateral or sylleptic shoots. The regulation of shoot development is useful technique for yield control and limiting phytosanitary inputs [26–28].

The vegetative architecture of grapevine plants needs to be modified periodically. Possibly, the most useful of all interruptions is to modify the plant vigor and overgrowth. In particular, the parallel is to balance the trophic competition between vegetative axes, source-sink (leaf-cluster) balance, and maintain the vigor of buds and shoots [29].

As they grow, the shoots bear the fundamental sources of the next-gen axis, the fruitful winter buds. These vegetative organs obtain the quantity of yield per vegetative axis in a close correlation with variety dispositions. It is necessary to select the correct level of buds during the pruning season, as there numerous types can occur with various prepositions [30]. Grapevine growing management is estimated by the strength and vigor of the shoots. The proportion of dry matter within the shoots is generally constant, i.e., 50%, and the rest of the tissues and components are related as annual accumulated biomass.

Ravaz Index and the Plant Vitality

The strength and vigor of the shoots is related to the plant's resource management ability during the vegetation period. A wider scale of extreme conditions impact the plant's ability to develop more or less vital shoots. As Ref. [31] mentioned in their study, the plant's vitality should be related to drought, but also to the mechanic tissue damage (hail storms) and larger yield reduction (cluster or berry thinning) from previous vegetation. Most of this matter comes out during lignification, harvest, and pruning, making a footprint in the plant's vitality. The Ravaz index is capable of bringing a closer reference to the complexity of the issue with plant vitality, to understand the plant's reactions in different situations [31]. The value of plant balance is related to the fresh pruning wood/yield ratio. This index tends to express the quality of the canopy during vegetation with the correlation of lignified shoots. The index can provide a useful interpretation of the plant's reaction to extremes. It should be a useful tool, giving the viticulturist an accurate chance to obtain more or less weak plants with vigorous and less vigorous shoots, or with lower biomass production [32].

3.2. Other Morphological Factors of Inner Tissues

The grapevine is a liana, so the inner tissues have a special composition and its morphology should be a useful tool for building the functional structure of vessels and tissues. The internal structure of grapevine wood is morphologically segmented. Starting with the internodes, their diameter after lignification points out all of the precursors for good or weak sap-drawing features—intensity of lignification and the proportion of secondary tissues and flesh [33].

Grapevines, in line with other perennial plants, develop many secondary tissues located within the cortex of structures. Many of these consist of less-lignified cells, including vascular cambium, the phelloderm, and phellogen tissues (suberin, cork) [32,34]. The phelloderm is suberic cambium and plays a role in shoot development and canopy architecture. Sideways, the vascular cambium has an essential influence on grapevine morphology. This tissue is primarily involved in the production of the xylem, the main tissue of the stem, and is responsible for the process of structural ramification [35,36]. Some diversity in the length and diameter of primary axis shoots and internodes was observed. During the process of lignification, the primary structure of the trunk is developed year by year until it reaches the demanded shape and height. It consists of less supporting tissues with a larger collenchyma in the cortex. This ability is useful for arranging the ideal anatomical flexibility of the apex with plastic-like growing direction, composed of three main directions—gravitropism (root–soil relationship), trimorphism (mechanosensory movement), and phototropism (canopy–sun relationship) [37].

All of these factors combined have a significant role in shoot morphology, affinity of scion and rootstock, growing potential, and vigor [38]. Following the composition and continuity of tissues, a complex structure is formed of physiological and morphological traits, forming the system of living nutrition channels. This sap-flow path remains unchanged throughout the plant's lifespan and any intervention—dried wounds, scars—disrupts it. Pruning without considering the natural sap-flow conducts a large decrease in the trunk, canopy, and production [39].

3.2.1. The Dormancy

In areas where the annual winter temperatures are under 10 °C, the grapevine tends to perform one vegetative cycle per year. Considered as an end of the green period, facing a few days of lesser temperatures than 10 °C, dormancy is a subordinate process to the traits of various climate influences. It is supposed to end one growth cycle and to culminate nutrition and set up the winter buds for the next vegetation; therefore, dormancy is an essential period for the plant's rest [40–42].

Three successive stages are typical for dormancy. It starts with pre-dormancy, where the inhibition process is set to prevent the winter buds from breaking with influence of external conditions and limiting the internal resources to plant level [43]. Dormancy (endo-dormancy) is where all the internal processes are regulated by physiological factors, mainly the cold temperatures of abiotic stress [44]. Eco-dormancy is not affected by internal factors, but only by the environment, particularly the temperature initiation. After this stage, budburst is determined by the rate of nutrient resources and temperatures. As is known, pruning during eco-dormancy has a lower effect on budburst [45,46].

During the dormant stages, pruning is performed to adjust the fruitful potential for the next vegetation period, but also to limit the shoot development. Late pruning after the budburst limits the flowering and the ripening process. This factor is a useful tool for facing the spring frosts [47–49].

3.2.2. The Consequences of Pruning

The pruning process can be considered as the top of a glacier through the dormant period of plant. Pruners are dismantling the canopy from unnecessary shoots and living wood, giving an advantage to the residual fruitful wood in terms of nutrition and spacing, focusing the production of the future canopy directly to the reserved canes or spurs. On the other hand, during the pruning season, a large scale of damage and scars occurs, that will never be completely healed and which are sensitive to the trunk pathogens [50,51].

The pruning period is considered to be the most important and longest work undertaken in a vineyard during one plant cycle. This operation is necessary to maintain the health and production of the plants on a long-term basis. Moreover, every pruning system is dedicated to the number of fertile dormant buds per vine. This feature will determine the yield per plant, the number of primary shoots, or the number of buds per spur/cane [52]. It ends/starts the annual cycle, as we tend to prune after leaf fall and end it before or during the bud burst. It is necessary to obey the dormancy, to avoid abiotic disorders, such as spring frost or the lethal effect of susceptibility to pruning wound consequences [53].

