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Bud load management on table grape yield and quality – cv. Sugrathirteen (Midnight Beauty®)

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ABSTRACT: Viticulture is an activity of great economic and social importance in the Submedium region of the São Francisco River Valley, with emphasis on table grape and wine production. With the increasing expansion of the viticulture, a growing number of alternatives that do not affect fruit quality have been studied to maximize table grape yield, such as pruning and load adjustment. The aim of the present study was to evaluate the influence of different bud loads on canopy management to enable the marketable and economic production of cv. Sugrathirteen (Midnight Beauty®) in the submedium region of the São Francisco River Valley. This study was carried out for two years (2014/2015) in an experimental area for the introduction of new cultivars patented by Prodomo Farm in the municipality of Petrolina, Pernambuco, Brazil. The experiment was conducted in a randomized block factorial 2 × 5 design, with two seasons and 5 treatments, 6, 8, 10, 12 and 14 buds which correspond to 17, 23, 29, 34 and 40 buds·m^{-2} respectively, distributed in 4 plots, considering five plants per replicate. Our results show that pruning seasons significantly affected sprouting percentage. However, the difference in bud load influenced this variable, with higher values in the pruning at 14 buds in both seasons. According to the results, the selection of pruning system according to bud load and to genetic features of the cultivar, and their interaction with the environment, produced higher yields in pruning with 10 buds, without negatively affecting grape quality.

Key words: *Vitis vinifera L.*, yield, pruning.

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INTRODUCTION

Viticulture development in Brazil is mostly based on the results of studies that attempt to improve cultivation practices, aiming at higher yields and improved quality of the cultivated grape. It requires identifying and characterizing varieties better adapted to edaphoclimatic conditions in these regions and capable of producing quality wine grapes (Brighenti et al. 2013). Nevertheless, introducing a given cultivar in a region where cultivation is still scarcely known requires studies on phenological behavior according to local edaphoclimatic conditions (Tofanelli et al. 2011).

Apirenic cultivars have been preferred in the market (Santos et al. 2014), and this encourages the use of new areas. However, these cultivars have serious difficulties in adapting to tropical conditions in their first years of cultivation; in some cases, they produce berries smaller than the size required by consumer markets (Ferrara et al. 2014).

Viticulture is one of the most important agricultural activities in the hub Petrolina-PE/Juazeiro-BA in economic terms and in terms of workforce. However, all cultivars used have been introduced in the region over the last years, and have therefore required adaptation from the original management plan (Souza et al. 2012).

Sugrathirteen (Midnight Beauty®), a seedless table grape cultivar obtained by David W. Cain, is developed and grown throughout the world under license by Sun World International, LLC (Coachella, California, USA). This cultivar is characterized by an excellent yield, high bud fertility, naturally large, elongated, firm black berries, low acidity, and high soluble solid content. However, if there is high vegetative vigor there might be flower aborting.

Planting was experimentally conducted in mid-2008 in the municipality of Petrolina, Pernambuco, and the first marketable vineyards were only implemented by authorized producers in 2010. This cultivar is currently widely used by authorized farmers in countries such as South Africa, and is now produced under license by farmers in the USA, Chile, Brazil, Australia, Portugal, Italy, Israel, Mexico, and Spain (Technical Cultivation Recommendations, (Midnight Beauty®) Sun World, Brazil 2012).

It is worth of note that canopy management based on pruning type and severity has effect on the yield of the next cycle due to its impact on accumulated reserve content and bud fertility (Pellegrino et al. 2014). For Santos et al. (2013), vineyard management must seek to maintain the balance in the distribution of reserves between the vegetative and reproductive systems in plants, considering that the dynamics of reserves in grapes is influenced by seasonal and phenological variations.

The bud load attributed to a vine is intrinsically related to the plant's general state of vigor and sanity, and to the vegetative and reproductive response of the previous year. In order to achieve a balance between production and vegetative development it is crucial to determine an adequate load for each vine, and a properly balanced plant has enough vegetative growth to provide nutrients in adequate quantities to complete the maturation of the grape, to develop fertile or productive buds for the following year and store nutritional reserves (Jackson 2014).

