UNIVERSIDADE FEDERAL DO PARANÁ

NELSON PIRES FELDBERG

AGRONOMIC PERFORMANCE OF WHITE AND RED SEEDLESS GRAPE CULTIVARS ON DIFFERENT ROOTSTOCKS CULTIVATED IN SOUTH OF BRAZIL HIGHLANDS

CURITIBA

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Tese apresentada ao curso de Pós-Graduação em Agronomia - Produção Vegetal, Setor de Ciências Agrárias, Universidade Federal do Paraná, como requisito parcial à obtenção do título de Doutor em Agronomia (Produção Vegetal).

Orientador: Prof. Dr. Luiz Antonio Biasi

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Os membros da Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação AGRONOMIA (PRODUÇÃO VEGETAL) da Universidade Federal do Paraná foram convocados para realizar a arguição da tese de Doutorado de **NELSON PIRES FELDBERG**, intitulada: **AGRONOMIC PERFORMANCE OF WHITE AND RED SEEDLESS GRAPE CULTIVARS ON DIFFERENT ROOTSTOCKS CULTIVATED IN SOUTH OF BRAZIL HIGHLANDS**, sob orientação do Prof. Dr. LUIZ ANTONIO BIASI, que após terem inquirido o aluno e realizada a avaliação do trabalho, são de parecer pela sua APROVAÇÃO no rito de defesa.
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I dedicate

To my wife Erika and my daughters Tiemi and Ayumi, who encourage, support and accompany me throughout my life.

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I thank God for my life, for all the challenges he has given me so that I could overcome them and become a better person every day.

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Then, everyone in my life who supported me and encouraged me in my career.

Try to leave this world a little better than you found it and, when your turn comes to die, you can die happy in feeling that at any rate you have not wasted your time but have done your best.

Robert Baden-Powell

RESUMO

O Sul do Brasil é a principal região vitícola do país; as uvas são produzidas principalmente para vinificação, sucos, geleias e outros produtos. A produção de uvas de mesa é pequena quando comparada a outros polos vitícolas, e tem como alvo o consumo regional. Atualmente existem poucas cultivares de uva sem sementes adaptadas e recomendadas para plantio na região Sul do Brasil. A mortalidade das plantas é o principal problema da viticultura na região e é causada por vários fatores como a susceptibilidade fitossanitária das cultivares copa e dos porta-enxertos, solos argilosos e com baixa macroporosidade, vinhas com plantas nutricionalmente desequilibradas e a ocorrência de geadas e granizo, que contribuem para o enfraquecimento das plantas. A combinação de novas cultivares copa com porta-enxertos resistentes é um dos principais fatores para impulsionar a produção de uvas de mesa na região Sul. As uvas de mesa sem sementes ‘Neptune’, ‘Hope’, ‘Gratitude’, ‘Faith’, ‘Joy’ e ‘Jupiter’ foram introduzidas recentemente na região do planalto de Santa Catarina. Para avaliação dessas cultivares, foi implantado em 2018 um vinhedo experimental, com espaçamento de 3x2 m e sistema de condução em Y. Este trabalho foi dividido em dois experimentos: Experimento 1 – cultivares brancas sem sementes Neptune, Gratitude e Hope; Experimento 2 – cultivares vermelhas (Jupiter e Faith) e preta (Joy) sem sementes. Ambos os experimentos foram instalados em esquema fatorial 3x4 (cultivares enxertadas nos porta-enxertos: 'Paulsen 1103', 'VR 043-43', 'IAC 572' e 'IAC 766'. '), com 5 repetições de 3 plantas por parcela. O objetivo de ambos os experimentos foi avaliar o potencial agronômico, fenologia, características físicas e químicas de todas as 6 cultivares copa ('Neptune', 'Hope', 'Gratitude', 'Faith', 'Joy' e 'Jupiter'), enxertadas nos diferentes porta-enxertos em Três Barras-SC. Durante as safras 2020/2021 e 2021/2022, foram avaliados os principais estádios fenológicos (escala BBCH), peso de poda, número de ramos e cachos e peso total dos cachos para calcular a fertilidade das gemas, massa média dos cachos e produtividade. Caracterizaram-se também cachos e bagas, avaliaram-se os teores de sólidos solúveis totais (SST) e acidez total titulável (ATT) e calculou-se a relação SST/ATT. A ordem da colheita, da mais precoce para a mais tardia foi Jupiter (15/janeiro), Faith (18/janeiro), Neptune (3/fevereiro), Hope (7/fevereiro), Joy (05/fevereiro) e Gratitude (22/fevereiro). Todas as cultivares, principalmente quando enxertadas em ‘VR 043 43’ e ‘Paulsen 1103’, apresentam elevada fertilidade de gemas e produtividade. O porta-enxerto IAC 766’ antecipa a brotação (três a dez dias) e colheita (um a quatro dias). O porta-enxerto ‘VR 043-43’ atrasa a maturação em um a quatro dias e ambos os porta-enxertos combinados podem ser usados para escalonar a colheita. O uso do ‘IAC 572’ induz maior vigor às cultivares testadas. Todas as cultivares testadas apresentaram elevada relação SST/TTA, principalmente ‘Jupiter’, ‘Neptune’ e ‘Gratitude’.

Palavras-chave: *Vitis* spp.; viticultura; uvas de mesa; adaptação; fenologia.

ABSTRACT

The South of Brazil is the main viticulture region of the country; grapes are mainly produced for winemaking, juice, jams and other by-products. Table grape production is low, compared to other viticulture hubs, and targets regional consumption. There are currently few seedless grape cultivars adapted and recommended for planting in the Southern region of Brazil. Plant mortality is the main viticulture problem in the region and is caused by several factors such as cultivars and rootstocks phytosanitary susceptibility, clayey soils with low macroporosity, vineyards with nutritionally unbalanced plants and the occurrence of frost and hail that contributes to weakening the plants. The combination of new scions and resistant rootstocks is one of the main success factors to boost table grape production in the Southern region. Seedless table grapes ‘Neptune’, ‘Hope’, ‘Gratitude’, ‘Faith’, ‘Joy’ and ‘Jupiter’ were recently introduced in the highlands of Santa Catarina. For evaluating these cultivars, the experimental vineyard was established in 2018, with a 3x2 m spacing and vines trained on a Y trellis. This work was divided in two experiments: Experiment 1 – white seedless cultivars Neptune, Gratitude and Hope; Experiment 2 – red (Faith and Jupiter) and black (Joy) seedless cultivars. Both experiments were settled in a 3x4 factorial arrangement (cultivars grafted the rootstocks: ‘Paulsen 1103’, ‘VR 043-43’, ‘IAC 572’, and ‘IAC 766’), with 5 replications of 3 plants per plot. The objective of both experiments was to assess the agronomic potential, phenology, physical and chemical characteristics of all 6 grapevine cultivars (‘Neptune’, ‘Hope’, ‘Gratitude’, ‘Faith’, ‘Joy’ and ‘Jupiter’), grafted on different rootstocks in Três Barras-SC. During the growing seasons of 2020/2021 and 2021/2022, main phenology stages (BBCH scale), pruning weight, number of branches and clusters and total cluster weight were assessed to calculate bud fertility, average cluster weight and yield. Clusters and berries were also characterized, total soluble solids (TSS) and total titratable acidity (TTA) contents were evaluated, and the TSS/TTA ratio was calculated. In order of harvest date, from the earliest to the latest was Jupiter (January/15), Faith (January/18), Neptune (February/3), Hope (February/7), Joy (February/05) and Gratitude (February/22). All cultivars, especially when grafted on ‘VR 043 43’ and ‘Paulsen 1103’, presented high bud fertility and yield. IAC 766’ rootstock induces earlier budburst (three to ten days) and harvest (one to four days). ‘VR 043-43’ rootstock delays ripeness by one to four days and both rootstocks combined could be used to stagger the harvest. The use of ‘IAC 572’ induces greater vigor on the tested cultivars. All cultivars tested present high TSS/TTA ratio, mainly ‘Jupiter’, 'Neptune' and 'Gratitude'.

Key words: *Vitis* spp.; viticulture; table grapes; adaptation; phenology.

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SUMMARY

1 GENERAL INTRODUCTION

For years, world table grape production was based on *Vitis vinifera* and *V. labrusca* cultivars, additionally to other species with regional importance and some hybrid cultivars among them. In *V. vinifera*, some of the main traits that favored the increase of table grape production are present, such as firmness, high sugar content, berry size and seedlessness, one of the main characteristics increasingly appreciated by consumers. The absence of seeds occurs in two ways, by parthenocarpy when berry is formed without the ovule fertilization and embryo and seeds, and by stenospermocarpy, when there is the embryo formation, but during the berry development, embryos are aborted, and small structures remain, known as seed traces. From the domain of embryo rescue techniques of stenospermocarpic cultivars, there was a rapid advance in table grape improvements worldwide. Several table grape breeding programs are currently established in the world, however, targeting the release of cultivars for production in regions with low precipitation during the growing season, from pruning to harvest. Few breeding programs target humid areas, such as the South of Brazil.

In the United States, in the East Coast, cultivation of commercial varieties and hybrids of the native American species are predominant, such as *V. labrusca*, *V. riparia*, *V. aestivalis*, *V. rupestris* and *Muscadinia rotundifolia*. Cultivars from these species and their hybrids are more resistant to cold and leaf diseases that are associated to high humidity. In the West Coast, *V. vinifera* cultivars are predominant and, more recently, modern hybrids of this specie with others, mainly due to low rain and low relative humidity during the production cycles, essential conditions for a lower expression of leaf diseases and bunch rot. Six decades ago, the University of Arkansas, located in the Mid-West of United States, has started a grape breeding program, mainly focusing on obtaining seedless cultivars, adapted to the climate conditions of that region. Additionally to the seedlessness, skin cracking resistance (which is related to high precipitation) and adaptation, a rich and unique germoplasm with different berry shapes, flavors and texture, due to several crossings made between east and west coast cultivars, was obtained. Viticulture in Arkansas, presents challenging climate, with high temperature and relative humidity during the harvest period, with common summer thunderstorms and high precipitation. These climate conditions are, in some aspects, similar to what is found in the South region of Brazil, where high temperatures, high relative humidity and high precipitation is very common in the viticulture areas during the harvest time. For this area, few seedless cultivars are recommended, especially without the use of plastic cover.

Due to this similarity in climate and to test the possible adaptation, it was introduced in the country in 2016, six seedless grape cultivars release by the Arkansas Grape Breeding Program – ‘Neptune’, ‘Jupiter’, ‘Hope’, ‘Joy’, ‘Faith’ and ‘Gratitude’ (pedigrees are presented in the Appendix). After receiving the cuttings and two years propagation, it was possible to make the first plants of all cultivars to start evaluations in the country.

Regarding the rootstocks, ‘Paulsen 1103’ became predominant for the main cultivars, from wine, juice and table grapes. ‘VR 043 43’ has become prominent in the last decades, mainly in the State of Santa Catarina and some of the municipalities of Paraná. More recently, both ‘IAC 572’ and ‘IAC 766’, have presented promising results in sites with a history of plant death due to the Young Vine Decline, a complex of several factors without defined etiology, but associated to clay soils, nutritionally unbalanced vineyards, trunk and root diseases and soil insects.

Therefore, this study has aimed to assess the cultivars ‘Neptune’, ‘Hope’, ‘Gratitude’, ‘Faith’, ‘Jupiter’ and ‘Joy’, grafted on the main rootstocks recommended for table grape production in the South region: Paulsen 1103, VR 043 43, IAC 766 e IAC 572. This study was divided into two chapters. In the first chapter, phenology, productive performance, plant vigor, physical and chemical characteristics of bunches and berries of three white seedless table grapes cultivars, and the influence of those rootstocks were assessed and in the second part of this study, the agronomic potential, phenology and the physicochemical properties of red and black seedless table grapes, grafted on the same rootstocks were evaluated.

2 CHAPTER 1 – AGRONOMIC POTENTIAL OF NEW SEEDLESS GRAPES GRAFTED ON ROOTSTOCKS FOR SOUTHERN BRAZIL[1]

ABSTRACT

The objective of this work was to evaluate phenology, productive performance, plant vigor and physical and chemical characteristics of fruits of three white seedless grape cultivars, recently introduced in Brazil, grafted on the main rootstocks used in the South of country during two crop seasons. The experiment was carried out in completely randomized block design, in a 2×3×4 factorial arrangement (crop seasons×cultivars×rootstocks). Cultivars used were Neptune, Hope, Gratitude and rootstocks were Paulsen 1103, VR 043-43, IAC 572, IAC 766. 'Neptune' was the first cultivar to be harvested (Jan/27) followed by 'Hope' (Jan/31) and 'Gratitude' (Feb/15). Early sprouting (2 to 7 days) and harvest (2 to 3 days) occurred with 'IAC 766', while late sprouting (2 to 5 days) and harvest (2 to 3 days) occurred with 'VR 043-43'. Plants grafted on 'IAC 572' were more vigorous. The three cultivars showed high Total Soluble Solids/Total Titratable Acidity Ratio (TSS/TTA) (from 24.96 to 49.22). The three white seedless grape cultivars 'Neptune', 'Hope' and 'Gratitude' have different responses when grafted on the main rootstocks used in the South of the country, with differences in the phenological stages, yield, plant vigor and physical and chemical characteristics of fruits in both crop seasons.

Index terms: *Vitis* spp., viticulture, table grapes, adaptation, phenology.

2.1 INTRODUCTION

Despite the South of Brazil being the main grape production area in the country with 55,329 ha (IBGE, 2024), grapes produced in this region are mainly for processing into wines, juices, jams and other by-products (Mello & Machado, 2022). Table grape production is concentrated in the Northeast, having the ‘Submédio do Vale do São Francisco’ region the main center for production and export in the country with 10,325 hectares (IBGE, 2024). Over the last decade there was a fast

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[1] Article accepted for publication at Pesquisa Agropecuária Brasileira – PAB

replacement of old seeded table grapes by modern seedless cultivars, to increase the supply for the Brazilian domestic market and for export (Leão, 2020). Nowadays, the absence of seeds is one of the characteristics for the table grape market in the whole world (Leão et al., 2021).

Consumer preference for seedless grapes is increasing (Maia et al., 2018), however its production area in the Southern region is insignificant. The climate is very challenging, due to high relative humidity and excessive rain from budburst to harvest, and the lack of adapted cultivars hinders the increase in production. Therefore, three white seedless cultivars were introduced in Brazil in 2016: Neptune, Hope and Gratitude. These hybrid cultivars, released by the University of Arkansas, have good tolerance to rain, to berry cracking and to the main fungal diseases and show differentiated flavor (Clark & Moore 1999, 2013).

As for rootstocks, 'Paulsen 1103'is the main rootstock used for new vineyards in the Rio Grande do Sul and Santa Catarina States and on a smaller scale, 'VR043-43' is used, especially in areas of greater occurrence of ground pearl (*Eurhizococcus brasiliensis*) (Camargo et al., 2011). The occurrence of the young vine decline in the early years of planting has been the greatest difficulty encountered by the Santa Catarina viticulture. Plant mortality, previously associated with specific causes such as the susceptibility of rootstocks to fusariosis (*Fusarium oxysporum* f.sp. *herbemontis*) or ground pearl, is more complex, without defined etiology caused by several factors (Menezes-Netto et al., 2016). Susceptibility to other fungi such as black foot (*Cylindrocarpon destructans*) and descending rot (*Botryosphaeria* spp.), planting in clayey soils with low macroporosity, vineyards with nutritionally unbalanced plants and the occurrence of frost and hail also contribute to weakening the plants.

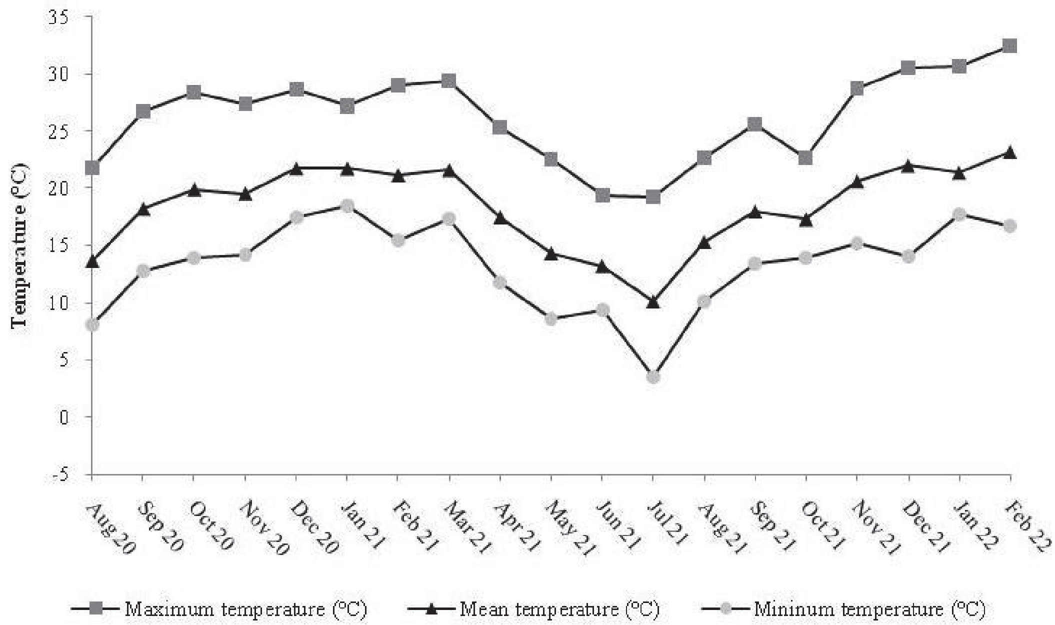
The use of resistant rootstocks is one of the main success factors in the implementation of new vineyards (Menezes-Netto et al., 2016). 'IAC 572' and 'IAC 766' were also promising in a region with the occurrence of young vine decline, in addition to the usual 'Paulsen 1103' and 'VR043-43' rootstocks, inducing good production for the scion tested (Dalbó & Feldberg, 2019).

