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Fertilidade de gemas de videiras 'Malbec' e 'Syrah' submetidas ao manejo de dupla poda no Centro-Oeste do Brasil

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Bud fertility of 'Malbec' and 'Syrah' grapevines subjected to double-pruning management in Central-West Brazil

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ABSTRACT: Knowledge of bud condition and vegetative vigor in grapevines is essential for making sound pruning decisions, directly affecting both yield and fruit quality. This study evaluated bud fertility and the influence of shoot characteristics on bud differentiation in 'Malbec' and 'Syrah' grapevines subjected to double-pruning management in the Central-West region of Brazil, where viticulture has been expanding. Based on visual assessment, buds collected from 'Malbec' and 'Syrah' grapevines from vineyards in Goiás State (GO) and the Distrito Federal (DF) were classified as fruitful, vegetative, dead, or absent. Vigor was estimated using shoot and bud diameter and internode length. The proportions of fruitful buds (53.4% in 'Malbec' and 48.4% in 'Syrah'), vegetative buds (21.4% and 26.4%, respectively), and absent buds (11.1% and 19.2%, respectively) were similar between cultivars. Fruitful buds were concentrated in the basal portion of the shoots, up to position 8, with mean values ranging from 47.5% to 70.6%, whereas their frequency declined markedly at positions 14 and 15, with means ranging from 0.8% to 5.3%. The number of fruitful buds was inversely related to variables associated with shoot vigor, indicating that excessive vigor impairs fruitful bud development.

Key words: *Vitis vinifera*, vegetative vigor, floral differentiation, viticulture.

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RESUMO: O conhecimento sobre a condição das gemas e vigor vegetativo da videira é importante para a tomada de decisões corretas durante o processo de poda, impactando a quantidade e a qualidade da colheita. Neste sentido, o presente estudo tem como objetivo avaliar a fertilidade de gemas e a influência das características do ramo na diferenciação das gemas em 'Malbec' e 'Syrah' submetidas ao manejo de dupla poda no Centro-Oeste do Brasil, região onde a viticultura tem se expandido. Para realizar o objetivo do estudo as avaliações ocorreram por avaliação visual e as gemas da 'Malbec' e 'Syrah' de videiras, de Goiás e do Distrito Federal, foram classificadas em frutíferas, vegetativas, mortas e ausentes. Além disso, o vigor foi inferido pelas variáveis diâmetros de ramos e gemas e comprimento de entrenós dos ramos. Os resultados observados mostram a porcentagem de gemas frutíferas (53,4% em 'Malbec' e 48,4% em 'Syrah'), vegetativas (21,4% em 'Malbec' e 26,4% em 'Syrah') e ausentes (11,1% em 'Malbec' e 19,2% em 'Syrah'). Ademais, foi possível constatar tendência de maior concentração de gemas frutíferas nas primeiras posições do ramo (até a gema 8, com médias de 47,5% a 70,6%), sendo que nas últimas posições (gemas 14 e 15) a porcentagem de gemas frutíferas foi reduzida (médias de 0,8% a 5,3%). Portanto, houve relação inversa entre a quantidade de gemas frutíferas e as variáveis indicativas de vigor dos ramos, mostrando que o excesso de vigor prejudica o desenvolvimento de gemas frutíferas.

Palavras-chave: *Vitis vinifera*, vigor vegetativo, diferenciação floral, viticultura.

1 The double-pruning management
2 strategy—consisting of two annual prunings that
3 shift grape harvest in Brazil from the rainy summer to
4 the dry winter of the Central-West region—improves
5 grape ripening and phytosanitary quality, resulting
6 in higher-quality fine wines produced from winter-
7 harvested grapes (TOLEDO et al., 2021). Production
8 pruning is a critical stage in vineyard management
9 because pruning decisions directly influence grape
10 yield and quality. However, many grape growers
11 face uncertainty regarding bud fertility. Insufficient
12 knowledge of bud status can lead to inappropriate

pruning decisions (WÜRZ et al., 2019). Determining
the distribution of fertile buds along the shoot is;
therefore, crucial for selecting an appropriate pruning
length and maximizing yield potential (SILVA, 2020).