As plants are facing the increased temperatures and unsuitable climate changes, several varieties and regions are affected by unnecessary metabolite accumulation, color intensity, and polyphenol concentration. One of the possible traits of seeking balance to these changes is to adapt the start of the pruning period. Later shoot pruning has a significant effect through the blue varieties, enhancing the canopy architecture and the photosynthesis efficiency [54]. Standard winter pruning is taking place in February. Late-performed pruning has an impact on the grapes, accelerating the ripening, especially the veraison of blue varieties, as late-pruning takes a one-week pace from mid-May until the end of June, synchronizing all the threats during veraison. This treatment may give an advantage to the blue varieties, syncing the phenolic compound of grape, must, and wine [55].

Pruning Wounds

With the conditions of pruning, there comes a significant obstacle of high humidity during the fresh cuts. Infections of living wood are caused by saprophytic parasitic fungi, which invade the pruning wounds and are associated with the complex of grapevine trunk diseases (GTDs) [56,57]. All of the spores and infections are located on the fresh pruning wounds within the dormant season, creating multiple entrance portals for pathogens [58].

Decay, death arms, and diebacks might be susceptible for the trunk establishment mistakes. The plant structure gains a large surface of open scars each year without capability of prompt regeneration. Older permanent structures are stacked by numerous pruning injuries and this study observation proved a higher loss of yield and canopy capacity of older, damaged plants [59]. The perennial wood structures, such as trunk and branches, contribute more of the fungal diseases within the structure, as there is an unbalanced texture of living wood and desiccated rotten wounds. Mostly, the struggling of vigor and fall of growing intensity includes concrete symptoms such as cordon strangulation, diebacks, and commonly the foliar symptoms of canopy with low vitality. The quantification of increased symptoms might be boosted by several surrounding factors, mostly by the extremes of climatic conditions—drying winds, frosts, and high humidity [60].

During the dormant period, the wood of grapevines is prone to the agents of infection, mainly the large pruning wounds, rainfall, and high humidity. Infectious spores are spread to the fresh wounds of woody tissues following rainfall. On the surface of pruning wounds, there was detected the presence of wound-colonizing microbes. What is notable for the practices of pruning, following the studies, is that the number of microbes found within rainfall-exposed pruning wounds was much higher than in those protected from rainfall [61].

Pruning is an essential practice dictated by the morphology of grapevine plants. To optimize yield and plant productivity, growers manage the bud load on the youngest, productive wood—the lignified shoots, also known as canes or spurs. This process creates wounds on the living wood, triggering physical and biochemical defense mechanisms, with different pruning techniques eliciting distinct defensive responses [62,63].

The pruning of shoots and old wood is causing long-range damage to the vine structure, equal to the range of the opened surface. This leads to the development of tyloses in damaged xylem vessels, disrupting the transport of water and minerals. There is a correlation between the gap of nodes and the distance from the permanent structure. Nodes closer to the trunk developed tylosis faster than distal ones. The development of tyloses might block up to 40% of vessels. However, the water transportation system may be restored [64,65]. The selection and character of 1-year-old wood, spurs, or canes, the fruitful vectors of future yield, are the main part of any pruning style. With new trends, there are many experiments with the length, density, and position of fruitful wood [66]. In 3-year-old grapevine wood, about 2 months after pruning, there is an increased amount of lignin development in the cortical parenchyma. Below the opened wound, many hyphae of fungi were detected [67].

Unlike in other fruitful trees, in the 3-year-old pruning wounds of grapevines, no suberin or calloses were detected. Pre-observation of desiccated pruning wounds verified that the preserved basal buds protected the lower vascular system from desiccation. The cones appeared greater in the 3-year-old wood than the 1-year-old of the same pruning style and the same age [68].

As it stands, with damaged wood, there is a higher chance of fungi infection within specific condition, penetrating into the living wood and stem tissues. Except for the roots, all the types of living tissues are prone to the spreading of trunk diseases. The highest infection rates were detected within the trunks and cane ends, proving that GTDs are primarily shoot- and trunk-focused pathogens, spreading through the open wounds [69].

There are many techniques of grapevine plant establishment in terms of morphology and production. However, there is not any significant proof that different plant establishment can interrupt the grape yield. Mostly, the habitus of grafted plants can withstand more injuries and damage. On the other hand, the own-rooted plants tend to increase the trunk weight [70].

Grafted plants have a strong influence against the leaf symptoms of GTDs. Different grafting techniques have an effect on plant xylem development within the grafting point. An important factor, besides the correct technique, is the choice of grape cultivar and rootstock [71].

3.2.3. GTDs, the Main Threat to Wooden Structures

Heat and water stress may affect the plant's physiology, production, and development. Also, the pathogen's life cycle is affected by individual or combined stress factors. The response of grapevines against stress may interfere with the recovery of the plant, such as the intensity, duration, and timing. On different occasions, most of the grapevine pathogens have a negative effect on the canopy architecture [72]. Local shoot necrosis and deformed vigor is similar for most of the diseases or specific fungi. All of the biotic stressors tend to produce an irregular plant morphology, limiting the lignification and causing specific damage to stem tissues [73].

Vineyards all over the world are facing issues with production and vitality loses subject through the vegetation stages. Many of the losses are caused by different fungi species. With the changes in vineyard cultivation, we have to face specific symptoms of fungi with a common injurious range in the old wood. Those fungi are a wide-ranging species, so-called grapevine trunk diseases (GTDs). According to the study of [74], the vascular system of the grapevine produces morphological and physiological mechanisms as a response to pathogen activities. GTD-fungi cause expressed symptoms relating to the formation of tyloses inside the xylem vessels. The complex also causes extracellular enzymatic ligninolytic activities of laccase, manganese-peroxidase, or lignin-peroxidase [74].

According to the authors of [75,76], GTDs consist of up to 135 fungal species of 35 genera and are considered the largest group of grapevine pathogens. Most of the GTDs are fungi ascomycetes; however, some basidiomycetous species also occur in the system. Stress and GTD infections, the main vascular pathogen disrupting vineyard sustainability in the last 30 years, are closely linked, influenced by factors such as the host–pathogen nature, rootstock, clone, and cultivar. While studies have suggested that water and thermal stress may trigger these diseases, the research on the combined effects of abiotic stress and GTD infections is lacking. Additionally, as per [77], endophytic fungi can remain latent in vines for years, complicating detection and the use of prophylaxis methods. Grapevine trunk diseases (GTDs), such as Eutypa, ESCA, Botryosphaeria dieback, or Petri disease, are related to the wilt of the vascular system. They are caused by set of taxonomically unrelated ascomycetes with different techniques of colonization, and host limitations. The plant objective is limited by the loss of hydraulic conductivity and the xylem transport capability. Many *V. vinifera* cultivars reflect different stages of vascular disease tolerance [39,78].