The objective of this work was to evaluate phenology, productive performance, plant vigor and physical and chemical characteristics of fruits of three white seedless grape cultivars, recently introduced in Brazil, grafted on the main rootstocks used in the South of country during two crop seasons.

2.2 MATERIAL AND METHODS

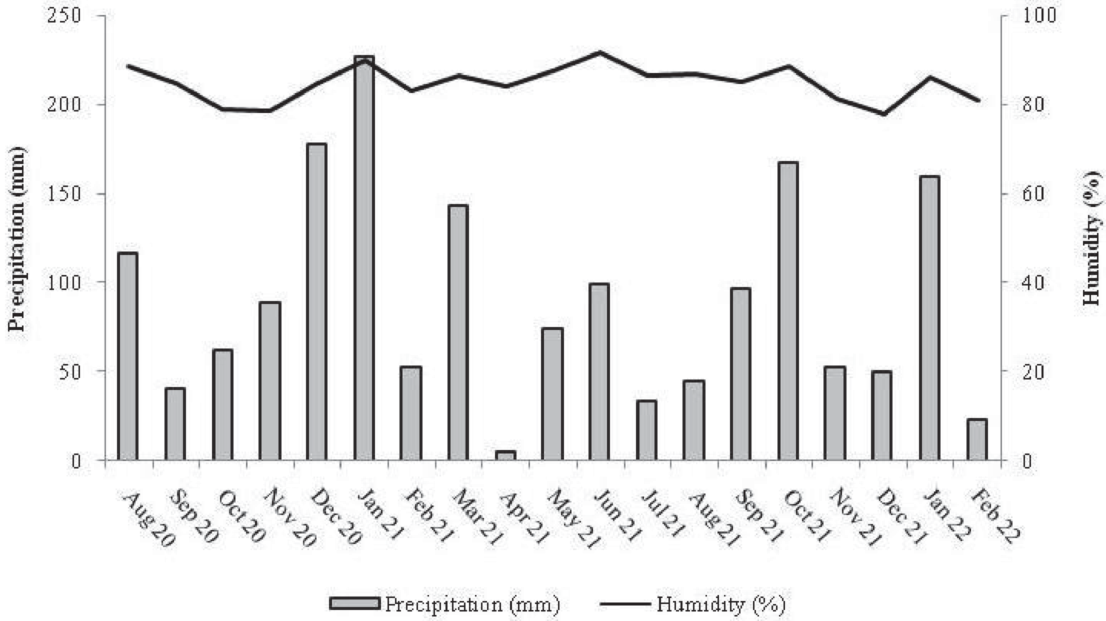
The experiment was carried out in “Três Barras”, (26°11'03"S; 50°16'22"W; 794 meters a.s.l.), Santa Catarina State, located in South region of Brazil, in the “Planalto Norte Catarinense region” in the 2020/2021 and 2021/2022 crop seasons. The climate in Três Barras is Cfb, according to Köeppen’s classification, with a constantly humid temperate climate, without a dry season, with cool summers and frequent frosts (Alvares et al., 2013). Climate data were provided by Epagri-Ciram (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina – Centro de Informações de Recursos Ambientais e de Agrometeorologia), including maximum, medium, and minimum air temperatures (°C), precipitation (mm), and humidity (%). Monthly meteorological data from August 1st, 2020 to February 28th, 2022 (Figure 2.1 and 2.2) were assessed from the closest weather station to the vineyard, located in Três Barras, SC, Brazil. Chilling hours (CH) (≤7.2 °C) were calculated from April 1st to August 31st, in each year evaluated, that was 355 CH in 2020 and 444 CH in 2021.

FIGURE 2.1 - Monthly maximum, mean, and minimum temperature from August 2020 to February 2022 in Três Barras, SC, Brazil.



SOURCE: The author (2025)

FIGURE 2.2 - Precipitation (mm) and humidity (%) from August 2020 to February 2022 in Três Barras, SC, Brazil.



SOURCE: The author (2025)

The soil of the experimental area is classified as Dystrophic Red Latosol (Oxisol) (Santos et al., 2018). In 2021, a soil sample was analyzed by the Santa Catarina State Soil Testing Laboratory (Epagri) and presented the following chemical characteristics at a depth of 0-20 cm: organic matter, 4.8%; pH in H_2O, 6.5; Al^{+3}, 0.0 $cmol_c$ dm^{-3}; H + Al^{+3}, 2.3 $cmol_c$ dm^{-3}; Ca^{+2}, 12.3 $cmol_c$ dm^{-3}; Mg^{+2}, 5.7 $cmol_c$ dm^{-3}; K^+, 304.0 mg dm^{-3}; P, 9.2 mg dm^{-3} and base saturation, 88.98 %.

The experimental design was in randomized blocks with 5 repetitions of 3 plants per plot, in a 2×3×4 factorial arrangement (two crop seasons × three cultivars × four rootstocks). Cultivars evaluated were Neptune, Hope and Gratitude, and rootstocks were Paulsen 1103, VR 043-43, IAC 572 and 'IAC 766. The phenology was determined and the productive performance, plant vigor, physical and chemical characteristics of bunches and berries were evaluated.

The vineyard was settled on the field in October 2018, with grafted vines, and the training system used was the Y trellis, with row spacing of 3 m and 2 m between plants (population density of 1,667 plants ha^{-1}) without irrigation or plastic cover. The plants were formed into a bilateral cordon in 2019 and pruned by alternating spurs with 2 to 3 buds and canes with 5 to 6 buds, with a maximum of 4 canes per plant. Winter pruning was carried out from the observation of the beginning of sprouting of the first buds from the apices of the canes. To standardize bud sprouting and, due to lack of prior knowledge of the behavior of the cultivars tested, hydrogenated

Cyanamide was applied at 3% and non-ionic adhesive spreader at 0.1%. Weed control was performed with frequent mowing and disease control through periodic spraying with fungicides, as recommended for the crop in the Santa Catarina State. No cluster intervention, such as thinning, topping or gibberellins application was conducted during the experiment, as its primary interest was to characterize the grape cultivars and the influence of rootstocks.

To define the phenological stages of the vine, the BBCH scale was used (Lorentz et al.,1995). The dates of the following phenological stages were noted: budburst, considered when around 10% of the buds were at the green tip stage (BBCH 07); beginning of flowering, considered when 5% of the flowers were open (BBCH 60); end of flowering, considered when less than 5% of the flowers were open and the rest were already fertilized (BBCH 69); beginning of ripening, appearance of the first berries with changes in color or consistency (BBCH 81); end of ripening, considered when more than 90% of the berries have changed color or softened (BBCH 85); harvest, established based on visual and sensory evaluation of the berries, when the bunches are ready for harvest (BBCH 89). From the dates observed for each phenological stage, the average of the dates for the two harvests evaluated was obtained.

Productive performance was evaluated by mean of number of shoots and bunches per plant, bunches weight (g), and the estimated yield (Mg ha^{-1}) and estimated bud fertility (number of bunches per number of shoots). Plant vigor was evaluated by winter pruning material per plant (Kg). The shoots were counted individually after canopy management operations of defoliation and lateral shoot thinning, during the production cycle. Bunches were counted and weighed at two harvest times, at the beginning of harvest and 7 days later, when all the bunches from the plants were harvested. For pruning weight, branches were weighed immediately after winter pruning. The average weight of bunches was estimated by dividing the total weight of bunches by the number of bunches harvested in each harvest period. Bud fertility was estimated by the relation between the number of bunches and the number of shoots. Yield was estimated by multiplying the bunch weight per plant by the density of plants per hectare (Mg ha^{-1}). To weigh the bunches and branches, an AY 220 electronic balance (Shimadzu, Kyoto, Japan) with precision of three decimal places was used.

For the physical characteristics of bunches and berries evaluations, length and width of bunches (cm), length and width of berries (mm), and number of berries per bunch were measured at the beginning and end of the harvest of each plot. One bunch with a weight close to the average weight was chosen for the physical characterization of the bunches and berries. The length and width of these bunches were measured with a ruler and all the berries were removed to count and measure the length and width of each berry, using a IP 54 digital caliper (Vonder, Curitiba, Brazil). The berries were weighed to calculate the average weight of the berries (g), based on the ratio between the total weight of the berries and the number of berries per bunch.

Chemical characteristics of the berries were evaluated analysing the Total Soluble Solids (TSS), Total Titratable Acidity (TTA) and TSS/TTA ratio. In which, samples of 100 berries were collected randomly from each plot, approximately 5 days after the first harvest, identified and immediately frozen. TSS content was measured using a REF 103 refractometer (General, New York City, United States) and expressed in ºBrix, and TTA using the 0.1N NaOH neutralization titration method, until reaching pH 8.1, with a DL-PH digital pH meter (Del Lab, Araraquara, SP, Brazil), expressed in grams of tartaric acid per 100 mL of must. From these parameters, TSS/TTA ratio was calculated.

The data were tested for normal distribution using the Lilliefors test and subjected to individual and joint analysis of variance in a factorial model for crop seasons, cultivars and rootstocks, and the means grouped using the Scott-Knott test ($p \leq 0.05$). All statistical analyzes were carried out using the Genes statistical program (Cruz, 2013).

2.3 RESULTS AND DISCUSSION

On average, cultivar Neptune had the earliest budburst (Sep/8) and harvest (Jan/27), followed by 'Hope' (budburst on Sep/15 and harvest on Jan/31), and 'Gratitude', the latest budburst (Sep/24) and harvest (Feb/15) (Table 2.1).

TABLE 2.1. Average dates of the phenological characteristics of the white seedless grapes 'Neptune', 'Hope' and 'Gratitude', grafted on 'Paulsen 1103', 'VR043-43', 'IAC 572' and 'IAC 766' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

Cultivar/ rootstock	Pruning	Budburst	Flowering		Ripening		Harvest		Cycle (days)
			Begining	End	Begining	End	Begining	End	
Neptune/IAC 766	Aug/30	Sep/5	Oct/16	Nov/6	Dec/22	Jan/2	Jan/24	Jan/31	141
Neptune/IAC 572	Aug/30	Sep/7	Oct/20	Nov/11	Dec/24	Jan/4	Jan/28	Feb/4	143
Neptune/P1103	Aug/30	Sep/8	Oct/21	Nov/11	Dec/24	Jan/4	Jan/28	Feb/4	142
Neptune/VR 043-43	Aug/30	Sep/12	Oct/24	Nov/16	Dec/26	Jan/9	Jan/30	Feb/6	140
Average	Aug/30	Sep/8	Oct/20	Nov/11	Dec/24	Jan/5	Jan/27	Feb/3	142
Hope/IAC 766	Sep/4	Sep/8	Oct/22	Nov/10	Jan/2	Jan/13	Jan/28	Feb/4	142
Hope/IAC 572	Sep/4	Sep/15	Oct/25	Nov/18	Jan/5	Jan/18	Feb/2	Feb/9	140
Hope/P1103	Sep/4	Sep/16	Oct/26	Nov/18	Jan/1	Jan/16	Jan/30	Feb/6	136
Hope/VR 043-43	Sep/4	Sep/20	Oct/28	Nov/22	Jan/9	Jan/22	Feb/3	Feb/10	136
Average	Sep/4	Sep/15	Oct/25	Nov/17	Jan/4	Jan/17	Jan/31	Feb/7	139
Gratitude/IAC 766	Sep/11	Sep/22	Oct/31	Nov/19	Jan/13	Jan/23	Feb/12	Feb/19	143
Gratitude/IAC 572	Sep/11	Sep/24	Nov/4	Nov/23	Jan/14	Jan/25	Feb/15	Feb/22	144
Gratitude/P1103	Sep/11	Sep/24	Nov/3	Nov/23	Jan/15	Jan/25	Feb/15	Feb/22	144
Gratitude/VR 043-43	Sep/11	Sep/26	Nov/7	Nov/25	Jan/17	Jan/26	Feb/17	Feb/24	144
Average	Sep/11	Sep/24	Nov/4	Nov/22	Jan/15	Jan/25	Feb/15	Feb/22	144

SOURCE: The author (2025).

It was observed that the three cultivars grafted on IAC 766 rootstock showed a small anticipation of the phenological stages, mainly for bud sprouting (2 a 7 days) and end of ripening (2 to 4 days) and harvest (2 to 3 days) compared to the other rootstocks.

Cultivars that have a natural late budburst, like 'Gratitude', are preferable for areas similar to the experiment, where frosts are common from late August to the first two weeks of September, as it decreases the risk of loss caused by frost damages on bud sprouting. Loss in production and yield in the harvest following the frost damage was observed by Dalbó & Feldberg (2019) only for plants grafted on 'IAC 766', comparing to other rootstocks, caused by a few days anticipation on budburst.

Knowing the influence of rootstocks on cultivars' phenological cycles may be a useful tool for grape growers to also scale its operations and labor in the vineyard, as well as move the harvest to earlier or later periods to obtain more favorable prices. For early spring-frost free regions, the anticipation of bud sprout and cycle may be an advantage and can also be improved by advance pruning. It may result in earlier harvest and better market prices. Techio et al. (2019) observed that 'IAC 766' induced anticipation of phenological cycle, from bud sprouting to harvest for 'Venus', an early seedless table grape cultivar, in the São Paulo State.

Phenological stages of the three cultivars grafted on the IAC 572 and Paulsen 1103 rootstocks were similar and occurred on intermediate dates, between 'IAC 766' and 'VR 043-43', that is, no significant differences were observed between 'IAC 572' and 'Paulsen 1103'. Differently, Dalbó & Feldberg (2019) stated that 'Moscato Embrapa' grafted on 'IAC 572' had bud sprouting some days after Paulsen 1103 rootstock and on 'VR 043-43', it had later bud sprouting, as in the present work.

Regarding the cycle duration, small differences from 1 to 3 days were identified for each cultivar considering their rootstocks (Table 2.1). Plants grafted on 'IAC 766' had the earliest bunch ripening and with 'VR 043-43' had the latest harvest, when compared to 'IAC 572' and 'Paulsen 1103'.

Comparing cultivars concerning cycle length, differences were of only 5 days. 'Hope' had the shortest cycle (139 days) and 'Gratitude' the longest (144 days). 'Neptune' cycle, considering the rootstocks' average, was of 142 days. In the cultivars' site of origin, the cycle from bud sprouting to harvest was of 140 days for 'Hope', 144 days for 'Gratitude' and 149 days for 'Neptune', with very similar cycle duration observed in present work, except for 'Neptune', which its cycle under the Santa Catarina’s conditions, was 7 days shorter (Clark & Moore, 2013).

There were significant interactions among the three factors for all the tested parameters.

For number of bunches, in the 2021 harvest, 'Hope' had the highest number, averaging 36.35 bunches per plant, while 'Gratitude' (21.5 bunches per plant) did not differ from 'Neptune' (21.8 bunches per plant). In the 2022 harvest, there were interactions between factors, cultivar and rootstocks, made 'Hope' to be superior to 'Gratitude' and 'Neptune' on all rootstocks, while 'IAC 766' favored the lowest number of bunches for that cultivar. For 'Gratitude', there are no difference between rootstocks, but for 'Neptune', both 'VR 043-43' and 'Paulsen 1103' induced the highest number of bunches per plant (Table 2.2). For the seedless table grape 'BRS Clara' evaluated onto six rootstocks in the São Francisco Valley, in the Northeast of Brazil, 'IAC 766' and 'Paulsen 1003' showed a greater number of bunches per plant than 'IAC 572', but this result wasn`t the same for other cultivars, demonstrating a strong interaction among cultivars and rootstocks (Leão et al., 2023).

There were factors interaction over the two crop seasons for bud fertility (Table 2.2). In 2021, 'Neptune' was the cultivar that had the highest bud fertility, along with 'Hope' grafted on the VR 043-43 rootstock. 'Hope' presented higher bud fertility when grafted both on 'VR 043-43' (1.48 bunches per branch) and 'Paulsen 1103' (1.40 bunches per branch), comparing to 'IAC 572' (1.26 bunches per branch) and 'IAC 766' (1.18 bunches per branch). 'Gratitude' grafted on 'Paulsen 1103' had the highest bud fertility value (1.24 bunches per branch) among the rootstocks. In 2022, 'Hope' had the highest bud fertility on almost all rootstocks (from 1.3 to 1.66 bunches per branch), along with 'Neptune' grafted on 'VR 043-43' (1.6 bunches per branch). For 'Gratitude', 'IAC 572' (0.78 bunches per branch) showed lower bud fertility comparing to the other rootstocks; for 'Neptune', both 'IAC 766' (1.08 bunches per branch) and 'IAC 572' (0.78 bunches per branch) were the ones inducing lower bud fertility.