The formation of fertile grapevine
buds is a complex process that occurs during
vegetative growth, particularly during the flowering
phenological stage (MUNHOZ et al., 2016). At this
stage, flowering of the current season's inflorescences
occurs simultaneously with floral induction for the
following cycle within the latent buds located at the
leaf axils (BRIGHENTI et al., 2017). This period is

also characterized by a natural water deficit and the accumulation of reserve compounds in the shoots. Together, these factors promote floral differentiation (MONTEIRO et al., 2021), whereby vegetative buds develop into fruitful buds (ANTALICK et al., 2021).

The formation of fruitful buds is influenced by multiple interacting factors, including juvenility, vine vigor, nutrition, carbohydrate content, growth regulators, water stress, photoperiod, light intensity, and temperature (LI-MALLET et al., 2016; MENEGUZZI et al., 2020). When these factors are not adequately balanced throughout the developmental cycle, bud mortality may occur, leading to yield losses (ALMEIDA JUNIOR et al., 2019).

The successful development of fruitful buds can also be compromised by bud necrosis, which typically affects the central primary axis of the dormant bud while leaving the secondary axes intact (AMES et al., 2016). However, these secondary buds generally produce shoots with low fertility, often resulting in reduced yields in vines exhibiting excessive vigor (GUTIÉRREZ-GAMBOA et al., 2018).

Studies investigating bud fertility under double pruning management remain scarce. Accordingly, this study evaluated bud fertility and the influence of shoot characteristics on bud differentiation in the wine grape cultivars ‘Malbec’ and ‘Syrah’ grown under double-pruning management in Central-West Brazil.

The study was conducted in 2023 using samples collected from six vineyards planted with ‘Malbec’ and ‘Syrah’ located in Goiás state (GO) and the Distrito Federal (DF), Brazil (Table 1). Across these sites, average annual temperatures ranged from 22 °C to 24 °C, relative air humidity varied between 22% and 87% and annual rainfall was approximately 1,600 mm (ALVARES et al., 2013).

The vineyards were trained using a vertical shoot positioning system (VSP), with 2.5 m spacing between rows and 1 m between plants. Vines were grafted onto IAC 313, IAC 572, or Paulsen 1103 rootstocks, and canopy height ranged from 1.0 to

1.3 m. The vineyards were managed under a double pruning system: the first pruning, which induced the vegetative cycle, was performed in winter (September), and the second pruning, which induced the reproductive cycle and was investigated in this study, was conducted in March.

Fifteen shoots per cultivar were randomly collected from each vineyard using a zigzag sampling pattern. Shoot and bud diameter, together with internode length, were measured with a digital caliper to characterize vegetative vigor. Each shoot was then cut into segments containing a single bud. Bud positions along the shoot were numbered sequentially from G1 (basal) to G15 (distal).