As per the studies of [77,79], the main part of the plant defense mechanism has not been completely evaluated. There is a significant evidence that commercial *V. vinifera* cultivars are ESCA-prone by the correlation with the open vessel diameter. There are many organism taxons which have a direct or indirect impact on plant biomass production and so on the strength and vigor of shoots. A significant example is the use of green manure of weeds as a cover-crop on the field. Green cultivation has a massive effect on plant development, and nutrient or water transport is boosted or reduced by its presence. Inside these tissues, there was detected minimal indication of spreading fungi. A similar relationship is seen with leaf fungal pathogens, as the competition for carbon and mineral resources, reducing the biomass assimilation by limiting the sources. And so, many of these pathogens are affecting the root system.

The main result of the study [80] is that there is significant proof of GTD infection caused by the removal of grapevine suckers and green shoots. The infection caused by GTD is on the verge if trunk the fungi penetrates the vascular system through the gap caused by pruning wounds. Another possible entrance for infection are the wounds caused by removal of green shoots and suckers. According to the results of the mentioned study conducted in South Africa, 62% of isolated sucker wounds were infected by GTD pathogens. Most common of the fungi species was *Diaporthe ampelina*, followed by *Eutypa lata*, *Diplodia seriata*, *Cryptovalsa ampelina*, and many others like *Phaeomoniella chlamydospora*, *Phaeoacremonium minimum*, or *Eutypella microtheca*.

4. Features of Shoot Architecture Occupying Different Trellis Systems

Different types of trellising are used around the world to suit their style of production. In choosing different trellis/pruning intensity, it is important to suit different cultivars, growing habits, and the vigor dispositions unique to the region. Growers around the globe are focusing on two different treatments—the vertical shoot position (VSP) trellis, including such strong advocates Guyot and spurred cordon and on the other hand, there are hanging high-wire trellises [81].

Selection of Canopy Architecture and Training System

A combination of pruning, plant management, and training systems results in a grapevine architecture model. It has to be calculated by using the plant spacing in the row (the distance of each plant represents density), and so the geometry of the trellis [82]. According to the variety, soil, and conditions for cultivation and the maintenance of buds per plant, it is really important to choose the right strategy of production using the training system. Choosing the spur pruning or cane pruning is a main task for the correct establishment of the training system and architectural model. For example, Guyot is a main cane-pruning system of the VSP (vertical shoot position) architectural group. The bud fertility is related to the position of buds on a cane and top–bottom sap-flow gradient. This training system is well-known to be suitable for many varieties and climate conditions. On the other hand, cordon pruning is based on the spurs of two visible buds and the number of spurs fixes the production of plant, but also stimulates the plant production [83].

A canopy is adjusted by green shoots with considered position on 1-year-old-wood of the plant structure. Those fruitful shoots are determined by interactions with biological agents, environmental factors, sinks, and reproductive organs. These interactions are used to optimize the mineral and water consumption of vegetative organs, but also to moderate the canopy microclimate. Grapevine growing dispositions are nearly unlimited in the natural habitat [84,85].

The training system is a vector of crop placement to ease the position for laboring, protection, and harvesting features. However, there is the density of the canopy biomass, which causes humidity inside the canopy and so supports the spreading of fungal infections [86,87].

Modern viticulture faces a huge challenge to pose a water limitation in many viticultural areas. In many production countries, water supplements are needed to preserve the economical yield and quality. The strategy is focused on improvement of water used by crops per dry matter produced, to consider the goals of sustainability and functionality of training [88,89].

Viticulturists tend to manage the canopy for sunlight exposition, yield control, and microclimate conditions [90]. Despite the yield demands, they have to consider total underwater availability, potential water consumption, and nutrition requirements. There is also the task connected with the prompt management of solar radiation inside the canopy, which is allied with cultivar dispositions, design of canopy, and trellis [91].

A large scale of trellis and training configurations is available at the moment. Therefore, many factors need to be considered—local climate, the official regulations, terrain and soil type, variety and clone, mechanization, management, human work resources, and so on [92].

5. The Selection of Suitable Training System—Effectiveness of Vertical Shoot Positioned (VSP) Training Systems in Comparison to Hanging Systems (SHWs)

The production of grapes is highly connected with shoot distribution and canopy architecture, as it features the potential vegetation, crop production, canopy gas exchanges, and thus the potential light interception [93]. In any event, the model of the shoot system is a matter of complex growing, design, and architectural attributes which have to work at many levels—shoot, plant, and site [47,94]. All of those integrations were approached many times with issues of creating variation in the plant model with local proposals and well-integrated sink–source interactions with the needs of plant, canopy, vineyard management, and climate properties [95]. As it stands, one of the biggest traits is shoot branching and control of the main growing axis [96,97]. As to control, there are many genetic factors of vegetative development that need to be included while choosing suitable viticultural model—the length of metameter, primary growth rate, above-ground biomass, tendril differentiation, or para-dormancy of winter buds [98,99].

- Facing the spring frosts in cool regions

The viticulture sector faces climate change adaptations since those charges have a massive influence on ripening, harvest dates, spreading of new diseases, and water stress. One of the common interceptions is that the wines have a lack of aromatic compounds, a lack of freshness with excessive alcohol content. There is a significant threat from spring frost damage, in growing regions with mild and inconsistent winter periods. As noted by [100,101], spring frosts are pushing the phenolic stages of plants. The worst scenario is if spring frosts disrupt the most sensitive parts of plant—the apex and inflorescences. A damaged apex does not tend to grow upwards in a natural position anymore, seeking new ways of branching out. On the other hand, disrupted inflorescences may cost us the crucial part of yield content. As mentioned in the previous studies, grapevines always burst new shoots, even if they are just suckers. But the crucial stage is the damage to the yield. Southern regions face a larger scale of traits, especially increased dryness with reduced yields, while the actual CO_2 accumulation may compensate for the dryness effects in Northern Europe, with increase in the maximal yield. According to the narrative of this article, one of the possible solutions for facing the spring frost is the trait of plant's growing nature. Suitable training and a higher altitude of the trellis should help to evade these dangerous spring frosts up to the delicate zone of burst buds. Actual problems also impact the production of a chained market and the potential changes in the suitability of viticulture [102,103].