The bud fertility is genetic determined but strongly affected by environmental factors and the first step to observe in new cultivar is if they have high values, because high bud fertility is a key factor to recommend cultivars capable to reach high yield potential (Leão et al., 2017). Low productivity is one of the main reasons why there are no white seedless grape cultivars in production in Southern Brazil.

TABLE 2.2. Productive performance and plant vigor of white seedless grapes 'Hope', 'Gratitude' and 'Neptune', grafted on 'VR 043-43', 'IAC 572', 'IAC 766' and 'Paulsen 1103' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

Rootstock	Cycle 2020/2021				Cycle 2021/2022			
	Hope	Gratitude	Neptune	Average	Hope	Gratitude	Neptune	Average
				Number of bunches per plant				
VR 043-43	38.20	22.40	23.60	28.07a	59.20aA	33.20aC	40.00aB	44.13
IAC 572	37.80	22.60	21.40	27.27a	63.40aA	31.00aB	20.00bC	38.13
IAC 766	32.00	20.20	20.20	24.13a	53.40bA	32.80aB	24.40bC	36.87
Paulsen 1103	37.40	20.80	22.00	26.73a	62.80aA	30.60aB	34.20aB	42.53
Average	36.35A	21.50B	21.80B		59.70	31.90	29.65	
CV%		13.94				12.28		
				Bud fertility (number of bunches per number of shoots)				
VR 043-43	1.48aA	1.08bB	1.46aA	1.34	1.56aA	1.04aB	1.60aA	1.40
IAC 572	1.26bB	0.94bC	1.56aA	1.25	1.40bA	0.78bB	0.78cB	0.99
IAC 766	1.18bB	0.98bC	1.54aA	1.23	1.30bA	0.96aB	1.08bB	1.11
Paulsen 1103	1.40aB	1.24aB	1.58aA	1.41	1.66aA	1.02aC	1.46aB	1.38
Average	1.33	1.06	1.54		1.48	0.95	1.23	
CV%		9.86				9.74		
				Yield (Mg ha^{-1})				
VR 043-43	23.60aA	14.80aC	19.16bB	19.19	32.98aA	24.62aB	33.98aA	30.53
IAC 572	17.42bA	14.74aA	18.82bA	16.99	31.90aA	21.14aB	10.28bC	21.11
IAC 766	12.64cB	13.06aB	16.52bA	14.07	25.98bA	21.24aA	12.02bB	19.75
Paulsen 1103	23.30aA	13.68aB	22.44aA	19.81	32.38aA	22.10aB	29.92aA	28.13
Average	19.24	14.07	19.24		30.81	22.28	21.55	
CV%		15.42				17.72		
				Pruning weight (kg $plant^{-1}$)				
VR 043-43	3.08bA	3.02bA	2.22aB	2.77	2.62	2.70	1.94	2.42c
IAC 572	3.98aA	3.52aA	1.78aB	3.09	3.50	3.40	2.44	3.11a
IAC 766	3.64aA	3.26aA	1.74aB	2.88	3.26	2.90	2.28	2.81b
Paulsen 1103	3.04bA	2.84bA	1.88aB	2.59	2.40	2.50	1.70	2.20c
Average	3.44	3.16	1.91		2.95A	2.88A	2.09B	
CV%		13.20				7.54		

Averages followed by equal letters, uppercase in the row and lowercase in the column, do not differ from each other, by the Scott–Knott grouping of means test, at 5% probability.
SOURCE: The author (2025).

In 2021, the highest average yields were achieved by cultivars Hope and Neptune (Table 2.2). As for rootstocks, the highest average yield was provided by 'Paulsen 1103' for all cultivars. 'VR-043-43' provided higher yields for 'Hope' along with 'Paulsen 1103'. Regarding the cultivar/rootstock interaction, for 'Hope' there were no differences between 'VR 043-43' and 'Paulsen 1103', which were superior to the other rootstocks. For 'Neptune', 'Paulsen 1103' provided higher productivity than the others, while for 'Gratitude' there were no differences between the rootstocks. In 2022, 'Hope' had the highest average yield, followed by 'Neptune' and 'Gratitude'. About rootstocks, the highest average yield was once again obtained using 'VR 043-43' and 'Paulsen 1103'. Hope cultivar with rootstock IAC 766 provided lower values than the others. For 'Neptune', the highest yield was obtained with 'Paulsen 1103' and 'VR 043-43' too; and for Gratitude again there were no differences between the rootstocks. In the semi-arid region of Brazil, there was a greater effect of the rootstock on production cycle of seedless table grape cultivar BRS Ísis and mean production of the six cycles was greatest on 'IAC 572' (Leão et al., 2020a).

In the cultivars site of origin, Clark and Moore (2013) reached 3-crop average yields of 28.3 Mg ha^{-1}, 23.9 Mg ha^{-1}, and 16.2 Mg ha^{-1} for 'Hope', 'Neptune' and 'Gratitude', respectively. Which means that average yields obtained in Santa Catarina has high yield potential for the cultivars evaluated, since it reached higher yields than those obtained in the United States.

In the “São Francisco” Valley, the main Brazilian producing and exporting region of seedless grapes, 14 cultivars grafted on IAC 766 rootstock were evaluated and the highest yields were just above 26 Mg ha^{-1}, in a pergola trellis system with irrigation (Leão et al., 2020b). Yields obtained in aforementioned study are promising, except for 'Gratitude' and 'Neptune' when grafted on IAC 572 and IAC 766 rootstocks. The authors highlight that the main difficulty in producing imported seedless grape cultivars is the lack of adaptation and low yields, opposite to the observed in present study.

Factors interactions for pruning weight occurred only in 2021 (Table 2.2). Both 'Hope' and 'Gratitude' had higher pruning weight than 'Neptune', considering all rootstocks. For 'Hope' and 'Gratitude' the least vigorous rootstocks were Paulsen 1103 (3.04 and 2.84 kg $plant^{-1}$, respectively) and VR 043-43 (3.08 and 3.02 kg $plant^{-1}$, respectively). In 2022, the least vigorous cultivar was Neptune (2.09 kg $plant^{-1}$).

Considering the rootstocks, IAC-572 induced the cultivars to reach their highest pruning weight (3.11 kg plant^{-1}).

The graft on tropical rootstocks, such 'IAC 572' and 'IAC 766', or *Muscadinia rotundifolia* hybrids, has been the best strategy to overcome the problem with young vine decline in Santa Catarina due to the higher vigor of scions (Dalbo et al., 2016; Menezes-Netto et al., 2016; Dalbo & Feldberg, 2019), but vigorous rootstocks can induce lower yields in seedless grapes (Feldberg et al., 2007; Leão et al., 2017). Until the 2022 harvest, no plants with young vine decline symptoms were observed in the experiment.

The heaviest bunches in 2021 were produced by 'Neptune' with all rootstocks (Table 2.3). In 2022, the heaviest bunches were produced by 'Neptune' when grafted on 'Paulsen 1103' (524.8g) and 'VR 043-43' (512.8g) and by 'Gratitude' grafted on 'IAC 572' (413.4g) and 'IAC 766' (391.2g). The heavier bunches may lead to higher yields, however, it can result in bunch compactness and berry size reduction. Bunches from 'Hope' weighted the lowest, in both 2021 and 2022 harvests. 'IAC 572' and 'IAC 766' induced cultivars to produce lighter weight bunches when combined with 'Hope' and 'Neptune' in 2021 and with 'Neptune' in 2022. Rootstocks that induce a lighter weight bunches can be recommended for cultivars that require thinning, making a quicker, easier and less costly operation.

In 2021, 'Neptune' longest bunches were produced by plants grafted on Paulsen 1103 (21.92 cm) and IAC 572 (21.48 cm) rootstocks (Table 2.3). 'Gratitude' had its longest bunches when grafted on 'VR 043-43'(18.68 cm) and 'Hope' on both 'VR 043-43' (17.76 cm and 'Paulsen 1103' (17.84 cm). In the 2022 harvest, no differences among cultivars and rootstocks were identified. The widest bunches, in 2021, were obtained for Neptune when grafted on 'IAC 572' (14.56 cm) and 'Paulsen 1103' (13.64 cm); for 'Gratitude' on 'IAC 766' (11.80 cm) and for 'Hope' on 'VR 043-43' (11.66 cm) and 'Paulsen 1103' (11.06 cm). In 2022, no differences identified among the rootstocks for 'Hope' and 'Gratitude', but 'Neptune' had wider bunches on the Paulsen 1103 (14.00 cm) and VR 043-43 (12.78 cm) rootstocks.

TABLE 2.3. Physical characteristics of bunches of the white seedless grapes 'Hope', 'Gratitude' and 'Neptune', grafted on 'VR 043-43', 'IAC 572', 'IAC 766' and 'Paulsen 1103' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

Rootstock	Cycle 2020/2021				Cycle 2021/2022			
	Hope	Gratitude	Neptune	Average	Hope	Gratitude	Neptune	Average
				Bunch weight (g)				
VR 043-43	369.6aB	405.0aB	490.4bA	421.7	335.4aC	439.8aB	512.8aA	429.3
IAC 572	275.8bC	407.6aB	531.8bA	405.1	303.2aB	413.4aA	305.6bB	340.7
IAC 766	237.4bC	394.2aB	488.2bA	373.3	293.2aB	391.2aA	293.8bB	326.1
Paulsen 1103	376.2aB	397.0aB	616.6aA	463.3	309.4aC	430.8aB	524.8aA	421.7
Average	314.8	400.9	531.8		310.3	418.8	409.3	
CV%		12.85				9.09		
				Bunch length (cm)				
VR 043-43	17.76aA	18.68aA	19.64bA	18.69	16.94	16.84	19.46	17.75
IAC 572	16.40bB	16.80bB	21.48aA	18.23	17.42	18.02	17.14	17.53
IAC 766	14.34cC	16.60bB	20.20bA	17.05	16.20	16.48	17.16	16.61
Paulsen 1103	17.84aB	16.94bB	21.92aA	18.90	17.54	17.48	19.30	18.11
Average	16.59	17.26	20.81		17.03	17.21	18.27	
CV%		5.92				6.94		
				Bunch width (cm)				
VR 043-43	11.66aA	10.80bA	11.72bA	11.39	12.26aA	13.52aA	12.78aA	12.85
IAC 572	10.30bB	10.68bB	14.56aA	11.85	11.58aA	12.72aA	11.54bA	11.95
IAC 766	10.20bB	11.80aA	12.42bA	11.47	10.74aA	12.32aA	11.44bA	11.50
Paulsen 1103	11.06aB	10.10bB	13.64aA	11.60	12.02aB	11.92aB	14.00aA	12.65
Average	10.81	10.85	13.09		11.65	12.62	12.44	
CV%		7.60				8.80		
				Number of berries per bunch				
VR 043-43	152.8aA	102.6aB	111.8cB	122.4	160.6aA	126.8aB	159.2aA	148.9
IAC 572	93.6cB	90.2aB	151.8bA	111.9	155.8aA	107.4aB	104.4bB	122.5
IAC 766	65.2 dC	88.8aB	132.4cA	95.5	122.6bA	116.4aA	102.8bA	113.9
Paulsen 1103	128.0bB	86.0aC	179.0aA	131.0	175.0aA	123.2aB	155.4aA	151.2
Average	109.9	91.9	143.8		153.5	118.5	130.5	
CV%		14.53				15.76		

Averages followed by equal letters, uppercase in the row and lowercase in the column, do not differ from each other, by the Scott–Knott grouping of means test, at 5% probability.
SOURCE: The author (2025).

Lengthier and wider bunches direct result in higher yields, as the bigger the bunches, the greater their weight. However, these features not always translate into higher bunch quality for fresh table grapes market. After reviewing each cultivar characteristics, management operations are indicated to promote adequate ripening, increase in berry size associated with the application of growth regulators, and to reduce the natural size of bunches to meet the needs of some markets. Cutting the cluster wings, topping and thinning the berries are recommended approaches to fulfill more demanding table grape markets.

Regarding the number of berries (Table 2.3), none of the rootstocks stood out with 'Gratitude' during the two harvests. For 'Hope', in the 2021 harvest, 'VR 043-43' has induced greater number of berries (152.8) and in 2022, 'IAC 766', the lowest number of berries (122.6). For 'Neptune', the highest number of berries in 2021 resulted when grafted on 'Paulsen 1103' (179.0) and in 2022, on 'VR 043-43' (159.2) and 'Paulsen 1103' (155.4). Zilio et al. (2019), recommend leaving only 50 to 70 berries per bunch for 'BRS Ísis' and 'BRS Vitória' in the “Serra Gaúcha” region in Rio Grande do Sul state, Brazil, to achieve the ideal bunch flavor and color, in addition to larger berry size.

There were no interactions among factors related to the berry weight (Table 2.4). In the 2021 harvest, 'Gratitude' produced berries with the highest weight (4.25g), while in the following harvest, both 'Gratitude' (3.47 g) and 'Neptune' (3.15 g), differed from 'Hope' (2.04 g), having higher berry weight. Rootstock influence on berry weight for the three tested cultivars were not identified.

During three harvest assessments in the United States, Clark & Moore (2013) reported average berry weight for 'Gratitude' from 3.5 to 3.7 g, 'Hope' from 2.5 to 3.1 g and 'Neptune' from 3.3 to 3.9 g, which were similar to those obtained in the present study.

TABLE 2.4. Physical characteristics of the berries of the white seedless grapes 'Hope', 'Gratitude' and 'Neptune', grafted on 'VR 043-43', 'IAC 572', 'IAC 766' and 'Paulsen 1103' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

Rootstock	Cycle 2020/2021				Cycle 2021/2022			
	Hope	Gratitude	Neptune	Average	Hope	Gratitude	Neptune	Average
				Berry weigth (g)				
VR 043-43	2.64	3.92	3.54	3.37a	2.08	3.42	3.22	2.91a
IAC 572	3.04	4.28	3.70	3.67a	1.96	3.70	2.94	2.87a
IAC 766	3.56	4.58	3.56	3.90a	2.34	3.30	3.14	2.93a
Paulsen 1103	3.04	4.20	3.38	3.54a	1.78	3.46	3.28	2.84a
Average	3.07B	4.25A	3.55B		2.04B	3.47A	3.15A	
CV%		10.17				12.50		
				Berry length (mm)				
VR 043-43	19.56	22.42	21.94	21.31a	18.30aB	21.34aA	20.34aA	19.99
IAC 572	20.46	23.32	22.78	22.19a	17.78aC	22.82aA	20.08aB	20.23
IAC 766	21.98	23.36	22.32	22.55a	19.36aB	21.46aA	20.40aB	20.41
Paulsen 1103	20.42	23.10	21.56	21.69a	16.34bB	21.56aA	20.96aA	19.62
Average	20.61B	23.05A	22.15A		17.95	21.80	20.45	
CV%		4.12				5.78		
				Berry width (mm)				
VR 043-43	14.54bC	16.56aA	15.52aB	15.54	12.90	15.54	15.10	14.51a
IAC 572	14.94bB	17.10aA	15.38aB	15.81	12.64	15.82	15.02	14.49a
IAC 766	16.14aB	17.44aA	15.32aC	16.30	12.90	15.12	15.22	14.41a
Paulsen 1103	14.90bB	17.10aA	15.26aB	15.75	11.62	15.32	15.20	14.05a
Average	15.13	17.05	15.37		12.52B	15.45A	15.14A	
CV%		3.23				4.87		

Averages followed by equal letters, uppercase in the row and lowercase in the column, do not differ from each other, by the Scott–Knott grouping of means test, at 5% probability.
SOURCE: The author (2025).

Cultivars with natural longer and wider berries are preferable by the consumers and less gibberellins application is required to reach the market demands. Cultivars Gratitude and Neptune produced berries with greater length in the 2021 harvest (23.05mm and 22.15mm, respectively). In 2022, there were interactions among factors (Table 2.4). 'Gratitude' and 'Neptune' when grafted on 'Paulsen 1103' and 'VR 043-43', reached the longest berry length. As for berry width, 'Gratitude' was superior to 'Hope' and 'Neptune' on all rootstocks. In the 2022 harvest, cultivars Gratitude (15,45mm) and Neptune (15.14mm) differed from Hope (12.52mm), reaching wider berries. The natural berry size of cultivar Thompson Seedless in Petrolina (Pernambuco State, Brazil) for example, which is the main white seedless grape cultivar in the world market and one of the main seedless cultivars planted in Brazil, reached 17.99 ±0.91mm of berry length and 15.04±0.68mm of berry width (Leão et al., 2020b).