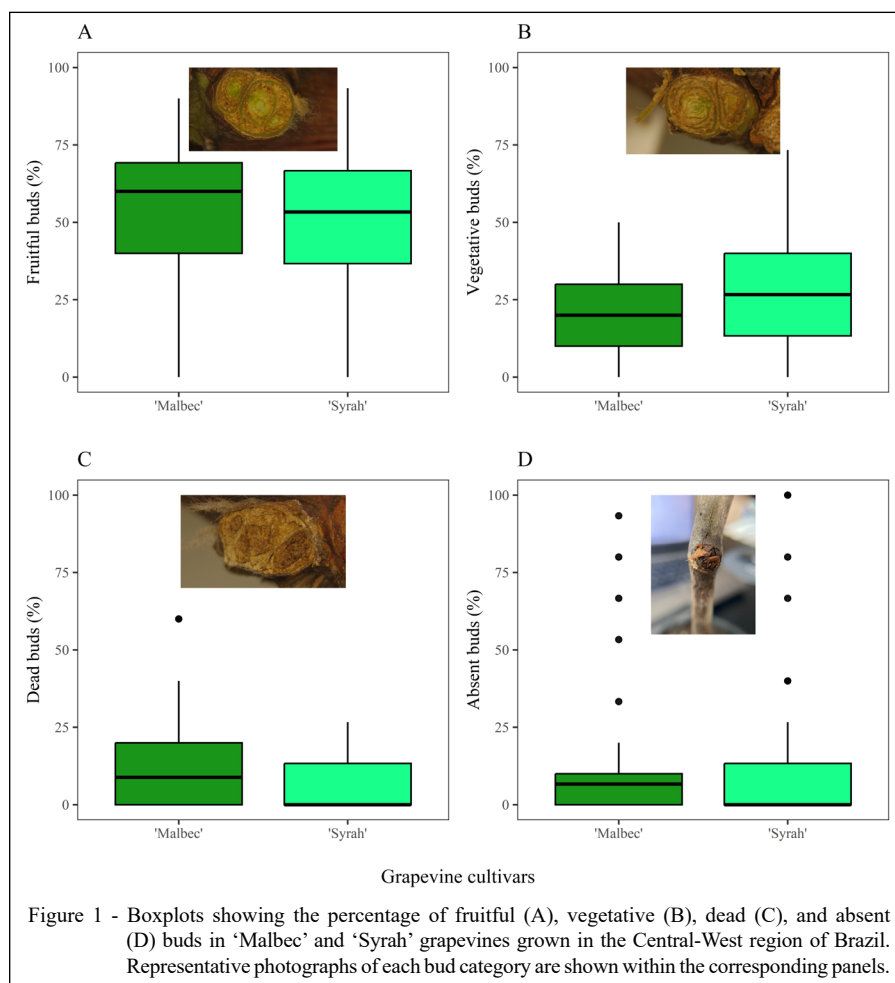
Bud cross-sections were prepared using a stereomicroscope (30× magnification) and a stainless-steel blade to visualize inflorescence primordia (clusters). Buds were classified as vegetative, fruitful, dead, or absent. Fruitful buds were defined as those capable of producing shoots bearing both inflorescences and leaves, while vegetative buds produced only leaves and tendrils. Dead buds exhibited necrosis, whereas absent buds were defined as nodes lacking a bud.

Statistical analyses were performed using R Studio software (R CORE TEAM, 2026). Bud fertility data were expressed as the percentage of buds in each category (vegetative, fruitful, dead, and absent). Differences among shoot positions were evaluated using the Kruskal-Wallis and median tests implemented in the agricolae package (MENDIBURU, 2023). Principal component analysis (PCA) based on correlation matrices was then used to assess the relationship between shoot vigor and the number of fruitful buds.

The proportions of fruitful buds were similar in ‘Malbec’ (53.4%) and ‘Syrah’ (48.4%), as were those of vegetative buds (21.4% and 26.4%, respectively), and absent buds (11.1% and 19.2%, respectively) (Figure 1A, 1B, and 1D). However, ‘Malbec’ had a higher proportion of dead buds (14.1%) than ‘Syrah’ (6.0%) (Figure 1C). The

Table 1 - Vineyards from which ‘Malbec’ and ‘Syrah’ grapevine samples were collected for bud fertility and shoot vigor assessment.

Vineyard	Municipality	Geographic coordinates	Altitude (m)
Casa Curado	Anápolis - GO	16°19'07"S / 48°48'13"W	943
Casa Moura	Nazário - GO	16°37'58"S / 49°46'48"W	947
Quartetto Vinhos e Vinhedo	Águas Lindas de Goiás - GO	15°49'22"S / 48°19'03"W	1.116
Vinhedo Girassol	Distrito de Girassol - GO	15°43'29"S / 48°23'15"W	1.072
Vinhedo Irmãs Alvim	Núcleo Rural Café Sem Troco - DF	15°51'28"S / 47°37'32"W	1.054
Vinhedos do Cerrado	Ipameri - GO	17°43'57"S / 48°11'35"W	800