5.1. Modern Threats of Selecting the Suitable Training System

The grapevine is a widely grown plant with a perennial life span. Viticulture and winemaking share an important cultural and agricultural legacy with social and economic features [104]. Furthermore, viticulture and winemaking share an environmental impact, with many pesticides used on small areas of cultivated land. For instance, in 2011 in France, there was a commission of 20% of pesticides used only for vineyards, leaving environmental impacts such as groundwater pollution and potential ecotoxicity of air, water, and soil [105,106].

Training systems are chosen to support our demands for grapes—the fruit composition, sugar content, volatile and aromatic compounds, and as a result, the phenolic content of grapes and must. Also, if we check different studies, changes might occur in the parameters, such as the acidity and sugar content, pH, or YAN, but also, many of the authors have suggested that different training systems have some impact on the wine sensory [107–109]. Training grapevines with appropriate canopy development may stimulate the vegetation period. This attribute will be hugely important in the future through the process of climate change adaptation. All the regions of Northern Europe start the ripening period much earlier than in recent years. This fact may cause the unwanted pre-maturing process or overripening of the early varieties and possibly a higher number of pests. One of the existing critical points, according to the sources, is when the variety cannot suit the climatic dispositions. Therefore, it needs to be grubbed up or regrafted and to be replaced by a different variety/crop [110,111]. On the other hand, training systems such as minimal pruning are suitable for the effect of delayed ripening. This is because of the higher leaf/fruit ratio in such a massive clutch of biomass; therefore, it is able to mitigate the negative effects of climate change and high temperatures [112,113].

5.1.1. Considering Vertical Shoot Position (VSP)

According to [114], there will always be competition between training with vertical shoot position and the free growing canopy. Both of those groups are locally considered as the category of hedgerow training systems, which account for 70% of total vineyard plantings worldwide, and still counting in a sense of smart mechanization. The essential feature of the VSP training model is the support of natural liana spreading on the trellis [114,115]. Moreover, the sprawled canopy is a revolutionary type of canopy habitus and the importance of having an upward or downward canopy is perceived. VSP obeys the factor of the narrow, vertical extension of the canopy with limitless vigor and ripening, gaining optimal leaf expression to the sunlight, giving this training an advantage by equalizing the ratio between the maximum canopy height and row-spacing to 1:1. Many viticulturists insist that various types of training demand different pruning and correct support trellis systems [116,117].

Many factors need to be considered when selecting the combination of trellis and training system. One of the huge and therefore very important challenges for the future is work with the sunlight exposure and shading dispositions. Really good examples are open-shaped trellises, such as Y-shape and Lyra, where the sunlight exposure of vigorous varieties is increased, pulling back the canopy density, making this system useful for improving the health condition and grape quality of humid and cool climate regions. However, higher canopy exposition has a threat of increased water consumption and may lead to different plant stress [32,118,119]. Summer periods in various regions became the hottest in the history of measurement and many vineyards over the world were affected—sunburned leaves and clusters are the first stage. After reaching 35 °C, the leaf is forced to enclose the stomata, cutting off the photosynthesis. Damaged foliar tissues reduce the photosynthesis and sugars gained, interrupting the C6 cycles and reducing phenolic content—the aroma of white varieties and pigments of blue ones. Reduced absorption of foliar and radical nutrients is exhibited in the plant's health by reduction in the trunk-accumulated reserves [120].

While choosing the VSP, to gain the best canopy exposure to sunlight, it is usually required to consider the orientation of the rows with the maximum of day light interception and daily photosynthesis rate of the whole canopy and display the effectiveness of CO_2 exchange in relation to the amount of intercepted light and the part of the best-lit part of the day [121,122].

By these inductions, the VSP-type management of the canopy is the most widespread system, uniformly exhibiting both sides of the canopy to the sun and contributing maximum sunlight [123]. However, the effectiveness of VSP fades in warmer areas. This can happen because the conditions of total sunlight in the canopy management interfere with grape ripening, exerting with berry composition, must content, and exact wine quality [124,125]. By the theory, in relation to controlling the canopy, there might be a highest effectiveness for the climate change, planting vineyards in an East-to-West orientation with sunlight exposition taking aim to the North–South, trying out the reduction in solar radiation interception in the afternoon. Under these conditions, this scenario would give more freshness and typicity to wines produced in Mediterranean areas with issues of using VSP or SHW [126,127].

5.1.2. Considering Hanging Canopy (SHW)

According to the study of [113], different training systems may change the wine sensory. To choose the criterion to consider while selecting the trellis system, there is the main trait of shoot posing—the upright shoot systems tent vegetation to face to the vertical trellis design and the hanging shoots are managed as descending vegetation models or minimal pruning. However, the genus of *Vitis* needs to be characterized more by the phenotypic and genotypic plasticity. It gives a perimeter for grapevine breeders to manage the shoot architecture traits, via the selection of rootstock and scion for better management, and biotic or abiotic stress adaptation [113].

It is necessary to consider that diverse trellis types have different reactions to main traits, significantly related to the climate. With different canopy treatments, there is a different valuation of vigor and yield control, pathogen-related sensitivity, or sustainability for charges. The final results are different in cool and warm climate areas [128]. Recent diversification of grapevine pruning system was based on low-level specification of canopy management, split into three main groups—minimally pruned canopy, vertical shoot position (VSP), and hanging (sprawl) shoot canopy, whereas all of them can be encompassed with the metabolic signature in final wines. A higher level of training system is an option of compositional preferences [129].