Regarding chemical analysis, in 2021 (Table 2.5), 'Neptune' had the highest TSS values, along with 'Gratitude' when grafted on VR 043-43 and 'Hope' on the IAC 766 and IAC 572 rootstocks. In the Sub-middle region of the São Francisco Valley, Cultivar BRS Magna showed higher sugar contents with Paulsen 1103 and IAC 572 rootstocks (Santos et al., 2022). Grapes produced by 'Hope' grafted on 'IAC 766' and by 'Gratitude' on 'VR 043-43' had the highest TSS values (16.08 and 16.72 ºBrix, respectively). In the 2022 harvest, there were no interactions among factors and differences induced by rootstocks, but Neptune (17.05ºBrix) and Gratitude (16.13°Brix), presented sweeter grapes. In the 2021 harvest, 'Neptune' had the lowest ATT values on all rootstocks, when compared to the other combinations. In the 2022 harvest, 'Hope', grafted on all rootstocks, stood out as having the highest acidity. 'IAC 766' produced the lowest acidity in all cultivars in 2021, and in 'Hope' and 'Neptune' in 2022. Rootstock influences the activity of key enzymes involved in acid metabolism and the expression of related genes, such as NAD-MDH enzyme, which positively correlated with malic acid content (Zang et al., 2023).

TABLE 2.5. Chemical characteristics of the berries of the white seedless grapes 'Hope', 'Gratitude' and 'Neptune', grafted on 'VR 043-43', 'IAC 572', 'IAC 766' and 'Paulsen 1103' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

Rootstock	Cycle 2020/2021				Cycle 2021/2022			
	Hope	Gratitude	Neptune	Average	Hope	Gratitude	Neptune	Average
Total Soluble Solids (ºBrix)								
VR 043-43	14.76bB	16.72aA	15.84aA	15.77	15.04	17.48	17.04	16.52a
IAC 572	15.24bA	13.68bB	16.16aA	15.03	14.20	15.36	16.72	15.43a
IAC 766	16.08aA	14.60bB	16.44aA	15.71	13.64	15.92	17.00	15.52a
Paulsen 1103	14.84bB	14.08bB	15.90aA	14.94	14.48	15.74	17.44	15.89a
Average	15.23	14.77	16.09		14.34B	16.13A	17.05A	
CV%		4.90				5.40		
Titratable Total Acidity (g tartaric acid 100 mL^{-1})								
VR 043-43	0.73aA	0.62aB	0.54aC	0.63	0.55aA	0.35bC	0.44aB	0.45
IAC 572	0.61bA	0.60aA	0.54aB	0.59	0.54bA	0.28cC	0.45aB	0.42
IAC 766	0.51cA	0.53bA	0.44bB	0.49	0.51bA	0.32bC	0.39bB	0.41
Paulsen 1103	0.65bA	0.63aA	0.58aB	0.62	0.59aA	0.41aB	0.45aB	0.48
Average	0.62	0.60	0.53		0.55	0.34	0.43	
CV%		5.54				8.81		
Ratio (TSS/TTA)								
VR 043-43	20.24cB	26.82aA	29.54bA	25.53	27.52aC	51.02aA	38.78aB	39.11
IAC 572	25.04bB	22.86bB	29.62bA	25.84	26.92aC	55.38aA	37.36aB	39.89
IAC 766	31.92aB	27.60aC	37.48aA	32.33	27.28aC	51.40aA	43.78aB	40.82
Paulsen 1103	23.00bB	22.56bB	27.70bA	24.42	24.66aB	39.08bA	39.16aA	34.30
Average	25.05	24.96	31.09		26.60	49.22	39.77	
CV%		7.94				11.32		

Averages followed by equal letters, uppercase in the row and lowercase in the column, do not differ from each other, by the Scott–Knott grouping of means test, at 5% probability.
SOURCE: The author (2025).

Regarding TSS/ATT ratio (Table 2.5), in the 2021 harvest, 'Neptune' stood out as having the highest values, along with 'Gratitude' grafted on 'VR 043-43'. In the 2022, 'Gratitude' reached the highest values, along with 'Neptune' grafted on 'Paulsen 1103'. Note that TSS/ATT ratio determines the flavor perception. The International Organisation of Vine and Wine (OIV) establishes an standard on minimum maturity requirements for table grapes. White table grape cultivars must present a minimum TSS/ATT ratio of 20, to be considered as ripe (OIV, 2024).

For all cultivar/rootstock combinations tested in this work, the TSS/TTA ratios were above this minimum standard, varying from 20,24 (Hope/VR 043-43) to 55,38 (Gratitude/IAC 572).

Results obtained by this study, such as high yields, high bud fertility and grape ripeness, are promising for the Southern region of Brazil, where no adapted white seedless grape cultivar is available to be recommended for growers.

2.4 CONCLUSIONS

1. The three white seedless grape cultivars 'Neptune', 'Hope' and 'Gratitude' have different responses when grafted on the main rootstocks used in the South of the country, with differences in the phenological stages, yield, plant vigor and physical and chemical characteristics of fruits in both crop seasons.
2. 'Neptune' and 'Hope' when grafted on 'VR 043-43' or 'Paulsen 1103' shows, independently of the crop season, high yield and bud fertility.
3. 'Neptune', 'Hope' and 'Gratitude' grafted on IAC 766 rootstock have earlier budburst, flowering and harvest, and on 'VR 043-43' have later budburst, flowering, ripening and harvest.
4. 'Hope' and 'Gratitude' grafted on 'IAC 572' or 'IAC 766' present higher plant vigor than 'Neptune' in all tested rootstocks.
5. All cultivars/rootstocks combinations tested present high TSS/TTA ratio.

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3 CHAPTER 2 – NEW SEEDLESS TABLE GRAPES ‘FAITH’, ‘JOY’ AND ‘JUPITER’ FOR THE SUBTROPICAL CLIMATE OF BRAZIL AND ROOTSTOCKS INFLUENCE

ABSTRACT

There are currently few seedless grape cultivars adapted and indicated for production in the Southern region of Brazil. The objective of this study is to assess the agronomic potential, phenology, physical and chemical characteristics of ‘Faith’, ‘Joy’, and ‘Jupiter’ seedless table grapes, recently introduced in Brazil, grafted on different rootstocks in Três Barras-SC. The experimental vineyard was established in 2018, with a 3x2 m spacing and vines trained on a Y trellis, in completely randomized block design, in a 3x4 factorial arrangement (cultivars Faith, Joy, and Jupiter and rootstocks ‘Paulsen 1103’, ‘VR043-43’, ‘IAC 572’, and ‘IAC 766’), with five replications of three plants per plot. The experiment was conducted during the 2020/2021 and 2021/2022 growing seasons. ‘Jupiter’ had the earliest harvest (15/January) and the highest Total Soluble Solids/Total Titratable Acidity ratio. Plants grafted on ‘IAC 572’ rootstock were the most vigorous and ‘Paulsen 1103’ resulted in lesser vigor plants. Both ‘VR043-43’ and ‘Paulsen 1103’ resulted in higher bud fertility and yield to ‘Faith’, ‘Joy’, and ‘Jupiter’. ‘IAC 766’ rootstock induced early budburst and harvest to the cultivars, while the ‘VR043-43’, a later budburst and harvest. ‘Faith’, ‘Joy’, and ‘Jupiter’, regardless of the rootstock used, present high bud fertility and yield. Additionally, its cluster physicochemical characteristics overcome the requirements of the Southern table grape market in Brazil, which is based on seeded *Vitis labrusca* and hybrids cultivars.

Key words: *Vitis* spp., viticulture, grapevine, adaptation, hybrids.

3.1 INTRODUCTION

Brazilian viticulture is developed on 75,007 hectares, with 73% of this area located in the Southern region with Subtropical climate (Mello & Machado, 2022). Table grapes are mainly produced in tropical regions, where two or three crops a year may be obtained using plant growth regulators to promote budburst and harvest at the most favorable time, when less rain and low relative humidity are present. At these table grape production sites, the main cultivars are still seeded, 'Niágara Rosada' (*Vitis labrusca*), 'Itália' and its mutations 'Rubi', 'Benitaka' and 'Brasil' (*Vitis vinifera*). Seedless cultivars have been rapidly replacing and occupying a considerable part of new plantings, mainly in the Northeast region, responsible for almost all of the country's grape exports (Maia et al., 2018).

In the Southern region of Brazil, the climate is characterized by moderately cold winters with severe frosts, no defined dry season, high relative humidity and frequent rainfall during the growth cycle and harvest. Grape production is based on *Vitis labrusca* and hybrids (Maia et al., 2018), mainly for winemaking and processing into juices, jams and other by-products (Mello & Machado, 2022), due to tradition and the lack of cultivars adapted to the climatic conditions. Table grape production is low, compared to other production hubs, and targets regional consumption. The use of plastic covers is recommended for production (Maia et al., 2018) and accounts for a significant increase in costs, limiting its expansion.

In the last two decades, 'Paulsen 1103' rootstock became predominant in the implementation of new vineyards in Southern states, and on a smaller scale, 'VR043-43' also began to be used, especially in areas of greater occurrence of ground pearl (*Eurhizococcus brasiliensis*), one of the main pests (Camargo et al., 2011). Even with the use of these rootstocks, the young vine decline has been the greatest difficulty encountered by Southern viticulture. Menezes-Netto et al. (2016) reports that plant mortality, previously associated with specific causes such as the susceptibility of rootstocks to fusariosis (*Fusarium oxysporum* f.sp. *herbemontis*) or ground pearl, is more complex, with no defined etiology, caused by several factors. Susceptibility to other fungi such as black foot (*Cylindrocarpon destructans*) and descending rot (*Botryosphaeria* spp.), planting in clayey soils with low macroporosity, vineyards with nutritionally unbalanced plants and the occurrence of frost and hail also contribute to weakening the plants.

The use of resistant rootstocks is one of the main success factors when implementing new vineyards in the Southern region (Menezes-Netto et al., 2016). 'Moscato Embrapa' (*Vitis* spp., hybrid cultivar for winemaking), when grafted on 'IAC 572' and 'IAC 766' showed promising results in an area affected with young vine decline in the region (Dalbó & Feldberg, 2019). Despite these rootstocks being widely used in the tropical areas of Brazil, this was the first and is one of the few results available for the Southern region.

The University of Arkansas, in the United States, released seedless table grape cultivars with differentiated flavor and disease resistance, adapted to challenging climate conditions that in some aspects are similar to South region of Brazil: high temperatures, high relative humidity and high precipitation during the harvest time (Clark & Moore, 1999; Clark & Moore, 2013). Three of these cultivars, 'Faith', 'Joy', and 'Jupiter', were introduced in Brazil in 2016. There are few seedless grape cultivars adapted to the Southern region of Brazil, which do not require plastic covers and canopy management, such as cluster thinning, berry thinning and gibberellin applications (Maia et al., 2018).

The objective of this work was to evaluate the agronomic potential, phenology and the physicochemical properties of 'Faith', 'Joy', and 'Jupiter' seedless table grapes, grafted on different rootstocks, in the Southern Region of Brazil.

3.2 MATERIALS AND METHODS

The experiment was carried out in Três Barras, Santa Catarina state, located in the South of Brazil, in the Planalto Norte Catarinense region. Its altitude reaches 794 meters, and its geographical coordinates are26°11’03’’ S and 50°16’22’’ W.

The climate is Cfb, according to Köeppen's classification, with a constantly humid subtropical climate, without a dry season, with cool summers and frequent frosts (Alvares *et al*. 2013). Climate parameters were provided by the State of Santa Catarina Climate Office (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina - Centro de Informações de Recursos Ambientais e de Agrometeorologia), including maximum, medium, and minimum air temperatures (°C), precipitation (mm) and relative humidity (%). Monthly data from August 1st to February 28th of each season (2020/2021 and 2021/2022 seasons) were assessed from the closest weather station to the vineyard, located in Três Barras, SC, Brazil. The parameters’ monthly average for both years is presented in Table 3.1.

TABLE 3.1. Monthly precipitation (mm), relative humidity (%), and monthly maximum, mean, and minimum temperature (°C), from pruning (August) to harvest (February) in Três Barras, SC, Brazil, average of the 2020/2021 and 2021/2022 seasons.

Climate Factors	August	September	October	November	December	January	February
Precipitation (mm)	80,5	68,4	115,0	70,4	113,6	193,1	37,8
Relative humidity (%)	87,7	84,9	83,8	79,9	81,3	88,3	82,0
Maximum temperature (°C)	22,3	26,2	25,5	28,1	29,6	28,9	30,7
Mean temperature (°C)	14,5	18,1	18,6	20,1	21,9	21,6	22,2
Mininum temperature (°C)	9,1	13,1	13,9	14,7	15,7	18,1	16,0

SOURCE: The author (2025).

Chilling hours (CH) (≤7.2 °C) were calculated from April 1st to August 31st, in each year of the assessments, totaling 355 CH in 2020 and 444 CH in 2021.

To characterize the soil of the experimental area, a soil analysis was conducted in 2021. The soil was classified as very clayey (67% clay) and presented the following characteristics at a depth of 0 to 20cm: Organic Matter = 4.8%, pH in H_2O = 6.5; Al^{+3} = 0.0 cmolc.dm^{-3}; H^{+}+Al^{+3} = 2.3cmolc.dm^{-3}; Ca^{+2} = 12.3 cmolc.dm^{-3}; Mg^{+2} = 5.7 cmolc.dm^{-3}; K^{+} = 304.0 mg.dm^{-3}; P = 9.2 mg.dm^{-3} and Base Saturation = 88.98%.

The vineyard was planted in October 2018, with grafted vines, on Y trellis system training system, with a three meters row spacing and two meters between plants (population density of 1,667 plants ha^{-1}) without using irrigation or plastic cover. The plants were formed into a bilateral cordon in 2019 and pruned by alternating spurs with two to three buds and canes with five to six buds, with a maximum of four canes per plant.

Since the characteristics of these cultivars were unknown in Brazil, pruning time was decided by observing the initiation of bud sprout, which on Y trellis and in the subtropical climate starts at the apices of the canes. To standardize budburst and, due to lack of prior knowledge on the behavior of the tested cultivars, hydrogenated cyanamide was applied at 3% and non-ionic adhesive spreader at 0.1% in both years. Weed control was managed using frequent mowing. Disease control was done, as recommended according to the Santa Catarina state, with periodic fungicide spraying. No cluster intervention, such as thinning, topping or gibberellins application, was conducted during the experiment, as the primary interest was to characterize the grape cultivars and the influence of rootstocks on their physicochemical properties.

The experimental design was in randomized blocks with five repetitions of three plants per plot, in a three x four factorial arrangement. The first factor was the new seedless cultivars recently introduced in Brazil -‘Joy’ (black), ‘Jupiter’ and ‘Faith’ (red). The second factor was the rootstock -‘Paulsen 1103’ (*V. berlandieri* x *V. rupestris*) and ‘VR043-43’ (*V. vinifera* x *M. rotundifolia*), that are already being used in the region; ‘IAC 572’[101-14 MGT (*V. riparia* x *V. rupestris*) x *V. caribaea*] and ‘IAC 766’ {106-8 MGT [*V. riparia* x (*V. cordifolia* x *V. rupestris*] x *V. caribaea*}, that already showed few promising results for young vine decline areas and needed further investigation.

Evaluations were conducted in the 2020/2021 and 2021/2022 seasons. ‘Faith’ did not produce in the first harvest due to frost damage at the end of August 2020, after its budburst.

The BBCH scale was used to define the vine phenological stages (Lorentz *et al*., 1995). Dates of the following phenological stages were noted as following: budburst when around 10% of the buds were at the green tip stage (BBCH 07); beginning of flowering, when 5% of the flowers were opened (BBCH 60); end of flowering, when less than 5% of the flowers were opened and the rest were already fertilized (BBCH 69); beginning of ripening, appearance of the first berries with color changes or consistency (BBCH 81); end of ripening, when more than 90% of the berries have changed color or softened (BBCH 85); harvest, established based on visual and sensory evaluation of the berries, when the clusters are ready for harvest (BBCH 89). The average dates for the two harvests evaluated were obtained by using the dates of each phenological stage.

The variables analyzed were the number of shoots and clusters per plant, cluster weight and winter pruning material per plant, according to the methodology used by Feldberg *et al.* (2007). The shoots were counted after canopy management operations of defoliation and lateral shoot thinning, during the production cycle. The clusters were counted and weighed at two harvest times, at the beginning of harvesting and seven days later, when all the clusters were harvested. In the Southern region of Brazil, grape ripeness is not uniform and around 15% to 30% of the crop reach ripeness earlier, reason for establishing two harvest time and berry sample collected in the middle of this period. Each combination (scion/rootstock) was harvested at a different time when reaching ripeness. Uniform color of the clusters and berries were considered, along with berry tasting and evaluations of sugar content using a portable refractometer, every three days to decide the beginning of harvest of each plot. These cultivars are still being tested in Brazil and no previous data were available.

To obtain the pruning weight, the canes were weighed immediately after winter pruning. The average cluster weight was estimated by dividing the total weight of clusters by the number of harvested clusters in each harvest period. Bud fertility was estimated by the relationship between the number of clusters and the number of shoots. Productivity was estimated by multiplying the cluster weight per plant by the plant density per hectare (t ha). Clusters and shoots were weighted using an electronic scale with precision of three decimal places. At the beginning and end of the harvest of each plot, a cluster weighing close to the average weight was chosen for the clusters and berries characterization. The length and width of these clusters were measured with a ruler (cm), all the berries were removed and counted, and each berry had its length and width measured, using a digital caliper (mm). The berries were weighed to calculate the average weight of the berries, based on the relationship between the berries total weight and the berry number per cluster (g).