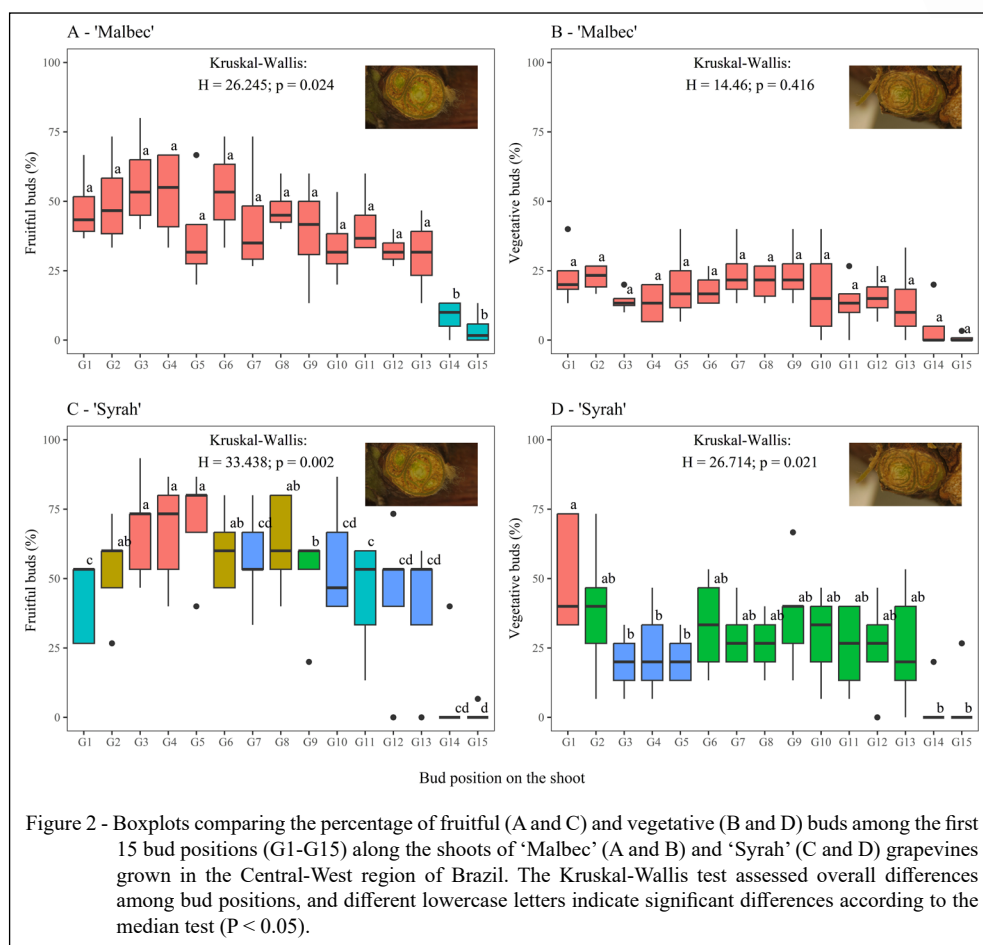
differentiation of vegetative buds into fruitful buds is closely associated with management practices, including vine nutrition, light exposure, vigor control, and pruning strategies (BOTELHO et al., 2006). Appropriate management of these factors is therefore essential for maximizing vineyard productivity and maintaining vine health.

The relatively high proportion of dead buds observed in 'Malbec' (Figure 1C) suggests less favorable plant health conditions. Primary bud mortality, which results in bud necrosis, is a significant issue affecting several grape cultivars worldwide, due to its negative impact on yield (VASCONCELOS et al., 2009). Although several studies have investigated the causes of bud necrosis, no specific pathogenic agent has been identified, suggesting that physiological or developmental factors may be involved (SOUZA et al., 2015). Several environmental and physiological factors have been associated with this disorder, but the mechanisms underlying its development remain

unclear (DIAS et al., 2017). Bud necrosis begins after floral differentiation, during flowering, and has been associated with nutritional imbalances, diseases or pests, the accumulation of soluble sugars, and water deficit (KAVOOSI et al., 2013; MONTEIRO et al., 2021).