The distribution of photosynthates is called partition, and plant hormones play a key role in regulating source-sink ratios, as they control sink growth during plant growth, and sugars can be used for respiration and synthesis of other molecules needed for development. Studies conducted by Almanza-Merchán et al. (2014) show that, unlike temperate climates, plants do not slow down their growth in tropical conditions and photosynthesis continues to occur.

Santos et al. (2011) believe a high yield in the first harvest can influence the plant's second harvest as it tends to reduce the balance of accumulated reserves, and it causes plant weakening, alternate production, and shortening of vineyard lifetime. According to Callejas et al. (2013), production can be controlled by pruning as a sufficient amount of buds is selected to provide the number of clusters the plant can bear until harvest.

The aim of the present study was to evaluate the influence of different bud loads on canopy management to enable the marketable and economic production of cv. Sugrathirteen (Midnight Beauty®) in the submedium region of the São Francisco River Valley.

MATERIAL AND METHODS

The field study was developed in the Prodomo Farm, in an experimental field of seedless cultivars of Sun World International, LLC, with an area of 1.0 hectare. Planting was conducted in 2008, in a vineyard of cv. Sugrathirteen (Midnight Beauty®) grafted onto rootstock Paulsen 1103 (*Vitis berlandieri x Vitis rupestris*) in the municipality of Petrolina, Pernambuco, Brazil.

In the first production cycle, formation pruning was performed in mid-November 2013, with bud pruning in "crowns" or base buds, which consists of providing a good vegetative development to the young plant, being a way of determining the shape and height of the trunk, in which it will remain throughout its useful life, and application of Hydrogen cyanamid at 2% (Dormex®) to standardize sprouting. All inflorescences were eliminated in this cycle, forming only productive branches. Shoots were already lignified as from July 2014, and production pruning (carried out with the intention of eliminating the branches that already produced in the previous cycle and forcing the emission of new shoots that will house the production of the new cycle) and harvest were performed in October 2014. In the second year (2015), formation pruning, production, and harvest were performed in the same periods: November, July, and October, respectively (Fig. 1).

The climatic data during the period of conduction of the work are shown in Fig. 2 and collected at a meteorological station installed 1 km from the experiment.

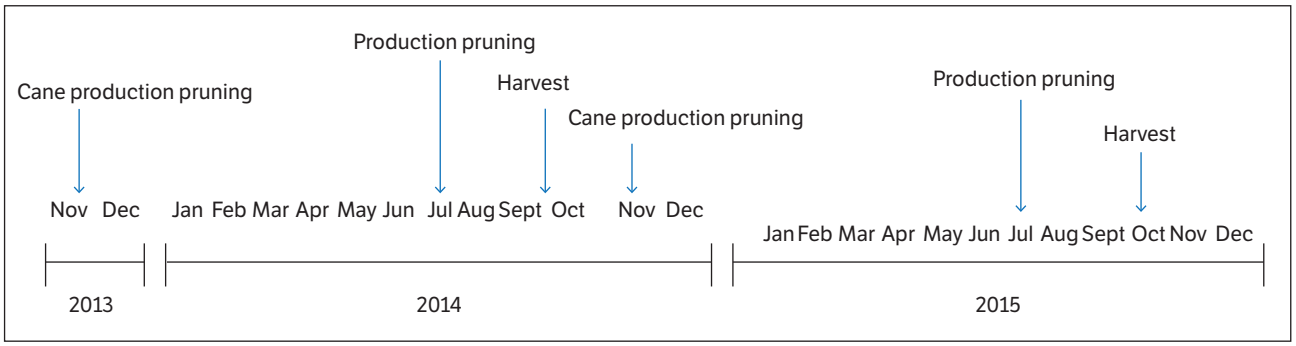

Figure 1. Production cycles of the vine cultivar Sugrathirteen (Midnight Beauty®) in two years farming.