The SHW training model tends to become an extremely important growing system for the next generation of viticulturists. There is a massive advantage of cost due to minimal trellis structure, cultivation needs, and mechanization used. Also, in a long-term comparison of different training systems, as previously mentioned, with the correct establishment, management, and support, there is also similar grape and yield composition as in the case of VSP. As confirmed in [130], by the use of different SHW trellis systems on representative warm-climate varieties, we can promote the accumulation of total soluble solids (TSSs) and more stable anthocyanins and flavonols in berry skins. Nevertheless, the main factor of success remains in the interaction of the canopy with cultivation issues, such as the factors of vine growing— the association of scion with rootstock, that develops the appropriate canopy with both good ripening and wood maturation potential [130,131].

5.2. Different Groups of Trellis Systems

Trellis systems can be divided into various groups, as the architecture of the canopy is followed by vigor of the trunk, wires, and poll system. All of the trellis types have different features and attributes, such as susceptibility to fungal diseases, sustainability, wine style, mechanization model, plant vigor dispositions, yield control, and the climate-related features in general.

According to [132], we can divide pruning styles into two main categories—cane- or spur-pruned types, as they are followed by the nature of fruitful shoots. By the evaluation of canopy management, pruning attitude, and wooden structure, we can divide the styles as follows:

- Classic VSP (vertical shoot position): the majority of plantings all around the world—spurred cordons, Guyot, and more. They are suitable for the majority of viticulture regions.
- Spreading and hanging trellis types: (pergolas, chamber system, Raggi-Bellussi, Tendone) are sustainable, easy to maintain, and have high yield potential. We can find them more in the cool and humid areas of Northern Italy or Northern China.
- Single-high-wire training (SHW, Curtain, Sylvoz) are suitable for higher yield varieties. However, they are considered to be the future, because of the shading potential and easy costs.
- Split canopy systems (GDC, Scott Henry, Vertiko, Kniffin system) are considered as really high-yield trellis systems. With mid-easy management of the canopy, they are commonly used in warmer climates such as New Zealand or Mediterranean areas.
- Closing shape (Y-shape, SAYM, Lyra) is still in development, but obtains serious potential for VSP variations in regions with higher shading demands.
- Single-pole systems (Trier Slamka wheel, Mosel stake training, pole cultivation. . .) are low demand trellis models with higher participation of hand work. The design is planned for the conditions of steep riverbank slopes and narrow terraces.

- Traditional spatial systems (Gobelet, Bush vine. . .) are the remains of elder wide-space trainings. The design is planned for semi-arid areas with high sun exposure such as regions of Southern Spain, Southern France, Portugal, California, Middle East, and so on.
- Special pruning styles with local traditions (Chablis, Vallé de la Marne, Cordon Royat, Nest/Basket/Kouloura) are designed to face specific conditions of the regions from which they come. What is typical for these trellises is that only a few pruners are authorized to take care of them.

In a different way of diversity, we can divide the training systems by the shape/orientation of the canopy—vertical, hanging, or minimal pruning canopy.

5.2.1. VSP—Vertical Shoot Position Variations

Vertical position is suitable for low to medium vigor cultivars. First, the base wire is installed less than 3 feet above the ground with multiple pairs of movable catching wires above the base cordon wire. The training of shoots is vertical from the base to reach and tuck the flexible catch wires. Those trainings initiate a well-organized canopy with hanging clusters and easier access inside. However, it is more expensive and requires more maintenance [86,133].

As you can see in the Figure 1, here are various pruning styles and trellis systems with a controlled vertical canopy fixed more or less at trellis construction. Many of them are on stakes, such as (A) arm stake and (B) Mosela heart stake. This type of trellis management is related to very specific conditions of steep slopes with harder mechanic management. Also, there are trainings represented by canes with a horizontal wire trellis, such as (C) Guyot and (D) Sylvoz. These trainings are versatile and fit to various conditions over the whole winemaking map. Following the production goals, there exist more cordon training variations with numerous multiplications of cordon arms. A few of them are regional, for example, (E) Lyra or (F) three-tier top cordon, but there also exist versatile variations for the general part of the winemaking world, such as (G) spurred cordon or (H) four-armed cordon. The potential of these trellis systems is connected with specific regions all over the world. Different traditions, varieties, production goals, and terrain exposition give growers more or less developed opportunities for vineyard management.

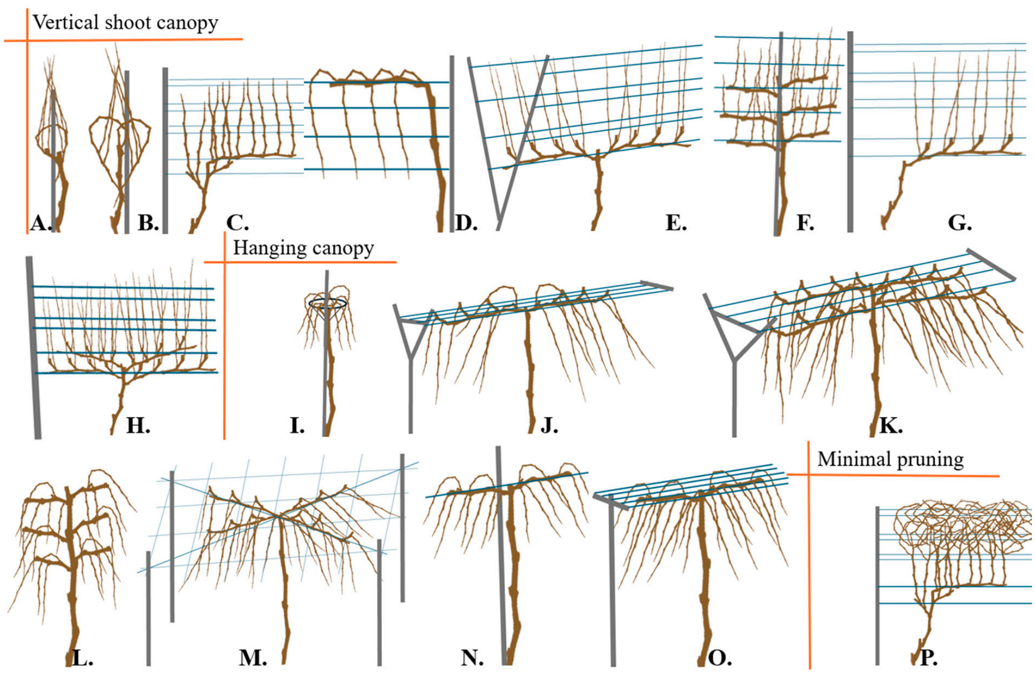

Figure 1. Different types of canopy, sorted by trellis model and dispositions of shoots—vertical shoot canopy (**A**–**H**); hanging canopy (**I**–**O**); and minimal pruning (**P**).