Both cultivars exhibited relatively high proportion of absent buds (Figure 1D), which are likely to reduce yield and therefore warrant growers' attention.

The distribution of fruitful buds differed between the two cultivars (Figure 2). In 'Malbec', fruitful buds were distributed from position G1 through G13, with mean values ranging from 30.8% to 56.7% (Figure 2A). The highest percentages occurred at G1 (47.5%), G2 (50%), G3 (56.7%), G4 (52.5%), and G6 (53.3%), indicating good fruitful bud development in the basal and intermediate portions of the shoot. These findings suggest that 'Malbec' may achieve satisfactory yields with shorter pruning. In 'Syrah', fruitful buds were concentrated between positions G3 and G8, with mean values ranging from 57.3% to 70.6% (Figure 2C), suggesting



1 that this region of the shoot is more conducive to
2 fruitful bud development.

3 The distribution of vegetative buds was
4 relatively similar in the two cultivars. Vegetative
5 buds were most abundant between positions G1
6 and G13, with mean values ranging from 13.3% to
7 50.7%, whereas positions G14 and G15 had lower
8 percentages, ranging from 0.8% to 5.3% (Figure 2B
9 and 2D). In 'Syrah', the percentages of vegetative buds
10 were highest at positions G1 (50.7%) and G2 (38.7%).
11 The remaining positions showed lower percentages
12 because they had a higher proportion of fruitful buds.

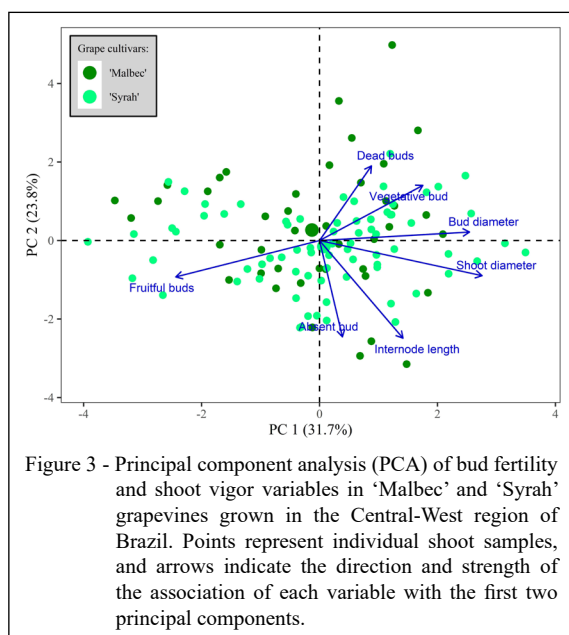
13 Mean internode length was 77.44 mm for
14 'Malbec' and 85.23 mm for 'Syrah'. Mean shoot
15 diameter was 7.06 mm for 'Malbec' and 6.89 mm for
16 'Syrah', while mean bud diameter was 4.45 mm and
17 4.41 mm, respectively.

18 Shoots that develop early in the vegetative
19 cycle under normal growth conditions typically
20 exhibit adequate internode length, indicating favorable
21 conditions for the development and maturation of

fruitful buds. By contrast, excessively long internodes
indicate excessive vigor, which can impair fruitful
bud development (MANDELLI & MIELE, 2015).
Conversely, very short internodes may result from
nutrient deficiency, water stress, or pest and disease
pressure (MANDELLI & MIELE, 2015).

Plants with larger shoot diameters tended
to allocate metabolic resources to wood production,
likely because of the limited number of fertile
buds available for fruiting. Well-developed buds
are generally conspicuous and globose; however,
under conditions of excessive vigor, buds tend to
be less developed and more conical than globose
(MONTEIRO et al., 2021).