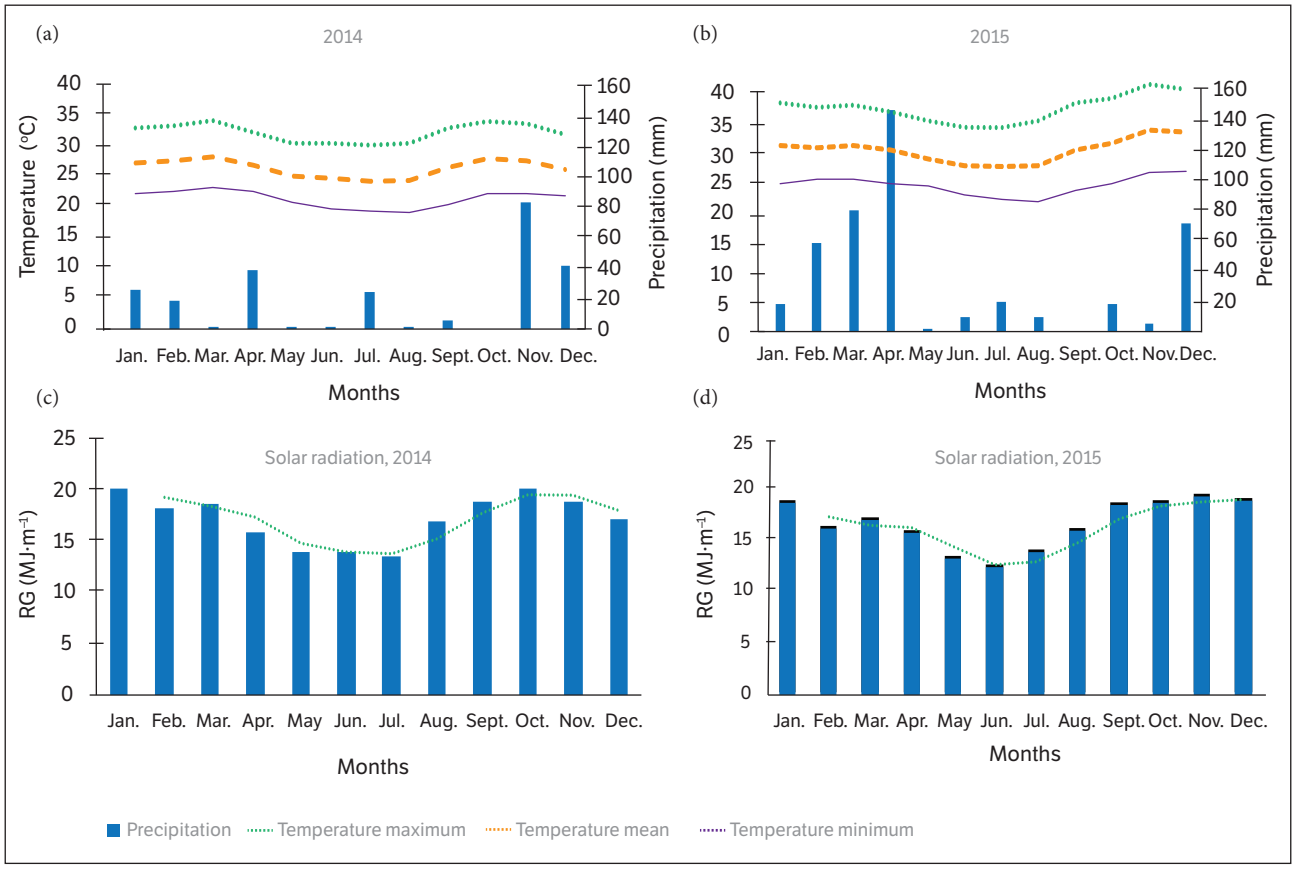

Figure 2. Internal temperature and Relative humidity (a and b); Solar radiation inside (c and d). Juazeiro, Bahia, Brazil.

Plants were trained onto intrellising systems with density of 1428 plants·ha^{-1}, and 3.5 m × 2.0 m spacing. While conducting the experiments, we performed management, phytosanitary control, irrigations, fertilizations, and other operations according to cultivar requirements, and grapes were drip-irrigated in a single row, with polyethylene micro-perforated hoses.

The local soil is classified as yellow red latosol eutrophic and high natural fertility (Table 1).

All plants had bud break induced in the production pruning by applying hydrogen cyanamid at 5% by spraying the commercial product Dormex® (which contains 49% of active principle) on all buds of each shoot 24 hours after pruning. All treatments in the experiment were pruned on one single day in all harvests.