5.2.2. Hanging Shoot System Variations

Moving to the hanging trainings, many of those systems were designed to be easily cultivated by mechanization such as the (I) Slamka system on the steep slopes of the Mosel river, or the (J) cordon curtain. There are numerous regions over the world, such as Veneto or Trentino, where producers aim for a quantity of grapes and where the conditions of cultivation are suitable for high-yield hanging trellises, such as (K) GDC, (L) GDC duplex, (M) pergola, (N) Vertiko, (O) curtain, or (P) tied curtain training.

Single high wire system (SHW) is suitable for cool climate viticulture, suiting well cold-hardy varieties and hybrids with higher vigor through vegetation. SHW requires less labor, mechanization, and investment, moreover demands less pruning practice and shoot positioning than more complex training systems. All of the trainings consist of 1–3 wires 1.2–1.8 m above the ground. Two cordon arms should be trained along the top wire. The high position allows good sun exposure for the fruit and the "renewal zone", establishing fruiting buds for next season [134,135].

5.2.3. Minimal Pruning System

This (no)pruning system (P) takes place if there is minimal effort given to the canopy. It is based on the natural habit of lianas for acrotony. Yield and quality is consistent and provides a serious impact of minimal growing costs. Agronomists are satisfied with the minimal human work resources and maximum of work obtained by tractor. It is important to mention that the trellis needs to be strengthened by adding more wires. The biomass of living tissue grows annually. The basis of this training is the classic cane, with controlled growth upwards, then twisted into the wires [136].

5.3. The Well-Suited Training Systems—Guyot and Spurred Cordon

According to [82], two of the most effective VSP training systems are Guyot and spurred cordon. As we can observe in the Figure 2, both of these models are considered to be part a training and part a pruning system, according to many styles and variations in them. Both of them can be used for the majority of grape cultivars. Guyot is determined by the cane, obtaining as many buds as needed by its length and production rate. This cane needs to be bent in a horizontal position, avoiding acrotony. The density of the vegetation depends on the length of internodes. Spurs are providing the supporting role, giving this training a supporting basement of stronger shoots, obtaining more possibilities of selection of future canes for the next season. Guyot training is also well suited to cool climate regions. The fruitful cane is better preserved and in case of frosts that bring different dangers. On the other hand, cordons are determined by the number of spurs, the tertiary structure, located on the secondary structure, the cordon arm. The production capacity and density of the vegetation will depend on the number and distance of spurs. The selection of a cordon trellis is notable for higher quality production goals. Various countries around the globe use cordons in different shapes, as mentioned in the Section 5.2. What is also really important to mention is that historically cordons were more suitable for warmer climate regions, such as South Africa, California, Southern Italy, and Spain. Nowadays, the popularity of cordon training is also increasing in cool climate areas. The main reason is to minimalize hand work by machinery [137].

The modern threats of viticulture have made growers reflect on all of the factors that bring functional and sustainable training systems for both of the high-quality pruning styles. Research studies from Italy have developed sustainable and functional method of pruning, using Guyot and cordon with a special setup. These rules give the wooden structure a beneficial opportunity to gain as much compact wooden structure as possible, using a special technique of old-wood ramification, as displayed at Figure 3. This method is called the Simonit & Sirch pruning technique and its role in modern viticulture is becoming crucial. Grape-growers are facing the modern threats of climate change, diebacks, and new diseases. Plants are hardly withstanding all of the pressures of climate change, desiccation, and spreading infections. Compact pruning with structure work is obtaining large-scale popularity across the field of growers. One of the benefits is to properly preserve the old vineyards, as they produce a different quality of grapes [138].

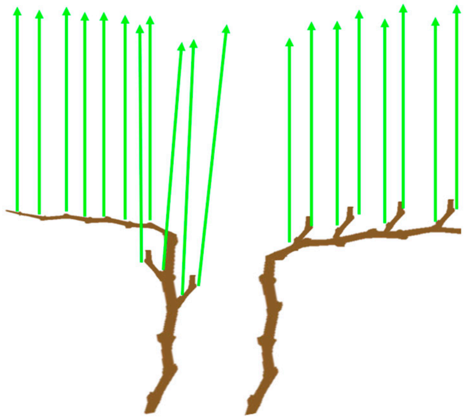

Figure 2. Comparison of canopy of Guyot and spurred cordon.

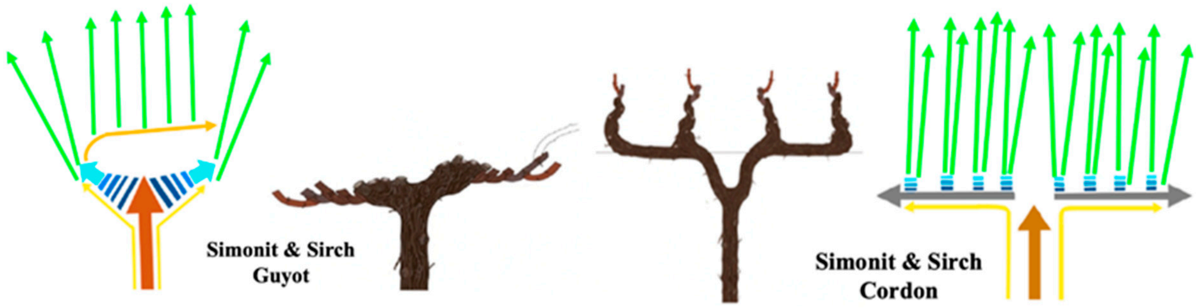

Figure 3. Comparison of structure, growth, and canopy of two classic Simonit & Sirch trainings—bilateral Guyot and double-armed spurred cordon.