The first two principal components
accounted for 55.5% of the total variation, with PC1
and PC2 explaining 31.7% and 23.8%, respectively
(Figure 3). The number of fertile buds was inversely
associated with the number of vegetative and dead
buds, internode length, and both bud and shoot
diameters. Conversely, the number of vegetative



buds was positively associated with bud and shoot diameters. Overall, more vigorous shoots had more vegetative buds, whereas less vigorous shoots—particularly those with smaller diameters—exhibited a greater proportion of fruitful buds (Figure 3).

The inverse association between vigor-related variables and the proportion of fruitful buds reflects the negative effect of excessive vegetative vigor on the differentiation of vegetative buds into fruitful buds (MANDELLI & MIELE, 2015). This pattern is well documented in viticulture and is largely explained by assimilate allocation. Under conditions of excessive vegetative vigor, grapevines allocate a substantial proportion of assimilates to leaf expansion, shoot elongation, and other vegetative structures at the expense of reproductive development (KELLER, 2015; MONTEIRO et al., 2021). As a result, fruitfulness declines, reducing both yield and quality. Conversely, when a vine carries an excessively high crop load, it diverts significant resources to fruit development and maturation, which can limit vegetative growth and lead to reduced vegetative vigor, resulting in slower leaf and shoot development (KELLER, 2015).

Inadequate management of vegetative vigor, including the absence or improper execution of pruning, can lead to excessive vigor and, consequently, reduced grape yield. Similarly, inadequate crop management, such as the lack of cluster thinning or inappropriate pruning, may result in excessive crop loads that exceed the plant's available resources

(MANDELLI & MIELE, 2015). This inverse relationship between vegetative vigor and productive performance highlights the importance of vineyard management practices that balance vegetative growth and fruiting to ensure high grape yield and quality.

Grapevine cultivars grown in traditional wine-growing regions, such as southern Brazil, may perform differently from those grown in tropical environments, such as Central-West Brazil, because of differences in climate, soil, and altitude. In tropical climates, grapevines exhibit continuous growth and do not undergo the winter dormancy typical of subtropical and temperate regions (MUNHOZ et al., 2016). Under the edaphoclimatic conditions of Central-West Brazil, pruning is the primary trigger of the phenological cycle (SILVA et al., 2006), making proper double-pruning management essential for optimizing production. Accordingly, the present findings can help guide pruning practices by identifying the shoot segments with the greatest fruiting potential, thereby improving yield.

To maximize fruitful bud development in 'Malbec' and 'Syrah' under the conditions evaluated, pruning practices should be adjusted to control vegetative vigor. For 'Malbec', shorter pruning, with cuts between positions G1 and G6 is recommended to maximize fruiting potential. By contrast, 'Syrah' benefits from slightly longer pruning, extending to position G8, to take advantage of its greater bud fertility while moderating vegetative vigor. Moderately vigorous rootstocks, such as IAC 572 or Paulsen 1103, may also help balance vegetative growth and fruiting, thereby preventing excessive vigor. In addition, shoot thinning and canopy management help reduce internode length and improve light exposure, promoting more efficient allocation of reserves to bud development. Maintaining a double-pruning system, with vegetative induction in September and reproductive induction in March, together with adjustments in pruning intensity according to cultivar and field-observed vigor, promotes a more synchronized and efficient cycle of fruitful bud differentiation.

DATA AVAILABILITY STATEMENT

The results supporting the conclusions of this study are presented in this manuscript. The raw data underlying these results are available from the corresponding author upon reasonable request.

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DECLARATION OF CONFLICT OF INTERESTS

We have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

ACDS conceived the study, collected the data, and drafted the manuscript. RJF provided samples and contributed to manuscript preparation. MSA contributed to manuscript writing and revision. ECR analyzed the data and contributed to manuscript writing and revision.

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE

The authors declare that they did not use artificial intelligence resources in conducting this study or in preparing and writing the manuscript.

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