The experiment was conducted in a randomized block factorial 2 × 5 design, with two seasons and 5 treatments distributed in 4 blocks, considering five plants per replicate. Vineyards were pruned with different bud loads in the following treatments: pruning at 6 buds (17 buds·m^{-2}), 8 buds (23 buds·m^{-2}), 10 buds (29 buds·m^{-2}), 12 buds (34 buds·m^{-2}), and 14 buds (40 buds·m^{-2}). The number of branches was standardized in production pruning, by selecting 20 branches·plant^{-1} in all treatments.

Physical evaluations were performed on the grapes collected in the experiments, determining the following variables: cluster mass (g), cluster length and width (cm), berry length and diameter (mm), berry mass (g), number of clusters·plant^{-1}, and yield (t·ha^{-1}). The following phytotechnical aspects were evaluated: branch diameter (mm), internode length (cm), sprouting percentage, and potential fertility (%).

Cluster weight, length, and width were evaluated by sampling 5 clusters per plant collected randomly from three plants, with a total of 60 clusters per treatment. To evaluate berry diameter and length, 10 berries were collected randomly per cluster (3 upper parts, 4 medium parts, and 3 lower parts of the cluster), totaling 40 clusters per treatment.

Mean cluster length and width (cm) were measured with a scaled ruler, and mean berry diameter and length (mm) were measured using a digital caliper. The mean number of clusters·plant^{-1} was counted in all plants by selecting 7 clusters·m^{-2}, which was determined right after fruit ripening and standardized in all treatments.

Yield was obtained by weighing 5 plants in each block totaling 20 plants per treatment. The mean production per plant in each plot was multiplied by the number of plants per hectare, and the result is expressed in t·ha^{-1}.

Sprouting percentage was calculated by the ratio between the number of sprouted buds and the total number of buds, determined prior to sprout thinning. Potential fertility index was determined by using a stereomicroscope magnifier with 45 times augmentation. All buds were desiccated and examined according to each treatment and the presence or absence of inflorescence primordia was checked by calculating the percentage of inflorescence primordia in the primary bud. A total of 5 branches were evaluated in each treatment per plot, totaling 20 branches per treatment.

Branch diameter and internode length were evaluated using a digital caliper.

For statistical analyses, data were submitted to the analysis of variance (F test) and means were compared to each other using Tukey's test with 5% probability and polynomial regression analysis; regression coefficient estimates were tested using the Student t test with 5% probability with the help of Assitat® computer program version 7.7.

RESULTS AND DISCUSSION

This study shows the results obtained for cultivar Sugrathirteen (Midnight Beauty®) grafted onto rootstock Paulsen 1103, pruned with different bud loads in two production seasons. These results characterize the productive behavior of plants, qualitative characteristics, chemical and physical aspects.

Table 2 shows the comparative test of mean values of all parameters, comparing study seasons based on the results previously mentioned.

Table 1. Physical and chemical characteristics of the yellow red latosol eutrophic at a depth of 0 – 0.2 m.

Seasons	pH	CE	Ca2+	Mg2+	Na+	K+	Sb	H+Al	T	Al3+	V	C	MO	P	Cu	Fe	Mn	Zn
			(cmolc·dm^{-3})								(%)			(mg.dm^{3})				
2014	6.8	1.3	5.3	2.9	0.1	0.6	9.0	0.9	10	0	90	0.9	1.6	480	3	98	93	154
2015	6.5	1.1	4.8	1.9	0.1	0.7	7.5	1.4	8.9	0	83	1.0	1.7	463	2.9	70	64	125

Table 2. Summary of the phytotechnical characteristics of branch diameter (mm), internode length (cm), sprouting percentage, potential fertility (%) in cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Seasons	Branch diameter (mm)	Internode length (cm)	Sprouting percentage	Potential fertility (%)
2014	8.23 A	8.23 A	73.08 A	69.55 A
2015	8.01 A	7.90 B	65.53 B	64.94 B

Means followed by the same letter in the column do not differ using Tukey's test with 5% probability.

The production seasons did not have a significant effect only on branch diameter, with mean values of 8.23 mm and 8.01 mm in the treatments in 2014 and 2015, respectively.

On the other hand, the highest internode length, sprouting percentage, and potential fertility were obtained in the first study year, significantly differing between seasons (Table 2).

Nevertheless, branch diameter was influenced by bud load and Fig. 3 shows the quantitative interpretation of the results.