5.4. Choice of Suitable Trellis and Training System

If it comes to the comparison of cool and warm climate training models, lateral cordons are the most common training at all. Its establishment is lower in cost and easier for pruning, harvesting, and manual work. As we can observe on warm climate training representatives, such as gobelet of Bush wine, the canopy of the warm area is configured to prevent the excessive sunlight exposure of the grapes. Highly vigorous vines tend to require the shading and higher humidity inside the canopy. However, as mentioned in the article [139], popularity is also increasing when used as a combination of upward and downward shoot positioning, making this system a hybrid of a vertical and hanging canopy. Generally, it is used in coastal regions. The lower fruiting zone always becomes weak over time. A cane pruning alternative with a combination of up and down canopy is also desired to be suitable for vigorous vineyards in warmer climates [139].

To consider the trellis system, there is the main trait of shoot posing—the upright shoot systems tent vegetation to face the vertical trellis design and the hanging shoots are managed as descending vegetation models or minimal pruning. In general, all the sorts of *Vitis* genus need to be characterized more by the phenotypic and genotypic plasticity. These charges should be a perimeter for grapevine breeding, to face the shoot architecture traits. Either way, this should be considered as an opportunity for proper selection of rootstocks and scions for better biotic or abiotic stress adaptation [116,140].

The liana-like nature of the grapevine makes the reaction of plants to the pruning more sensible. Moreover, vertical shoot position (VSP)-based training systems, such as cordon and Guyot, are generously adapted worldwide. However, the presence of longer than one-year-old wood makes cane-pruned training systems suitable for the pruning style transformations with a lower limitation of plants. Global climate changes have created a lot of new challenges for grapevine development. The task is concerned with tackling features such as the length of growing season, phenology formation, ripening, overheating and sunburnt stress, and extreme weather events. However, is there any coincidence that makes the training system an adaptation tool of viticulture against climate changes [141,142]?

5.5. Future of Training Systems and Canopy Modifications

The future of training systems, regardless of the mechanization demands, has various needs depending on the climate conditions of the relevant areas. Therefore, we can divide into two main climate models—cool and warm climate areas. According to [143], interest in the heresy of pruning and trellis models broke out as average temperatures rose through vine-growing regions worldwide. The laboring conditions became inconsistent in various areas [143]. Vintners understand that under these changes, they have to utilize the physiological tools of the vine. Nowadays, they are working with different varieties and rootstock selections, genotypes, and training systems to accelerate the ripening process through the controlled yield and vigor of plants. In line with the study of [144], vineyards are receiving ideal shade content, better bunch exposure, aromatic and phenolic expression, and leaf-to-fruit nutrient ratios. Meanwhile, in the scenario of [145], current warm areas head to becoming sub-tropical and the cool climate areas would rise in quality. Traditional SHW, VSP, or gobelets are limited by the number of canopy manipulations, as the trend tends to increase the number of manipulations, building more from fresh leaves and shade. Despite the selection of suitable training models, it will be essential to change our minds about plant demands, especially cluster shading, delayed or slowed ripening, drought, and frost damage. It will be necessary to start choosing natural-shading systems such as curtains of different SHW representatives that are suitable for mechanization [145].

In humid and relatively cool areas, such as Poland, where hybrid varieties are preferred and where white wines represent most of the production, a downward canopy should be preferred for it is easier to maintain by mechanical trimming close-to-the-ground. Meanwhile, in Mediterranean areas, the SHW cordon trellis is also developing, which has an ability to produce more shade for clusters inside the canopy. The effect of shading is one of the present precipices of viticulture [86,146]. The trimming of VSP tends to promote the habitus of canopy and is very useful to control the vigor of reluctant varieties, such as Pinots. In fact, there are also varieties which tend to develop a straight and modified canopy, such as Cabernets [147].

Moreover, recent publications have compared the characteristics based on the development and quality of gas and solar exchange in the canopy. Many 3D-spaced models of canopy have been integrated, which are declared as the non-spreading ones. These are enabled to intercept higher light ratio into the best favorable cluster microclimate with lesser requirements for cultivation works as the classic VSP demands. The research into which deals with efficient sun lit perceptive by canopy—leaf area index (LAI)—showed that the VSP system lacks more than 25–30% of this index in comparison to the bilateral hang-cordon [148].

However, in different validity, there is a study [149] investigating the measurement of CO_2 rate (NCER) in an enclosed vine system. However, this study had to deal with uncertain factors of compact leaf area, row-spacing, different light exposure, or aging. The vines were manipulated in two different forms, simulating the VSP canopy conditions and free-form sprawl canopy. Through additional studies by the team, the hanging sprawl canopy received a 26% higher photosynthetic rate due to better sunlight penetration inside the layers of canopy. In addition, the VSP model achieved less midday light capture. According to these results, the sprawling canopy has a lot of potential. Even if we consider it formally as a shading variant, there is a possibility for this training to reach better physiologic content than VSP [149].

There has been recent research into grapevine training systems and related pruning consequences, vine spacing, precise viticulture, and structure development. As a topic of research, it attracts less funding than any other area of research (e.g., smart viticulture, mechanized viticulture) [150,151]. Nevertheless, global climate changes obtain more of the focus, so there are explored areas such as New World (South Africa, Argentina, Chile) or Mediterranean lands (Balkan, Italy), where a training model gains more relevance as a remedy of viticultural plasticity. Adaptation to climate change is the main part of modulation of a regional grape-growing business by matching trunk geometry and canopy shape. As the conditions are changing year by year, it will soon become a relevant field to study the potential of trellis adaptation in growing areas as a trait of sustainable viticulture [152].