For chemical analyses, samples of 100 berries were collected randomly from each plot, approximately five days after the first harvest, when most clusters were ripened and two days before the final harvest. Samples were identified and immediately frozen. Total soluble solids (TSS) content was measured using a refractometer and expressed in ºBrix, and total titratable acidity (TTA) using the 0.1N NaOH neutralization titration method, until reaching pH 8.1, with a digital pH meter, expressed in grams of tartaric acid per 100 mL of juice (Instituto Adolfo Lutz, 2008). From these parameters, TSS/TTA ratio was calculated.

Data were tested for normal distribution using the Lilliefors test and subjected to individual and joint analysis of variance in a factorial model for rootstocks and cultivars, and the means grouped using the Scott-Knott test ($p \leq 0.05$). All statistical analyzes were carried out using the Genes statistical program (Cruz, 2013).

3.3 RESULTS AND DISCUSSION

Considering the average of 2020/2021 and 2021/2022 seasons, 'Faith' was the earliest cultivar to start budburst in the upper buds of the canes and had to be pruned earlier (August 11th), followed by Jupiter (August 27) and Joy (September 1). Considering the average of all rootstocks for both seasons, ’Faith’ budburst (August 23) occurred 14 days before ‘Jupiter’ (September 6) and 24 days before ‘Joy’ (September 16) (Table 3.2).

In terms of the harvest time, ‘Jupiter’ was the first to reach ripeness at 141 days after pruning (January 15), followed by ‘Faith’, harvested about three days later (January 18), with 160 days of cycle, from pruning to harvest. 'Joy' showed the latest budburst among the three cultivars (September 16), which is a good characteristic in some places where late frosts are common. ‘Joy’ reached ripeness at 157 days after pruning (February 05), 18 days after ‘Faith’ and 21 days after ‘Jupiter’, the latest to be harvested.

The ‘IAC 766’ rootstock induced the advancement of some phenological stages for the three cultivars. For ‘Jupiter’, budburst occurred six days earlier (September 3) than for plants grafted on ‘Paulsen 1103’ (September 9) and ‘VR043-43’ (September 9) and one day on ‘IAC 572’ (September 4). For 'Joy' (September 10), this advancement in budburst was greater, ten days compared to 'VR043-43' (September 20), eight days compared to 'Paulsen 1103' (September 18) and seven days compared to 'IAC 572' (September 17).

TABLE 3.2. Number of days after pruning and dates for phenological stages of red and black seedless grapes 'Jupiter', 'Joy' and 'Faith', grafted on 'Paulsen 1103', ‘VR 04-43', 'IAC 572' and 'IAC 766' in Três Barras-SC, Brazil, average of the 2020/2021 and 2021/2022 seasons.

Cultivar/ rootstock	Pruning	Budburst	Flowering		Ripening		Harvest
			Beginning	End	Beginning	End	Beginning
Faith/IAC 766	11/Aug	5 (16/Aug)	60 (10/Oct)	77 (27/Oct)	121 (10/Dec)	138 (27/Dec)	159 (17/Jan)
Faith/ P1103	11/Aug	14 (25/Aug)	64 (14/Oct)	78 (28/Oct)	119 (08/Dec)	142 (31/Dec)	161 (19/Jan)
Faith/IAC 572	11/Aug	12 (23/Aug)	61 (11/Oct)	77 (27/Oct)	122 (11/Dec)	140 (29/Dec)	161 (19/Jan)
Faith/VR043-43	11/Aug	20 (31/Aug)	62 (12/Oct)	78 (28/Oct)	122 (11/Dec)	146 (04/Jan)	162 (20/Jan)
Average	11/Aug	12 (23/Aug)	61 (11/Oct)	77 (27/Oct)	121 (10/Dec)	141 (30/Dec)	160 (18/Jan)
Jupiter/IAC 766	27/Aug	7 (03/Sep)	43 (09/Oct)	64 (30/Oct)	101 (06/Dec)	121 (26/Dec)	137 (11/Jan)
Jupiter/P1103	27/Aug	13 (09/Sep)	51 (17/Oct)	71 (06/Nov)	105 (10/Dec)	126 (31/Dec)	142 (16/Jan)
Jupiter/IAC 572	27/Aug	8 (04/Sep)	46 (12/Oct)	67 (02/Nov)	105 (10/Dec)	124 (29/Dec)	141 (15/Jan)
Jupiter/VR043-43	27/Aug	13 (09/Sep)	51 (17/Oct)	71 (06/Nov)	105 (10/Dec)	126 (31/Dec)	145 (19/Jan)
Average	27/Aug	10 (06/Sep)	47 (13/Oct)	68 (03/Nov)	104 (09/Dec)	124 (29/Dec)	141 (15/Jan)
Joy/IAC 766	1/Sep	9 (10/Sep)	50 (21/Oct)	64 (04/Nov)	116 (26/Dec)	147 (26/Jan)	156 (4/Feb)
Joy/ P1103	1/Sep	17 (18/Sep)	56 (27/Oct)	71 (11/Nov)	114 (24/Dec)	146 (25/Jan)	158 (6/Feb)
Joy/IAC 572	1/Sep	16 (17/Sep)	57 (28/Oct)	72 (12/Nov)	120 (30/Dec)	151 (30/Jan)	159 (7/Feb)
Joy/VR043-43	1/Sep	19 (20/Sep)	60 (31/Oct)	77 (17/Nov)	118 (28/Dec)	144 (23/Jan)	158 (6/Feb)
Average	1/Sep	15 (16/Sep)	55 (26/Oct)	71 (11/Nov)	117 (27/Dec)	147 (26/Jan)	157 (5/Feb)

SOURCE: The author (2025).

For ‘Faith’, ‘IAC 766’ (August 16), advanced budburst by seven days comparing to ‘IAC 572’ (August 23), nine days for ‘Paulsen 1103’ (August 25), and 15 days for ‘VR043-43’ (August 31) (Table 3.2). This same influence on the advancement of budburst induced by the ‘IAC 766’ rootstock was also observed by Dalbó & Feldberg (2019) in the Santa Catarina state. However, clusters from all rootstocks were harvested on the same day, the only indication that 'IAC 766' also induces early harvesting was that the plants grafted onto it presented an absolute TSS value higher than the other rootstocks, considering the average of the four harvests evaluated. Techio *et al.* (2019) reported that 'IAC 766' promoted advancements for 'Vênus', seedless table grape, from budburst to harvest, corroborating the results observed in this work.

The harvest of the three cultivars grafted on 'IAC 766' was advanced by two to eight days, when compared to the other rootstocks. Differences between rootstocks were observed in lesser or greater extent for the beginning and end of flowering and for the beginning and end of ripening. Exception of 'Joy' and 'Faith', grafted on 'Paulsen 1103', which had the first berries to change color (Table 3.2).

‘VR043-43’ rootstock induced the three cultivars to a later budburst, delaying ripeness, except for'Joy'. For 'Jupiter', 'VR043-43' delayed harvest by eight days (January 19), compared to 'IAC 766' (January 11). For ‘Joy’, the difference between ‘IAC 766’ (February 4) and ‘VR043-43’ (February 6) was only two days, along with ‘Paulsen 1103’ (February 6) and three days earlier than ‘IAC 572’ (February 7). As for ‘Faith’, the harvest date differences were also observed. ‘IAC 766’ (January 15) reached ripeness three days earlier than ‘VR043-43’ (January 20) and 2 days earlier than the intermediate ones (January 19).

Knowing the natural development of the scions on each rootstock is a crucial start for future cultivation. Using plant growth regulators, irrigation and plastic covers, along with the use of rootstocks that promote advancements, such as ‘IAC 766’, enable further anticipation of harvest. Additionally, using rootstocks that delay budburst and promote longer cycle as observed for ‘VR 043-43’, can extend the harvest time and also be recommended for areas with risk of spring frost damage.

Analyzing the growth cycle, 'Faith' cycle was 160 days, 'Jupiter' 141 days and ‘Joy’ 157 days, considering the average of all rootstocks. 'IAC 766' influenced the three scions to have a shorter cycle duration, from one to four days when comparing their average but also to seven days when comparing to the rootstock with the longest cycle, ’VR 043-43’. (Table 3.2).

The cycle duration where the cultivars were bred (Clarksville-Arkansas, United States) was 125 days for ‘Jupiter’, 135 days for ‘Joy’ and 126 days for ‘Faith’. The budburst of 'Faith' and 'Jupiter' occurred just two days apart, with 'Jupiter' being earlier and 'Joy' two to four days later. There, ‘Jupiter’ reached ripeness just one day before ‘Faith’ and only 10 days earlier than ‘Joy’ (Clark & Moore, 2013).

In this first observation in Brazil, the harvest dates followed the same trend for ‘Jupiter’ and ‘Faith’ with just three days apart. ‘Joy’ reached ripeness much later, on average 21 and 18 days after ‘Jupiter’ and ‘Faith’, respectively; indicating that in the Brazilian region, the growth cycle is slower.

Even though 'Faith' had an earlier harvest date than 'Joy', it had the longest cycle, with 148 days, due to its very early budburst, which causes a longer period between budburst and flowering, as this phenological subperiod is significantly more affected by temperature than the subsequent intervals between flowering to veraison and between veraison to maturity, as observed in 15 grapevine cultivars in Australia (Cameron *et al*., 2022).

The influence of rootstocks on phenology can be used by grape growers to change the budburst period, aiming to mitigate the risk of frost damage, change in the harvest period, to offer fruits in more favorable price periods or even to stagger activities, with extension of pruning periods, management operations and harvesting of the same cultivar.

Furthermore, the harvest of ‘Jupiter’ and ‘Faith’ clusters is concentrated in a period when few table grape cultivars are ripened (Epagri, 2021). Applying management techniques, stimulation of early budburst and planting in regions where frost damage presents a lower risk, this advantage can be even greater, with grapes being harvested in a period when there is less supply of other cultivars, reaching higher prices.

Bud fertility, according to Leão *et al*. (2017), is strongly determined by genetic and environmental factors and, knowledge of bud fertility contributes to the selection and indication of new seedless cultivars with high yield production. In the 2021 harvest, ‘Jupiter’ and ‘Joy’ had a similar number of clusters. ‘IAC 766’ was the only rootstock to induce fewer clusters for both cultivars. Regarding bud fertility and productivity, 'Paulsen 1103' and 'VR043-43' presented higher values for both parameters compared to 'IAC 572' and 'IAC 766', with 'Jupiter' having greater bud fertility than 'Joy', and 'Joy' a greater number of clusters than 'Jupiter' (Table 3.3).

In the 2022 harvest, for ‘Faith’, the ‘IAC 766’ was the only rootstock with fewer clusters. ‘Paulsen 1103’ stood out with the highest bud fertility and yield. For 'Jupiter', there was no difference between rootstocks for number of clusters, bud fertility and productivity. For ‘Joy’, the highest number of clusters, bud fertility and productivity were obtained in plants grafted on ‘VR043-43’ and ‘Paulsen 1103’ (Table 3.3).

Yields for the 2022 harvest, when the plants were already mature and formed, were 36.2 t ha for 'Faith', 24.85 t ha for 'Jupiter' and 18.54 t ha for 'Joy', higher than those obtained by Clark & Moore (2013), which were 20.4 t ha, 21.9 t ha and 18.3 t ha respectively, or the same cultivars in Clarksville-Arkansas, United States, indicating good adaptation to the location of the experiment in Brazil.

Leão *et al*. (2020) evaluated the production of 14 seedless grape cultivars in the São Francisco Valley, the main Brazilian producing and exporting region, and found that the highest yields were just above 26 t ha, in a pergola trellis system with irrigation. This shows that the yields obtained in this experiment are promising because the main difficulty in producing seedless grape cultivars in the Southern region of Brazil is the lack of adaptation and low yields. Table 3.1 shows that the relative humidity is always above 79%, after pruning (August). In January, when grapes are ripening or at harvest, it reached 88,3% on average, due to high precipitation. From pruning to harvest, precipitation amounted to 678,8 mm in the average of 2020 and 2021 seasons. From December to February, at the final stages of ripening, precipitation reached 344,5 mm, showing how challenging seedless table grape production in this region is.

TABLE 3.3. Productive performance and plant vigor of red and black seedless grapes 'Jupiter', 'Joy' and 'Faith', grafted onto 'Paulsen 1103', 'VR043-43', 'IAC 572' and 'IAC 766' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

Rootstock	Cycle 2020/2021				Cycle 2021/2022			
	Jupiter	Joy	Faith	Average	Jupiter	Joy	Faith	Average
Number of clusters per plant								
Paulsen 1103	46.20	47.00		46.60a	56.40aB	54.80aB	76.20aA	62.47
VR043-43	46.80	49.60		48.20a	56.60aB	55.00aB	78.60aA	63.40
IAC 572	40.20	43.40		41.80a	64.60aB	46.40bC	77.20aA	62.73
IAC 766	33.40	33.80		33.60b	58.80aA	41.00bB	62.20bA	54.00
Average	41.65A	43.45A		42.55	59.10	49.30	73.55	60.65
CV (%)	11.95				10.58			
Bud fertility (number of clusters per number of shoots)								
Paulsen 1103	2.64	1.56		2.10a	1.92aA	1.44aB	2.02aA	1.79
VR043-43	2.86	1.60		2.23a	1.90aA	1.38aB	1.86bA	1.71
IAC 572	2.16	1.30		1.73b	1.98aA	1.08bC	1.72bB	1.59
IAC 766	1.98	1.14		1.56b	1.96aA	1.04bB	1.80bA	1.60
Average	2.41A	1.40B		1.90	1.94	1.24	1.85	1.67
CV (%)	11.49				7.92			
Yield (t ha)								
Paulsen 1103	15.72	23.20		19.46a	23.60aB	21.00aB	45.80aA	30.13
VR043-43	18.36	24.20		21.28a	26.64aB	23.14aB	40.06bA	29.95
IAC 572	11.30	19.62		15.46b	27.86aA	14.62bB	28.00cA	23.49
IAC 766	9.10	12.48		10.79b	21.30aB	15.40bC	30.92cA	22.54
Average	13.62B	19.87A		16.74	24.85	18.54	36.20	26.53
CV (%)	28.67				16.27			
Pruning weight (kg plant)								
	Jupiter	Joy	Faith	Average	Jupiter	Joy	Faith	Average
Paulsen 1103	1.98	3.78	3.92	3.23b	1.72bC	2.96cB	3.40cA	2.69
VR043-43	2.18	4.24	4.56	3.97a	1.82bC	3.40bB	4.16bA	3.13
IAC 572	2.24	4.78	4.90	3.71a	2.36aC	4.28aB	5.06aA	3.90
IAC 766	2.60	4.12	4.42	3.66a	2.06aB	3.96aA	3.96bA	3.33
Average	2.25B	4.23A	4.45A	3.64	1.99	3.65	4.15	3.26
CV (%)	16.47				9.83			

* Averages followed by the same letter in uppercase in the row and lowercase in the column do not differ from each to the Scott–Knott grouping of means test ($p \leq 0.05$).
SOURCE: The author (2025).

In 2021, the cultivars with the highest pruning weight were 'Faith' and 'Joy' and the rootstock with the lowest pruning weight was 'Paulsen 1103', differing from the others. In 2022, the most vigorous rootstocks for ‘Jupiter’ and ‘Joy’ were ‘IAC 572’ and ‘IAC 766’ and for ‘Faith’ it was ‘IAC 572’ (Table 3.3). At the same time those vigorous rootstocks can induce lower yields in seedless grapes (Feldberg *et al*., 2007; Leão *et al*., 2017), the greater vigor of plants grafted on tropical rootstocks, such ‘IAC 572’ and ‘IAC 766’, or *Muscadinia rotundifolia* hybrids, which are also vigorous, has been the best strategy to overcome the problem with young vine decline in Santa Catarina (Dalbo *et al*., 2016; Menezes-Netto *et al*., 2016; Dalbo & Feldberg, 2019). Until the 2022 harvest, no plants with young vine decline symptoms were observed in the experiment.

'Joy' produced clusters with higher weight, longer and with a greater number of berries than 'Jupiter' in 2021. Considering the tested rootstocks, the values were statistically similar for all parameters, except for number of berries, in which ‘IAC 766’ and ‘IAC 572’ rootstocks influenced the two cultivars to have cluster with lower berry numbers, which may be related to flower setting and vigor. Regarding cluster width, Joy’ produced clusters with greater width than ‘Jupiter’ only when grafted onto ‘VR043-43’ (Table 3.4).

‘Faith’ (296.25g), ‘Jupiter’ (253.15g) and ‘Joy’ (223.75g) cluster weight in 2022 were close to those reported by Vance *et al.* (2017), who tested these cultivars in two different locations in the Oregon state. The harvested clusters in the United States weighted on average 257 g and 329 g for 'Faith', 327 g and 358 g for 'Joy' and 228 g and 172 g for 'Jupiter', which clearly indicates that site conditions considerably influence cluster characteristics (Table 3.4).

In 2021, there was no significant difference between the rootstocks and ‘Joy’ had a higher cluster average weight than ‘Jupiter’. In 2022, there was an interaction between the factors, and for ‘Jupiter’, only ‘IAC 766’ produced clusters with lower weight than the others. For 'Joy', 'IAC 572' was the one with the lowest value and for 'Faith', 'Paulsen 1103' was the one that stood out from the others with the highest cluster weight (Table 3.4).