If we take mean branch diameter as a parameter, there is a higher mean value in pruning at 6 buds (8.59 mm), which shows a quadratic behavior, and the minimum value, close to 10.6 buds, refers to 29 buds·m^{-2} (Fig. 3a).

Chalak et al. (2011) observed a reduction in branch diameter with increased number of buds per branch in cv. Tas-A-Ganesh, obtaining a maximum value of 7.99 mm in 4 buds·branch^{-1} and a minimum value of 5.10 mm in 12 buds·branch^{-1}. This behavior was similar to our results, as there was a reduction in mean branch diameter with increased bud load.

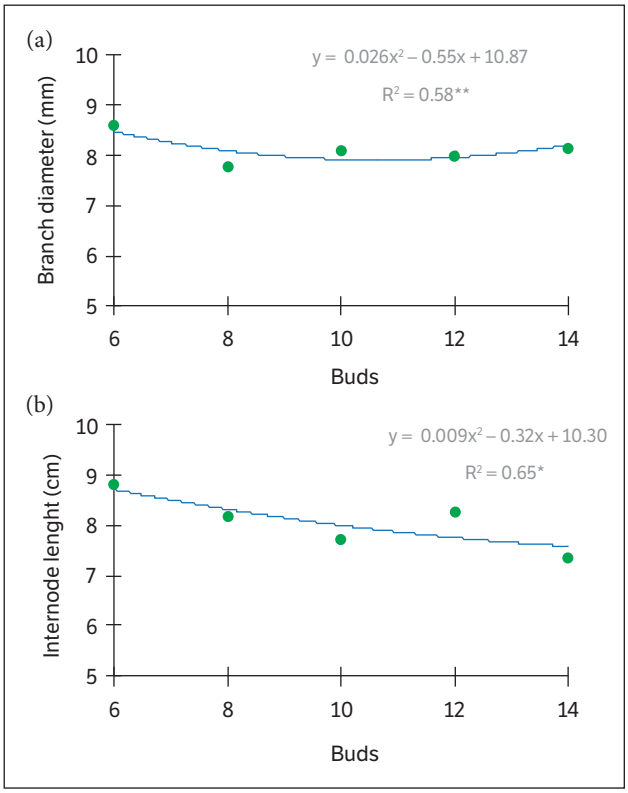

Figure 3. Evaluation of the effect of bud load on (a) mean branch diameter (mm) and (b) mean internode length (cm) in cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

We observed higher vegetation potential in pruning at 6 buds in the field in both years, which resulted in a higher mean branch diameter (8.59 mm), thus characterizing higher apical dominance (Fig. 3a). Omari et al. (2017) observed in the cultivar Sharad Seedless, submitted to different types of pruning, that the largest branch diameter (9.65 cm) was obtained in the treatment with 4 buds.

On the other hand, according to Santos et al. (2013), vineyard management must attempt to keep the balance in the distribution of reserves between vegetative and reproductive systems in the plant. The same physiological process that determines the increase in stem wood mass induces growth and increases branch diameter. Therefore, this is a good indication of the vegetative vigor and metabolic activity of the vineyard, as well as of soil potential in terms of availability of micro- and macronutrients, water, etc.

Bud load had a significant effect on mean internode length, showing a quadratic behavior (Fig. 3b). According to internode length, the highest mean branch length was obtained in 6 buds (8.83 cm), and there was a reduction in internode length with decreased mean values (7.36 cm) when branches were pruned at 14 buds, which equals a load of 40 buds·m^{-2}.

These results were different from those mentioned by Chalak et al. (2011), who studied several wine grape cultivars and observed that maximum internodal length was 3.48 cm in 12 buds·branch^{-1}, whereas the minimum was 3.22 cm in 4 buds·branch^{-1}, and that there were no significant differences in 6 buds·branch^{-1} (3.24 cm).

Due to the higher internodal lengths observed in the treatment with the lowest pruning level (6 buds·branch^{-1}), with a mean value of 8.83 cm, a higher vegetative vigor was evident, as was the uneven distribution between vegetative and reproductive growth.

In general, branches that show smaller internodal length tend to have higher fruiting and to produce better quality grapes (Pires and Pommer 2003). Moreover, excessive vigor is unfavorable to several physiological processes in the vineyard. A vigorous sprout produces more sugars; however, it has higher respiratory activity, as the produced sugars are used in the plant's own vegetative growth, thus hampering the accumulation of these soluble solids in the berries.