6. Conclusions

Due to the impacts of climate change, it is possible that the typical conditions for grapevine cultivation will need to be adjusted. These changes in average temperatures or sunlight distribution primarily concern the training systems that help plants withstand extreme weather conditions. However, high average temperatures, sunlight exposure, and strong UV have a serious impact on the balanced quality of grapes—high alcohol content, lack of freshness, lower acidity, and subtle aromatic compounds. This review examined both well-known and traditional, as well as unconventional, vine training systems typical of the so-called cool climate zone of viticulture. The canopy of these cool-climate available training vine systems, is set up on trellises of various shapes, sizes, and spatial arrangements. Use of various trellis designs depends on the terrain or site conditions with the canopy opened for sunlight. Grapes located within these training systems are exposed to the sunlight but also well-protected by a vigorous canopy. The most common vine training system in the Central European area is the VSP type, or vertical shoot positioning. Any training within this shape of canopy involves pruning to canes or spurs and this style is nearly universal for the majority of grape-growing regions. The main reason for this preference is the comfortable position of the grapes and so their exposure to sunlight. However, in recent years, even vine-growing regions in cool climate zone have experienced conditions typical for warmer, southern wine regions, such as long periods of unusual higher temperature and intense sunlight. Therefore, it is essential to assess the efficiency of the training systems with trellis models. Growers will have to evaluate how well the chosen trellis system suits in the upcoming extremes. It would become an essential aspect of viticulture to consider the technical aspects of the chosen trellis design. Selecting the suitable training system should be a visionary ace for growers, as vineyards are established for several generations and must adapt to changing conditions over time. With prompt conditions for cultivation, there will be possibilities of stabilizing the shape of the most vulnerable varieties, such as Chardonnay, Sauvignon, Viognier, Gamay, or Merlot, in various regions. Recent analysis has proven numerous problems for grapes caused by excessive sunlight exposure. With upgrades to the shading capability of the trellis, there would be better freshness and even improvements to the aromatic and sensory profile of wines.

To assess the appropriate growing conditions in cool regions requires consideration of the total sunlight capability and the annual temperatures of vegetation period for different varieties. Using classic VSP in northern cool climate viticulture is probably the most suitable option for plenty of cultivars. The winemaker can profit from simple vertical exposition of grapes to the sun. Viticulturists are available to easily maintain the canopy if they need to obtain more the sun exposure, to empower the aromatic and sugar content. A simply designed trellis for a canopy of Guyot or spurred cordon training turns the main part of the grapes to the sunlight. With the combination of sloping terrain and east-to-west canopy orientation, it is much easier to contribute the benefits of terroir. However, the further south we go on the map of wine regions, the more areas face challenges with excessive grape exposure and overheating. Southern wine-growing states are gradually moving away from simple vertical shoot positioning (VSP) and instead favoring either spatial or hanging trellis systems. Somewhere between the northern and southern wine regions lies the challenging zone where vintage variability is highly unpredictable. Countries like Germany, Austria, Slovenia, Northern Italy, Czechia or Georgia are increasingly struggling with the classic, single VSP training system. For these regions, it is advisable to weigh the pros and cons of VSP and potentially start exploring shading solutions. Suitable systems for areas like Germany, Austria, as well as the Czech Republic and Slovenia, could include Lyre, Y-type, or SAYM vertical variations. However, these systems come with high costs due to trellis installation, along with significantly higher yields, which is less typical for central regions that usually avoid high-yielding production.

In contrast, regions like Northern Italy, specifically Franciacorta, traditionally used vertical Sylvoz training before it was largely replaced by cordon and Guyot systems. However, local growers now lean towards hanging systems for the future. In recent vintages, vintners of several wine regions have begun experimenting with variations in cordon curtains. Producers have to seek a balance between vigor and yield to maintain wine quality.

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Glossary

Branches—portion of living wood from previous vegetations, connected with structure of trunk and secondary structures.
Budburst—the annual onset of grapevine's growing season. Buds swell and burst due to the activity of inner tissues.
Cane—term used to determine one-year-old wood considered as the bearer of yield after pruning. It has to be longer than three fertile buds.
Canopy—the controlled complex of green shoots developed by plant.
Decay, death arm, dieback—different terms for large, decreased pruning wounds with various overlap into the inner tissues.
Desiccation (cone)—process, in which pruning wound dries out into the inner tissues of plant, marking a specific shape of cone/arrow.
Dormancy—physiological stage of grapevine. It is considered as the period of plant's rest during winter. Its length is tied to regional climatic conditions.
GTDs—complex of grapevine trunk diseases, dangerous group of wood-spreading fungi of vine tissues. Well-known symptoms are those of Eutypa, ESCA, Botryosphaeria dieback or Petri disease.
Permanent structures—that part of plant, which is designed and trained to stay and develop in time with no needs for reposition. Simonit&Sirch divided permanent structures into several parts:
primary—the trunk—vertical position, based since the start
secondary—the arms—horizontal position, ever-evolving with each year
tertiary—one-year-old wood, cane or spurs.
Phloem—specific inner tissue of woody plants, bast texture.
Pruning (vine)—specific method of selection of one-year-old fruitful, lignified shoots, that will bear the crop and canopy production for the next vegetation.
Regrafting—special technique in tree and vine production, that involves replacing the existing scion with new, more desirable variety while retaining the established root system. This technique is used to improve crop quality or plant adaptability without replanting.

Ramification—specific technique of building structural head grapevine plant. This technique uses portion of living wood from each of previous growing cycles, branches. It was promptly summarized by Simonit&Sirch pruning method.
Ravaz index—is used for evaluation of vine's vigor and vitality compared with yield and canopy distribution.
Sap-flow—is a term commonly used for the full size of inner vessels, to point out the direction, health and capacity of plant's structures.
Spur—term used to determine short (less than three fertile buds) one-year-old wood of cordon training or the whole ramified part of cordon arm, as known as tertiary structure.
Sucker (water-shoot)—green shoots bursting randomly anywhere on plant, not included cane/spur location. So-called water-shoots, they are not bearers of regular inflorescences.
Vegetation (stage)—in terms of viticulture, it is used to summarize the whole period of intense green biomass growth of the plant.
Veraison—a part of the grape's growing cycle, during which the skins undergo coloration.
Terroir (of vineyard)—refers to the unique signature of climate, topography, soil and human work that influence the character and quality of the grapes grown there.
Training system (grapevine)—is a vector of plant development in the trellis space. It also indicates the crop dispositions for laboring, protection and harvesting features.
Trellis model—is a specific construction (wires, poles, stakes) suitable for specific grapevine training system. Its role is to bear vegetation and to ease the sunlight exposure for shoots.
Xylem—specific tissue of woody plants—wood texture.

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