TABLE 3.4. Cluster physical characteristics of red and black seedless grapes 'Jupiter', 'Joy' and 'Faith', grafted onto 'Paulsen 1103', 'VR043-43', 'IAC 572' and 'IAC 766' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

	Cycle 2020/2021			Cycle 2021/2022			
Rootstock	Jupiter	Joy	Average	Jupiter	Joy	Faith	Average
Cluster weight (g)							
Paulsen 1103	203.20	288.80	246.00a	252.60aB	230.20aB	362.80aA	281.87
VR043-43	236.00	287.00	261.50a	282.40aA	251.00aA	303.00bA	278.80
IAC 572	170.40	272.00	221.20a	259.40aA	188.40bB	218.00cB	221.93
IAC 766	164.00	222.40	193.20a	218.20bB	225.40aB	301.20bA	248.27
Average	193.40B	267.55A	230.47	253.15	223.75	296.25	257.72
CV (%)	18.92			12.77			
Cluster length (cm)							
Paulsen 1103	18.22	18.82	18.52a	17.28aB	17.88aB	21.38aA	18.85
VR043-43	17.76	20.36	19.06a	18.54aB	15.98aC	20.76aA	18.43
IAC 572	17.26	19.96	18.61a	16.66aA	17.34aA	16.62bA	16.87
IAC 766	16.32	18.72	17.52a	15.34aB	17.10aA	18.14bA	16.86
Average	17.39B	19.46A	18.43	16.96	17.08	19.23	17.75
CV (%)	13.42			9.55			
Cluster width (cm)							
Paulsen 1103	9.72aA	9.80bA	9.76	11.54	10.20	10.68	10.81a
VR043-43	9.50aB	11.46aA	10.48	11.08	10.46	11.26	10.93a
IAC 572	9.06aA	10.18bA	9.62	11.64	9.96	8.64	10.08a
IAC 766	9.86aA	9.32bA	9.59	11.12	10.52	10.38	10.67a
Average	9.54	10.19	9.86	11.34A	10.28B	10.24B	10.62
CV (%)	9.74			11.86			
Number of berries per cluster							
Paulsen 1103	55.60	104.00	79.80a	76.80aC	118.00aB	193.00aA	129.27
VR043-43	62.80	113.20	88.00a	93.00aB	117.80aA	127.80bA	112.87
IAC 572	44.60	95.20	69.90b	82.60aA	96.00aA	93.60cA	90.73
IAC 766	45.20	70.80	58.00b	77.20aC	111.60aB	140.40bA	109.73
Average	52.05B	95.80A	73.92	82.40	110.85	138.70	110.65
CV (%)	18.98			16.24			

* Averages followed by the same letter in uppercase in the row and lowercase in the column do not differ from each to the Scott–Knott grouping of means test ($p \leq 0.05$).
SOURCE: The author (2025).

In the 2022 harvest, 'Faith' clusters were longer than those of 'Joy' and 'Jupiter', except for 'Joy' on 'IAC 572' and 'IAC 766' and 'Jupiter' on 'IAC 572'. There was no significant difference in cluster length among rootstocks for ‘Jupiter’ and ‘Joy’. For ‘Faith’, the longest clusters were harvested from plants on ‘Paulsen 1103’ and ‘VR043-43’. Regarding the cluster width in 2021, both 'Joy' and 'Jupiter' presented clusters with similar widths, except for those on ‘VR043-43’ rootstock, whose clusters were wider for 'Joy'. In 2022, ‘Jupiter’ produced wider clusters than the other cultivars and there was no difference between the rootstocks (Table 3.4).

These results were obtained from clusters without any intervention of thinning, topping or gibberellin applications, with the influence only of the rootstocks used. To adapt table grapes clusters to consumer demand, Zilio *et al*. (2019) recommend that, for cultivars with a short peduncle, the first clusters should be eliminated, and clusters should be shortened to 12 to 15 cm, depending on the cultivar, associated with the gibberellin applications to stimulate berry growth. After the initial characterization of these new cultivars, further work must begin to define specific management recommendations for each cultivar, increasing berry size and cluster shape.

'Joy' presented the highest berry number per cluster and 'Paulsen 1103' and 'VR043-43' rootstocks were superior to the others in 2021. For the 2022 harvest, there was an interaction between the tested factors and for 'Faith', 'Paulsen 1103' rootstock stood out with the highest berry number compared to the others. For ‘Joy’ and ‘Jupiter’ there was no difference among rootstocks (Table 3.4). The higher berry number per cluster may lead to higher yields, however, it can result in cluster compactness and berry size reduction. Increasing the berry size with gibberellin applications, cutting the cluster edges or wings and thinning berries are recommended approaches to fulfill a more demanding table grape market.

Zilio *et al.* (2019), recommend leaving only 50 to 70 berries per cluster for ‘BRS Ísis’ and ‘BRS Vitória’ in the Serra Gaúcha region, Rio Grande do Sul state, Brazil, to achieve larger berry size, the ideal flavor and uniform color. Rootstocks that induce a low berry number per cluster can be used for cultivars that require thinning, resulting in a quicker, easier and less costly operation.

‘Jupiter’ produced berries with the highest weight in 2021, and there was no significant difference among rootstocks. In 2022, there were no differences among rootstocks for ‘Jupiter’ and ‘Joy’, only for 'Faith', where the largest berries were produced by plants grafted on 'VR043-43' and 'IAC 572', probably due to the lower number of berries per cluster on both rootstocks, in relation to 'Paulsen 1103' (Tables 3.4 and 3.5).

In 2021, ‘IAC 766’ influenced the greater berry length only for ‘Joy’. In 2022, the same rootstock presented shorter berry length and width for ‘Jupiter’ than the others. For 'Joy', the IAC 572 rootstock presented shorter length and smaller width and, for 'Faith', the rootstocks with the best results for both length and width were 'VR043-43' and 'IAC 752', which is probably related to the lower number of berries (Tables 3.4 and 3.5).

TABLE 3.5. Physical characteristics of the berries of red and black seedless grapes 'Jupiter', 'Joy' and 'Faith', grafted onto 'Paulsen 1103', ‘VR043-43', 'IAC 572' and 'IAC 766' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

Rootstock	Cycle 2020/2021			Cycle 2021/2022			
	Jupiter	Joy	Average	Jupiter	Joy	Faith	Average
			Berry weight (g)				
Paulsen 1103	3.52	2.90	3.21a	3.22aA	1.92aB	1.80bB	2.31
VR043-43	3.74	2.72	3.23a	3.02aA	2.18aB	2.42aB	2.54
IAC 572	3.68	2.82	3.25a	3.06aA	1.84aC	2.36aB	2.42
IAC 766	3.42	3.10	3.26a	2.74aA	2.02aB	2.08bB	2.28
Average	3.59A	2.89B	3.23	3.01	1.99	2.17	2.39
CV (%)		6.52				11.78	
			Berry length (mm)				
Paulsen 1103	20.76aA	20.20bA	20.48	18.82aA	17.56aB	15.00bC	17.13
VR043-43	20.76aA	19.74bB	20.25	18.28aA	17.54aA	16.36aB	17.39
IAC 572	21.24aA	19.70bB	20.47	18.24aA	16.24bB	16.58aB	17.02
IAC 766	20.52aB	21.18aA	20.85	16.96bA	17.44aA	15.46bB	16.62
Average	16.47	14.35	20.51	18.08	17.20	15.85	17.04
CV (%)		2.46				4.84	
			Berry width (mm)				
Paulsen 1103	16.34	14.26	15.30a	15.08aA	12.24aB	12.74bB	13.35
VR043-43	16.62	14.40	15.51a	14.86aA	12.44aC	14.00aB	13.77
IAC 572	16.46	14.16	15.31a	15.24aA	11.30bC	13.96aB	13.50
IAC 766	16.48	14.58	15.53a	14.28bA	12.34aC	13.14bB	13.25
Average	16.48A	14.35B	15.41	14.87	12.08	13.46	13.47
CV (%)		2.60				4.01	

* Averages followed by the same letter in uppercase in the row and lowercase in the column do not differ from each to the Scott–Knott grouping of means test ($p \leq 0.05$).
SOURCE: The author (2025).

The highest TSS levels for 'Jupiter' were provided by the ‘IAC 766’ rootstocks and ‘Paulsen 1103’ in 2021 and on ‘VR043-43’ and ‘Paulsen 1103’ in 2022 (Table 3.6). In the Sub-middle region of the São Francisco Valley, ‘BRS Magna’ also showed higher sugar contents with ‘Paulsen 1103’ rootstocks and ‘IAC 572’ (Santos *et al.* 2022). For 'Joy', 'VR043-43' and 'IAC 766' stood out in 2021 and 2022, only 'IAC 572' presented a lower TSS value than the others. For ‘Faith’, there was no difference between the rootstocks (Table 3.6).

Regarding TTA, 'Joy' had higher acidity than 'Jupiter' and the ‘VR043-43’ rootstock was more acidic than the others in 2021. In the 2022 harvest, there was no difference between the rootstocks for TTA in 'Jupiter' and 'Joy'. For ‘Faith’, just ‘VR043-43’ differed from the others with the highest TTA value (Table 3.6).

High TSS/TTA ratio is greatly appreciated by local consumers. The highest TSS/TTA ratiowas observed for 'Jupiter', both in 2021 and 2022. In 2021, there was a significant interaction between the factors and the 'IAC 766' rootstock was the one with the highest TSS/TTA ratio value for 'Jupiter' (66,96), showing that clusters could be harvested earlier (Table 3.6).

In 2022, the three cultivars presented similar values (‘Faith’ - 32,32) or much higher (‘Jupiter’ – 60,61 and ‘Joy’ – 45,90) than the TSS/TTA ratio obtained by Leão *et al*. (2011) for ‘Sugraone’ (33,26 to 35,90) on different rootstocks. ‘Sugraone’ had a great importance on table viticulture and for many years was the main seedless cultivar for the domestic market and export, therefore planted on a large scale in the arid region of Northern Brazil.

TABLE 3.6. Chemical characteristics of the berries of red and black seedless grapes 'Jupiter', 'Joy' and 'Faith', grafted onto 'Paulsen 1103', 'VR043-43', 'IAC 572' and 'IAC 766' in Três Barras-SC, Brazil in the 2020/2021 and 2021/2022 cycles.

	Cycle 2020/2021			Cycle 2021/2022			
	Jupiter	Joy	Average	Jupiter	Joy	Faith	Average
Total Soluble Solids (ºBrix)							
Paulsen 1103	18.36aA	12.72bA	15.54	18.44aA	19.12aA	14.04aB	17.20
VR043-43	16.28cA	14.44aA	15.36	18.80aA	19.08aA	14.72aB	17.53
IAC 572	17.52bA	13.44bA	15.48	17.00bA	17.68bA	15.36aB	16.68
IAC 766	18.88aA	14.72aA	16.80	15.96cB	18.84aA	15.00aB	16.60
Average	17.76	13.83	15.80	17.55	18.68	14.78	17.00
CV (%)	4.24			4.56			
TitratableTotal Acidity (g tartaric acid100 mL^{-1})							
Paulsen 1103	0.39	0.58	0.49b	0.29aB	0.42aA	0.46bA	0.39
VR043-43	0.42	0.69	0.55a	0.32aC	0.39aB	0.51aA	0.41
IAC 572	0.38	0.58	0.48b	0.28aB	0.42aA	0.45bA	0.39
IAC 766	0.29	0.55	0.42b	0.27aB	0.42aA	0.43bA	0.37
Average	0.37B	0.60A	0.48	0.29	0.41	0.46	0.39
CV (%)	11.28			8.51			
TSS/TTA ratio							
Paulsen 1103	46.82bA	22.30aB	34.56	64.34	46.26	30.58	47.06 a
VR043-43	39.26cA	21.04aB	30.15	58.56	49.36	29.16	45.69 a
IAC 572	47.06bA	23.78aB	35.42	61.02	42.26	34.18	45.82 a
IAC 766	66.96aA	26.92aB	46.94	58.54	45.70	35.00	46.41 a
Average	50.03	23.51	36.76	60.61A	45.90B	32.23C	46.25
CV (%)	13.78			10.84			

* Averages followed by the same letter in uppercase in the row and lowercase in the column do not differ from each to the Scott–Knott grouping of means test ($p \leq 0.05$).

SOURCE: The author (2025).

3.4 CONCLUSIONS

'Jupiter', 'Joy' and 'Faith', regardless the rootstock used, present high bud fertility and yield.

'Jupiter' is the earliest at harvest and has the highest ratio.

Rootstocks influence phenological stages, productive performance, clusters' physical-chemical quality and plant vigor of 'Faith', 'Joy', and 'Jupiter'.

'IAC 572' rootstock induces greater vigor in the plants, followed by the 'VR043-43' and 'IAC 766'. 'Paulsen 1103' is the least vigorous.

'VR043-43' and 'Paulsen 1103' rootstocks provide to 'Faith', 'Joy', and 'Jupiter' vines greater bud fertility and productivity.

'IAC 766' rootstock induces earlier budburst and harvest, while 'VR043-43' induces later budburst and harvest.

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4 FINAL CONSIDERATIONS

Experiments were conducted in vineyards without plastic cover and with no bunch interventions to understand the cultivar’s natural behavior and the potential of use of each rootstock. At the end of this work, it is possible to recommend the most promising cultivars and respective rootstocks. However, new studies can deepen the knowledge and help obtain additional results. For later harvest cultivars, the use of plastic covering will allow for the production of bunches with better chemical characteristics, achieving better maturation rates.

Additional work on bunch management of these cultivars, such as thinning, topping or gibberellin applications, should be carried out to promote increase in berry size and improvement on bunch shape aligned with commercial expectations.

All cultivars should be tested in other regions, especially those with very early budding such as ‘Faith’, as they may have competitive advantages in regions without frost damage risks. Shorter cycle cultivars, such as Jupiter and Neptune, can be tested in regions where more than one annual harvest is possible.

Regarding tropical rootstocks, vigor can be an important ally for areas with a history of plant death due to young vine decline. However, in this study, the lowest yields were obtained in plants grafted onto ‘IAC 766’ and ‘IAC 572’, compared to ‘Paulsen 1103’ and ‘VR 043 43’. Further studies aimed at promoting greater balance of plants on these rootstocks may lead to the achievement of better production results, since in this study, all combinations of scion cultivars and rootstocks were managed under equal conditions. Larger spacing between plants and the use of expansive trellis systems, such as pergola trellis, can also be used to achieve better plant balance and consequently increase productivity in plants grafted onto these vigorous rootstocks. It is also expected that in less fertile soils or with some physical restriction, these rootstocks may prove to be more advantageous.

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5 APPENDIX

Bunches of cultivars Faith, Jupiter and Joy.

General view of 'Jupiter' plants in production.

General view of 'Faith' plants in production.

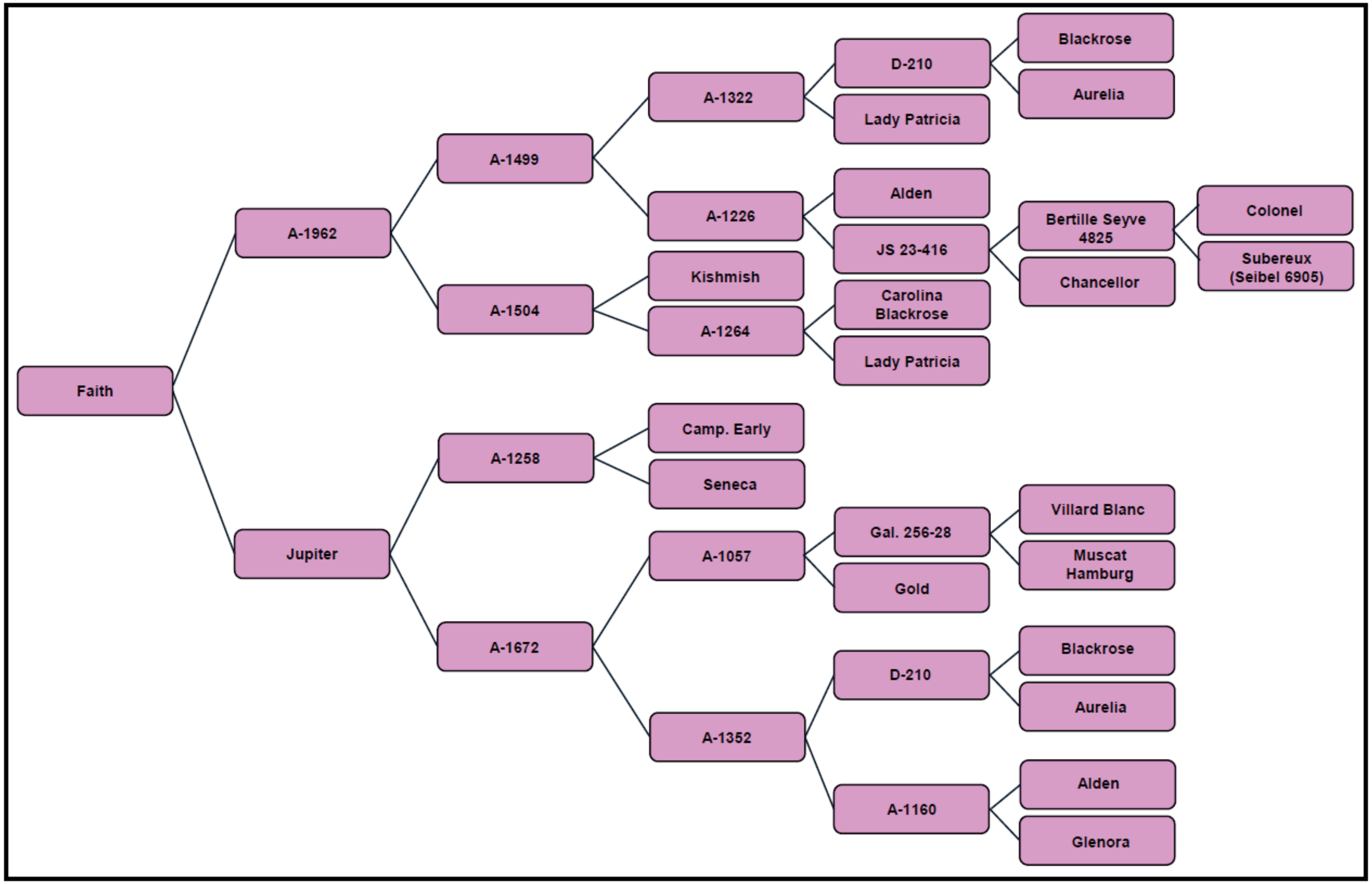
General view of 'Joy' plants in production.