Sprouting is a phenomenon controlled by internal and external factors among which are temperature and hormone stimuli; it is thereby frequently necessary to resort to an exogenous treatment with cyanamid CN_2 based products to standardize buds, which typically have delayed, prolonged, and reduced sprouting (Pires and Pommer 2003).

For Scarpare et al. (2012), when pruning is performed in hot periods, there is rapid solubilization of carbohydrate reserves, which are transported via root sap to the bud, thus expediting the sprouting process, in case dormancy has been released.

Bud load plays an important role in bud sprouting in vineyards. Dormancy release marks the beginning of growth and of reproductive behavior of vineyards (Kumar et al. 2017).

This behavior might be observed in Table 3, which shows the interaction between the factors evaluated, with significance between bud loads and quadratic effect.

The highest sprouting percentage was obtained in the first study year, and there was no differentiation between pruning systems, except when bud load was 6 and 14 buds. Moreover, the influence of load was less expressive in 2014. On the other hand, this gain in sprouting percentage in 2015 evidently benefitted from the presence of 14 buds (40 buds·m^{-2}).

Similar data were observed by Chalak et al. (2011), who observed that bud sprouting percentage decreased with decreased pruning severity. These data do not corroborate the findings by Fawzi et al. (2010), who observed that higher bud load provided lower sprouting percentage in cultivar Crimson. Different results were also observed by Kohale et al. (2013) who reported that in cv. Sharad Seedless, pruning at 4 buds per stick had a higher sprouting percentage.

The same effect was observed by Abdel-Mohsen (2013), who observed that sprouting was significantly affected by different pruning levels in cultivar Crimson Seedless. This author observed increased sprouting percentage in pruning at 6 buds (62.91% and 70.89%) compared to 12 buds (56.52% and 62.91%) in both study seasons, 2010 and 2011, respectively.

The analysis of variance showed that there was a significant effect regarding seasons; mean sprouting was 72.83% and 65.53% in the 2014 and 2015 harvests, respectively (Table 2). Overall, mean sprouting percentage in both seasons followed the standards recommended for cultivar Sugrathirteen (Midnight Beauty®).

Floral bud differentiation depends on several internal and external factors. The destination of the undifferentiated primordium depends on the balance between cytokinin/gibberellin. Cytokinin promotes the transition to the formation of inflorescence primordia and gibberellin inhibits their formation, leading to the formation of tendrils (Crane et al. 2012).

Mendonça et al. (2016) observed that pruning type influences bud fertility and some production components. According to Leão and Rodrigues (2009), bud fertility is quite influenced by genotype, i.e., with a differentiated behavior between cultivars, but that might have high variations in one single cultivar, from one cycle to the other, depending on the climatic conditions, or yet, within one single cycle, from one location to the other, according to differences in plant management.

Figure 4 shows a quadratic growth according to bud load, and this load variation showed a trend towards mean increase of potential bud fertility, despite the fact that the number of branches·plant^{-1} did not vary during the formation of productive branches in all treatments in both years. However, there were no significant differences in the interaction between buds and seasons.

We can observe that the potential fertility was lower in pruning with 6 buds, this fact can be explained due to →

Table 3. Interaction between pruning seasons in sprouting percentage (cm) on cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Seasons	6 buds (17 buds·m^{-2})	8 buds (23 buds m^{-2})	10 buds (29 buds·m^{-2})	12 buds (34 buds·m^{-2})	14 buds (40 buds·m^{-2})	Equation
2014	68.75 A	76.51 A	73.33 A	70.31 A	76.50 A	$y = -0.05x^2 + 1.52x + 63.53$ $R^2 = 0.19$
2015	67.01 A	61.19 B	64.58 B	63.88 B	70.98 A	$y = 0.38x^2 - 7.23x + 95.94$ $R^2 = 0.83$

Means followed by the same letter in the column do not differ using Tukey's test with 5% probability.

the larger diameter of branches and length of internodes observed in this treatment, it is also verified that the number of yolk that maximizes the potential fertility is estimated, from the regression curve, in approximately 11.41 buds, corresponding to the treatment with 12 buds corresponding to 34 buds·m^{-2} (Fig. 4).