Bunches of cultivars Neptune, Hope and Gratitude.

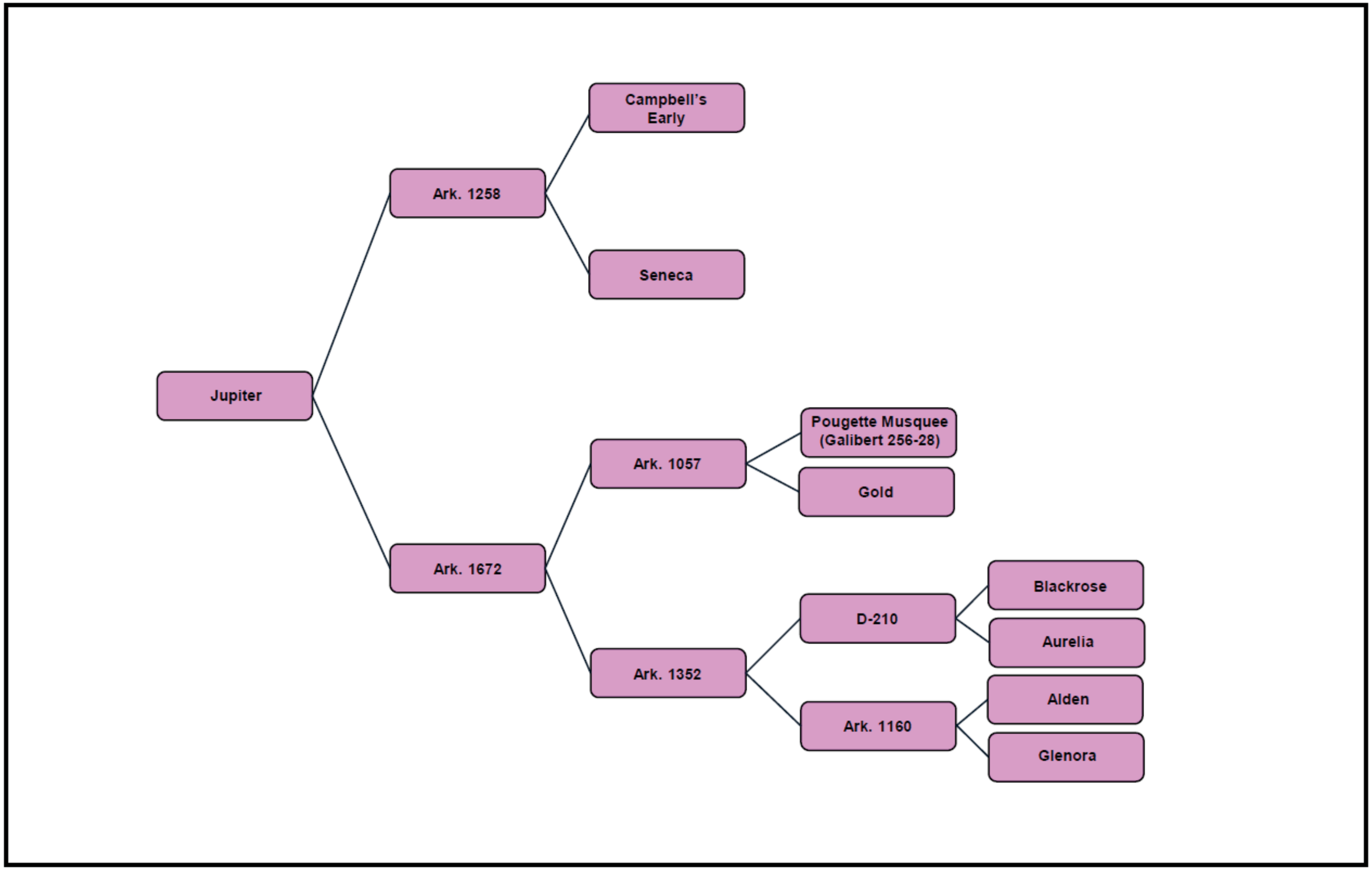
General view of 'Neptune' plants in production.

General view of 'Gratitude' plants in production.

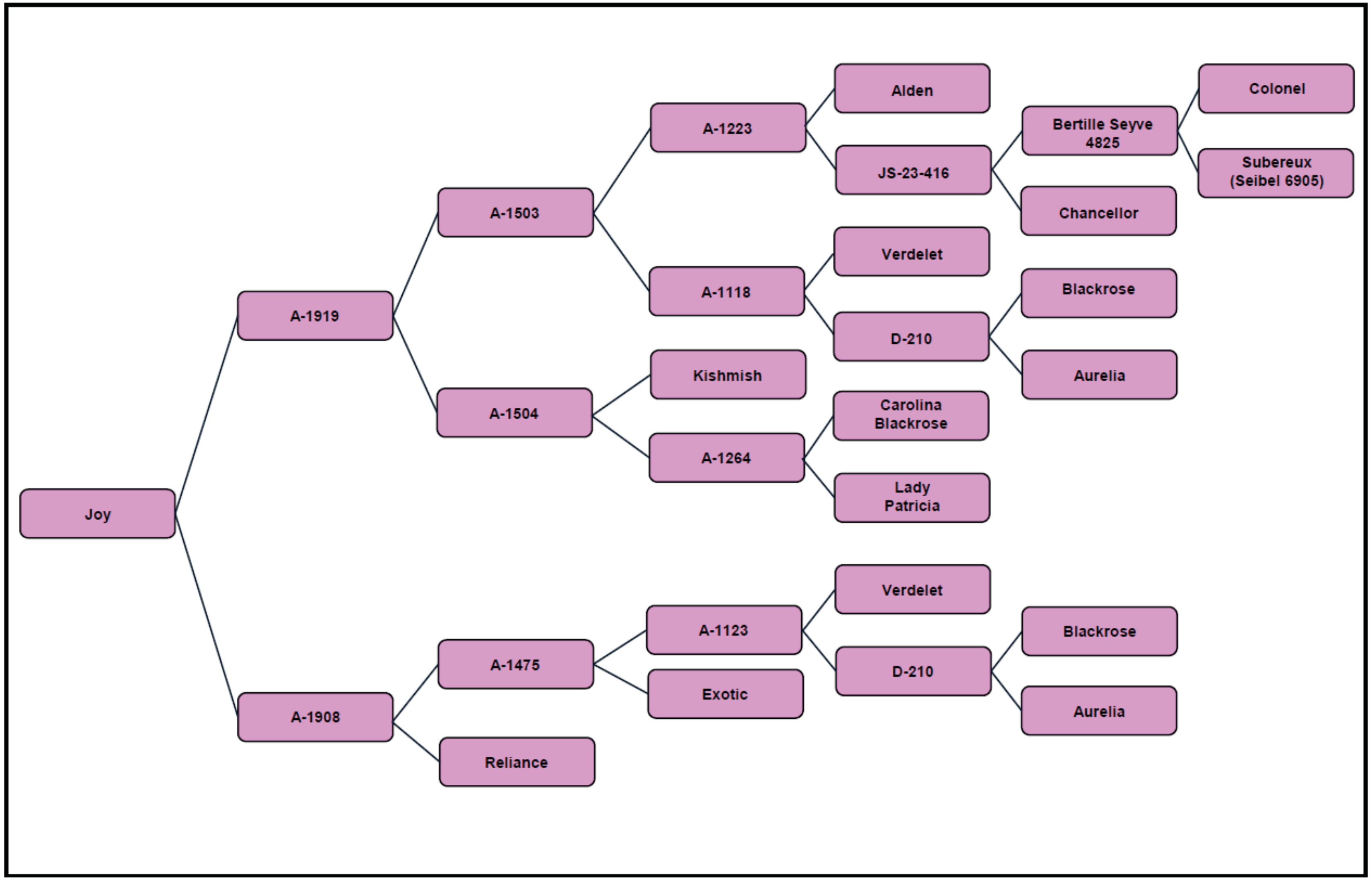
General view of 'Hope' plants in production.



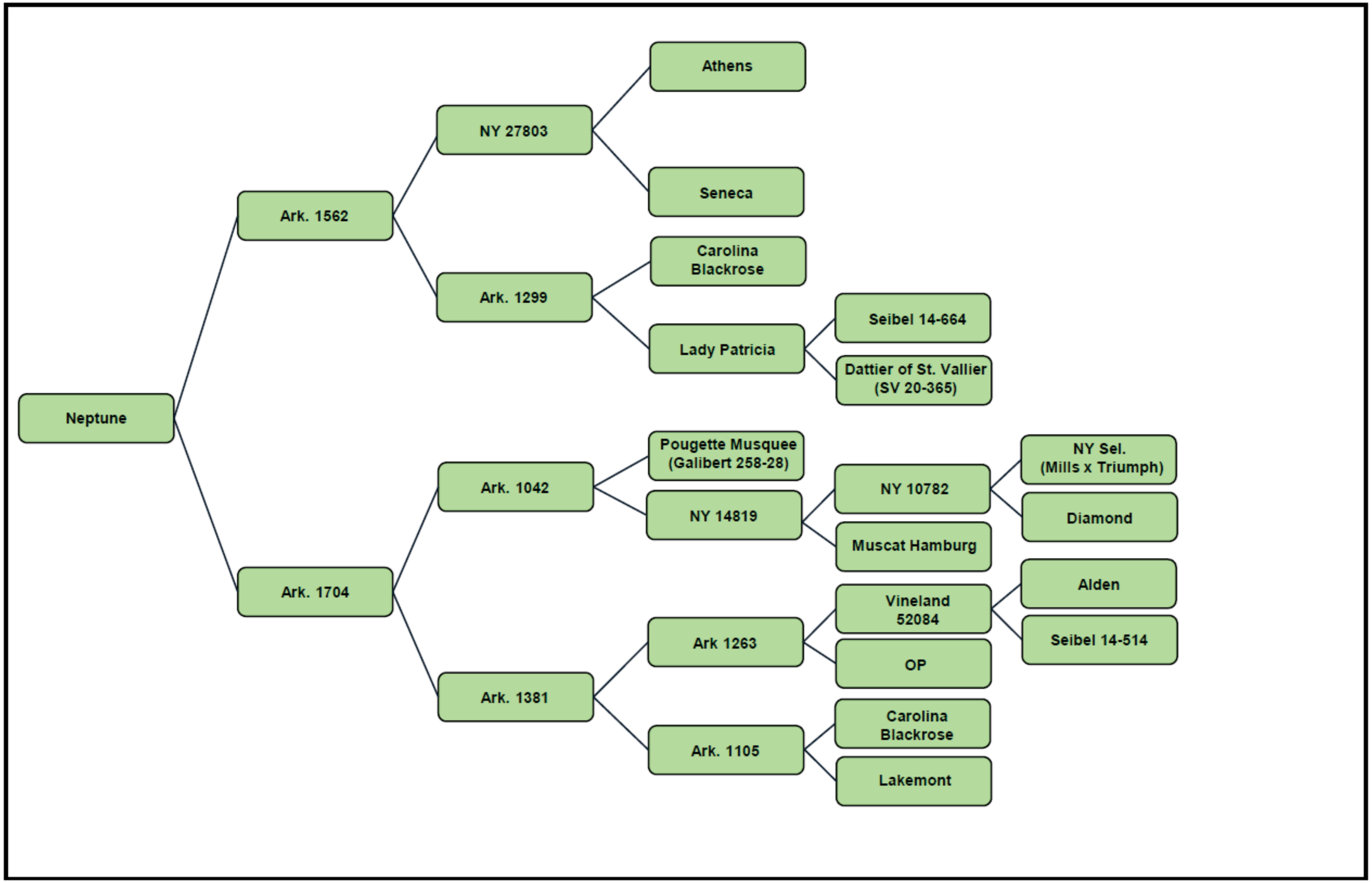
Pedigree of ‘Faith’ seedless table grape.



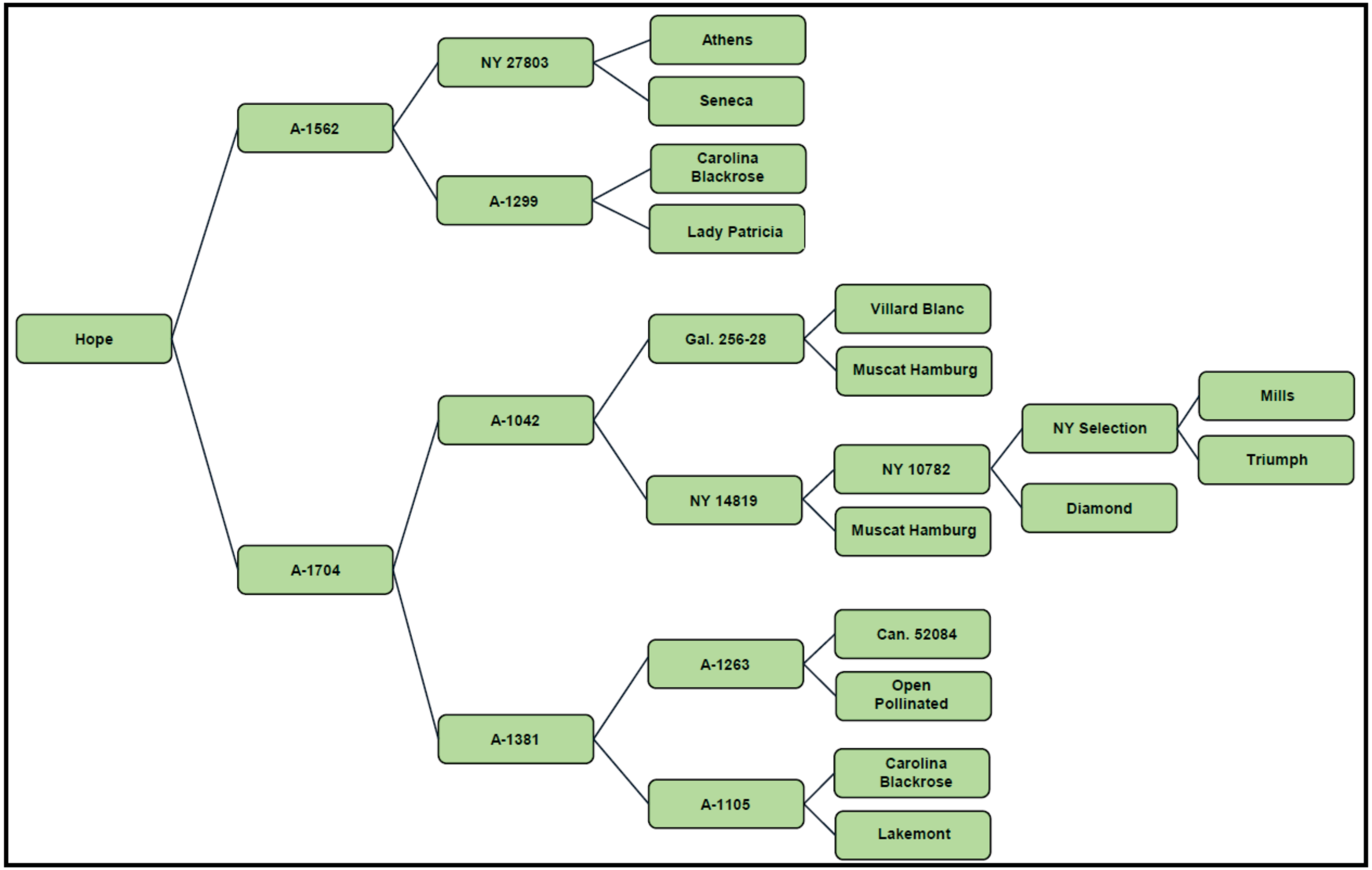
Pedigree of ‘Jupiter’ seedless table grape.



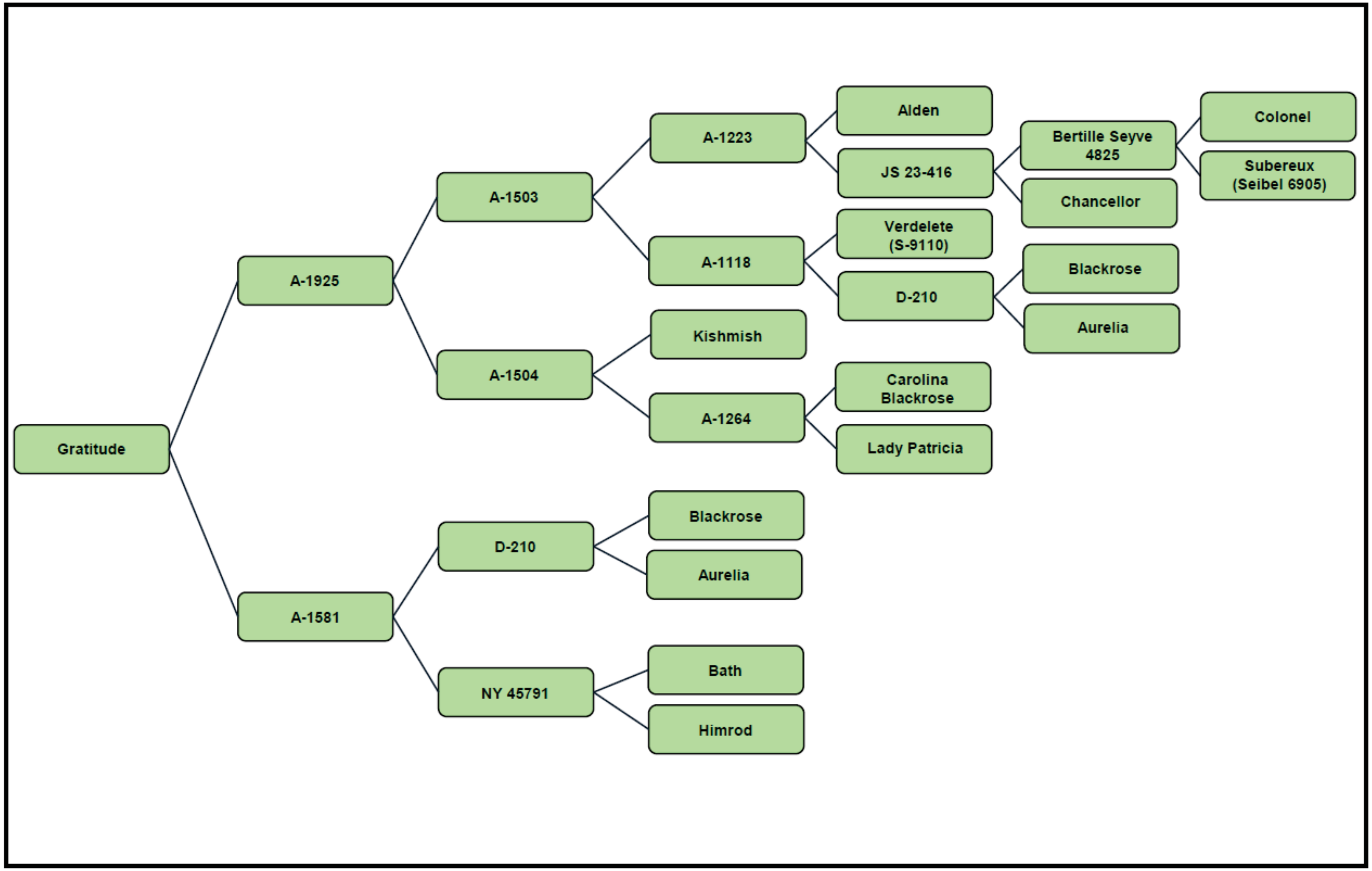
Pedigree of ‘Joy’ seedless table grape.



Pedigree of ‘Neptune’ seedless table grape.



Pedigree of ‘Hope’ seedless table grape.



Pedigree of ‘Gratitude’ seedless table grape.

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Growth stages of the grapevine

Editor's Introduction

As outlined hereunder, an accurate description of the growth stages of the grapevine, coded numerically, is considered to be an important aid to research and to viticultural practice. The following two papers discuss the descriptive schemes developed up to now. One of these schemes is recommended for adoption for the timing of grapevine development in the Australian vineyard; it will be used in articles in this Journal.

Phenological growth stages of the grapevine (*Vitis vinifera* L. ssp. *vinifera*)—Codes and descriptions according to the extended BBCH scale†

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Keywords: *Phenological growth stages, BBCH-Schema, Vitis vinifera grapevine*

Abstract

The detailed crop specific descriptions of the phenological growth stages of grapevine are supplementary to the general BBCH-scale. It will be instrumental in standardising the national and international experimentation in viticulture. The phenological development of the grapevine is divided into growth phases (principal growth stages 0-9) and each growth phase is subdivided into growth steps (secondary growth stages 0-9). A two-digit code is attached to each growth stage. The description and coding of the phenological growth stages covers the period between dormancy and leaf fall.

Introduction

Many scales for describing accurately the developmental stages of various cultivated plants have been developed in order to facilitate the coordination of experimental work. Various principles were used as basis for most of these scales and this, in the final analysis, has hindered considerably the scoring and evaluation of experiments and the comparison of data collected in the field. In order to create uniformity among these scales, a working party was appointed which was given the task to establish uniformity among the existing scales by creating a new system for describing the phenological stages of several monocots and dicots. The result was the so-called BBCH Scale (Hack et al. 1992). The acronym BBCH was derived from the names of the coordinating institutions, the Federal Biological Institute (BBA), the Federal Variety Institute (BSA) and the Industry Association Agrar (IVA), supported by other institutions that have appropriate expertise.

Work on developing a scale for viticulture dates back to 1952 when Baggiolini (1952) described various developmental stages in order to allow better timing of plant protective measures. This scale covered the period from winter rest to fruit set which was divided into ten stages coded by the letters A to I. The increasing importance of handling experimental data electronically demanded a more detailed scale which had to incorporate a numerical description of the various growth stages. This resulted in the new scale for the phenological stages of the development of the grapevine by Eichhorn and Lorenz (1977), here coded the EL scale. It divides the seasonal growth cycle into 24 stages, using for their characterisation two-digit numbers which range from 00 to 47 for the period from the start of vegetation, i.e. budburst, to its end at leaf fall. A summary of the scales for the phenological

† The article 'Phänologische Entwicklungsstadien der Weinrebe (*Vitis vinifera* L. ssp. *vinifera*) – Codierung und Beschreibung nach der erweiterten BBCH-Skala' – (*Die Weinwissenschaft – Viticultural and Enological Sciences* 49, 66-70; 1994) was translated, with permission, by P. May, Department of Horticulture, Viticulture and Oenology, Waite Agricultural Research Institute, The University of Adelaide.

Table 1. Encoding and description of the phenological stages of the grapevine according to the extended BBCH scheme.

BBCH-Code	Description
Principal growth stage 0	**Sprouting**
00	Dormancy: winter buds pointed to rounded, bright or dark brown according to cultivar, bud scales more or less closed according to cultivar
01	Beginning of bud swelling: buds begin to expand inside the bud scales
03	End of bud swelling: buds swollen, but not green
05	"Wool stage": brown wool clearly visible
07	Beginning of bud burst: green shoot tips just visible
09	Bud burst: green shoot tips clearly visible
Principal growth stage 1	**Leaf development**
11	First leaf unfolded and spread away from shoot
12	Two leaves unfolded
13	Three leaves unfolded
14	Four leaves unfolded
15	Five leaves unfolded
16	Six leaves unfolded
19	Nine or more leaves unfolded
Principal growth stage 5	**Inflorescence emergence**
53	Inflorescence clearly visible
55	Inflorescence swelling, flowers closely pressed together
57	Inflorescences fully developed, flowers separating
Principal growth stage 6	**Flowering**
60	First flowerhoods detached from the receptacle
61	Beginning of flowering: 10% of flowerhoods fallen
63	Early flowering: 30% of flowerhoods fallen
65	Full flowering: 50% of flowerhoods fallen
68	80% of flowerhoods fallen
69	End of flowering
Principal growth stage 7	**Development of fruits**
71	Fruit set: fruits begin to swell, remains of flowers lost
73	Berries groat-sized, bunches begin to hang
75	Berries pea-sized, bunches hang
77	Begin of berry touch
79	Berry touch complete
Principal growth stage 8	**Ripening of berries**
81	Beginning of ripening: berries begin to brighten in colour
83	Berries brighting in colour
85	Softening of berries
89	Berries ripe for harvest
Principal growth stage 9	**Senescence**
91	After harvest: end of wood maturation
92	Beginning of leaf discoloration
93	Beginning of leaf fall
95	50% of leaves fallen
97	End of leaf fall
99	Post-harvest treatments

The code has been jointly developed by Biologische Bundesanstalt für Land- und Forstwirtschaft (BBA), Bundessortenamt (BSA) and Industrieverband Agrar (IVA) in cooperation with Staatliche Lehr- und Forschungsanstalt, für Landwirtschaft, Wein- und Gartenbau (SLFA), Section Plant Pathology, Neustadt/W.

development of the grapevine established in Europe was published by EPPO (Anon. 1984). Therein, the homologous stages of the scales of Baggiolini and of Eichhorn and Lorenz were compared. Baillod and Baggiolini (1993) reworked the earlier scale of Baggiolini (1957) by including the period after flowering, coded by the letters J to P. The attempt to unify the classification of the various stages of development resulted in the general scheme of coding phenological stages of development, established by BBCH (Hack et al. 1992). This scheme divides the season into principal (macro-) growth stages used to describe developmental periods (coded 0–9), each of which is divided into secondary (micro-) growth stages (micro-stages 0–9) which describe shorter periods characteristic for the development of each crop. This permits the accurate coding of each stage by numbers of two digits.

The structure of the BBCH Scale for grapevines

The phenological development of the grapevine is divided into macro- and micro-stages in accordance with the general BBCH scheme. By omitting macro-stages 2 (formation of side shoots), 3 (development of the shoot) and 4 (development of vegetative propagating organs), the scheme deviates from the generally adopted pattern, but these stages are unimportant for

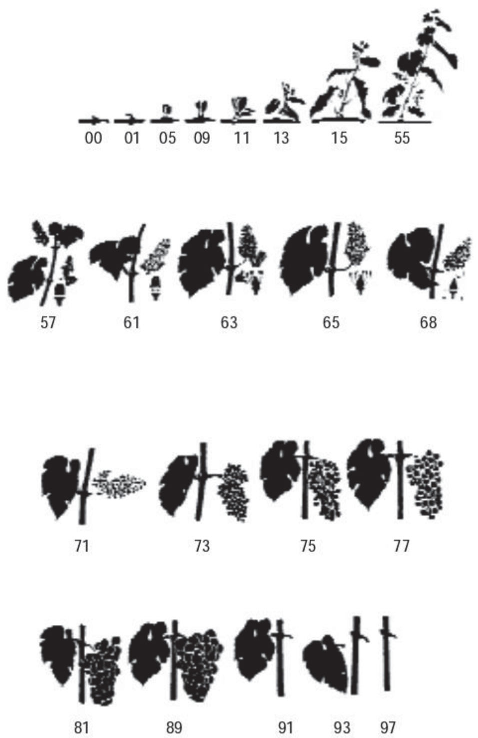

Figure 1. The phenological stages of the grapevine.

defining specific periods for applying e.g. plant protective sprays. In the following, the codes of the phenological development stages defined by Eichhorn and Lorenz (1977) are converted to those of the BBCH scale; the latter are recommended for further usage.

The grapevine is a domesticated plant which may suffer from numerous diseases and pests throughout its whole growth cycle. Plant protection therefore plays an important role in maintaining the productivity of the plant and in ensuring its yield, in particular the quality of the crop. While protection with chemical products remains indispensable, biological and biotechnological methods are used in preference, following the principles of integrated pest control. Here in particular, the success of such methods depends substantially on the correct timing of the measures taken relative to the weather, the parasites to be controlled, the grape variety and its stage of development. All this requires detailed knowledge of the growth cycle of the crop as well as of the life cycle of the parasite and of the mode of action of the products of plant protection to be used. The recommendations formulated by the manufacturers for the use of these products, and for fertilisers, have already taken into account biological and product-specific factors; they are based in the main on the phenological stages of development of the grapevine. This helps the user of these products to apply them at the correct time.

Table 2. Relationship between the Eichhorn and Lorenz scheme and the extended BBCH scheme.

Eichhorn Lorenz	BBCH	Eichhorn Lorenz	BBCH
00	–	25	68
01	00	26	69
02	01	27	71
–	03	29	73
03	05	31	75
05	09	33	77
07	11	–	79
09	12/13	35	81
–	14	–	83
12	15/16/53	–	85
15	55	38	89
17	57	41	91
–	60	–	92
19	61	43	93
21	63	–	95
23	65	47	97
		–	99

Description of the phases of development

(Refer to Tables 1 and 2 and Figure 1)

Principal growth stage 0 Budburst
Principal growth stage 1 Leaf development

The earliest stage of applying plant protection measures is stage 00 (=EL:01), i.e. after winter pruning and before the swelling of the buds. Sprays at this time are intended to hit e.g. the overwintering form of phomopsis (*Phomopsis viticola*), the overwintering young caterpillars of pyrale ('Springwurmwickler', *Sparganothis pilleriana*) and of the geometride ('Rhombenspanner', *Peribatodes rhomboidaria*) and the eggs of the red spider mite *Panonychus ulmi*. This winter treatment results however in incomplete control because the mites *Eriophyes vitis* and *Calepitrimerus vitis*, which overwinter under the bud scales, are not hit and the eggs of the mite *Panonychus ulmi* are still insensitive at this time.

The budburst treatments applied between the start of bud swell (stage 01 = EL:02) and the unfolding of leaves 2 to 3 (stages 12/13 = EL:09) achieve better control of these and other pests; their timing will vary depending on the pest or disease to be controlled. Hereby, two dates need to be considered:

1. The early budburst treatment from the start of bud swell (stage 01 = EL:02) to budburst (stage 07 = EL:05),
2. The so-called spring treatment between budburst (stage 07 = EL:05) and the unfolding of the first two or three leaves (stage 12 or 13 = EL:09)

Preventative sprays against Brenner (*Pseudopezicula tracheiphila*), whose spores can infect the young leaves shortly after budburst, are applied mainly during the 3- or 4-leaf stage (stage 13/14 = EL no code given) and/or the 6-leaf stage (stage 16 = EL:12).

Principal growth stage 5
Appearance of inflorescences
Important control measures against fungal diseases and animal pests of the grapevine are taken during principal stage 5. The so-called first pre-bloom sprays are applied, if necessary, when the first inflorescences are clearly visible (stage 53 = EL:12); this is a second period for controlling Phomopsis and Brenner.

A second pre-bloom spray, applied up to stage 57 (= EL:17) when the inflorescences are fully developed and the single flowers are separated, must protect the leaves, shoots and inflorescences from infection by downy mildew (*Plasmopara viticola*), powdery mildew (*Uncinula necator*), botrytis (*Botrytis cinerea*) and from attack by animal pests such as the Cochylis and Eudemis grubs ('Traubenwickler' genera, 'Heuwurm' = hay-worm, *Eupoecilia ambiguella* and *Lobesia botrana*). Its timing depends on infection pressure and weather.

Principal growth stage 6 Flowering
The five petals of the inconspicuous single flowers of the grapevine are fused and drop whole as 'caps' or calyptrae at anthesis. The stages of pricipal stage 6 are therefore based on the proportion of detached caps. Pesticide applications are not recommended during the period from the beginning of flowering (stage 61 = EL:19) to full bloom (stage 65 = EL:23) but treatments are essential during stage 68 (=EL:25) when most inflorescences have finished flowering, i.e. when at least 80% of the caps have fallen. The young, now-exposed ovaries are very sensitive and susceptible to attack and the inflorescences must be protected against fungal attack, in particular downy and powdery mildew. Furthermore, the establishment of botrytis infections on the flower residues remaining in the inflorescences ought to be prevented.

Principal growth stage 7 Fruit development
Further treatments during principal stage 7 are also necessary to protect the developing berries, the foliage and the shoots against downy and powdery mildew and botrytis. Summer treatments fall into the period between the start of setting (stage 71 = EL:27) and the start of bunch closure (stage 77 = EL:33) as protection against mite genera and the caterpillars of the second-generation of Eudemis and Cochylis ('Sauerwurm' = sour worm). This spray should prevent further attacks by the pests and thus limit the formation of their over-wintering forms.

Principal growth stage 8 Fruit maturation
During stage 81 (= EL:35), when berries commence to colour, plant protection ends with sprays against botrytis, downy and powdery mildew and, if necessary, again against the caterpillars of the second generation of the 'Sauerwurm'.

Summary
The detailed, crop-specific description of the phenological stages of the grapevine complements the 'General BBCH-scale' with the aim of contributing to the coordination of national and international experimentation in viticulture. The phenology of the seasonal cycle of the grapevine is divided into developmental phases (macro-stages or principal stages 0-9) and each of these is divided into developmental steps (micro-stages or secondary stages 0-9). Each developmental stage is coded by a two-digit number based on the decimal system. For the grapevine, the description and coding covers the period from the beginning of the growth cycle (the start of budburst) through to leaf fall.

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