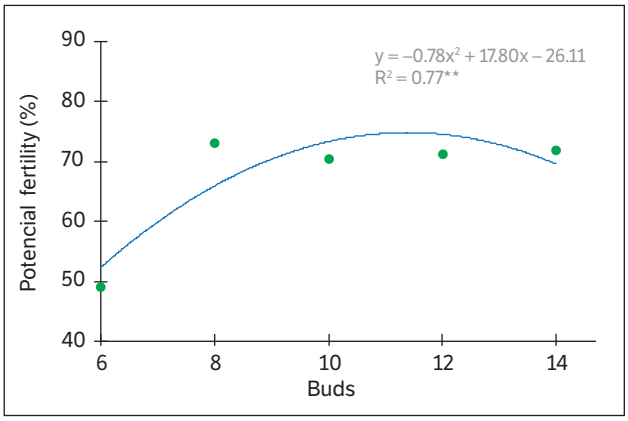

Figure 4. Evaluation of the effect of bud load on mean potential fertility (%) in cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Similar results were observed by Abdel-Mohsen (2013) in cultivar Crimson Seedless; bud fertility improved with a higher pruning level, while a lower pruning level had a low percentage of bud fertility.

Regarding pruning seasons, there were significant differences during both production seasons, with mean values of 73.08% and 65.53% in 2014 and 2015, respectively (Table 2).

In addition, canopy management according to pruning type and severity affects the yield of the next cycle due to its impact on the content of accumulated reserves and on bud fertility (Pellegrino et al. 2014).

Although potential bud fertility in 2014 was higher than in 2015, climatic conditions probably did not interfere with the floral differentiation process. Our data show that the mean temperatures obtained in the experimental area in the floral differentiation period from November through December of 2014 and 2015 were 27.7°C, 26.39 °C, 30.26 °C, and 29.26 °C, respectively.

Temperature affects plant metabolism directly, with influence on its growth and development, and consequently, playing an important role in floral organ differentiation and development. High temperatures, around 30 °C, favor the differentiation of inflorescence primordia, and the three weeks prior to the formation of inflorescence axle ("anlagen") in latent bud apexes (Leão and Rodrigues 2009) is the most critical period, as it is the most susceptible to responding to high temperatures.

There was significant interaction between bud load and pruning seasons in cluster length and width, and in yield. It is worth of note that all characteristics evaluated relative to pruning seasons and bud loads obtained significant differences, except for number of clusters and berry length.

According to the analysis of variance, there was a significant effect of pruning seasons on all biometric characteristics mentioned in (Table 4), except for number of clusters·plant^{-1}.

On the other hand, regarding results that showed significance for interaction between the factors evaluated, Fig. 5 shows the joint influence of parameters.

Considering the parameters above, with no interaction between factors, we see that cluster mass was higher in the first year and it was influenced by bud load.

Figure 5a shows a maximum mean value in pruning at 10 buds (29 buds·m^{-2}), with a value of 516.40 g. In addition, a significant effect was also observed regarding pruning seasons, 439.26 g and 378.29 g in 2014 and 2015, respectively (Table 4).

Sozim et al. (2007), studying the effect of dormancy release in cv. Vênus, observed that mean cluster mass showed a linear increase according to pruning season.

Fawzi et al. (2015), observed a significant effect of cluster mass on increased bud load in cultivar Sugraone (Superior Seedless®). However, the highest cluster masses were observed during both cycles, with 12 and 13 buds·stick^{-1}. On the other hand, bud load with 9 buds·stick^{-1} showed lower values.

An increasing trend in cluster mass was observed with the increase in bud load, even in the 10-bud pruning. On the other hand, the lowest mean value was observed in 6 buds (312.94 g) in both years (Fig. 5a).

Table 4. Evaluation of biometric characteristics of cluster mass (g), berry diameter (mm), berry mass (g), number of clusters·plant^{-1} and yield (t·ha^{-1}) in cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Seasons	Cluster mass (g)	Berry diameter (mm)	Berry mass (g)	Number of clusters·plant^{-1}	Yield (t·ha^{-1})
2014	439.26 A	16.85 B	5.29 A	48.60 A	30.10 A
2015	378.29 B	17.83 A	5.01 B	49.41 A	25.71 B

Averages followed by the same letter in the column do not differ using Tukey's test with 5% probability.

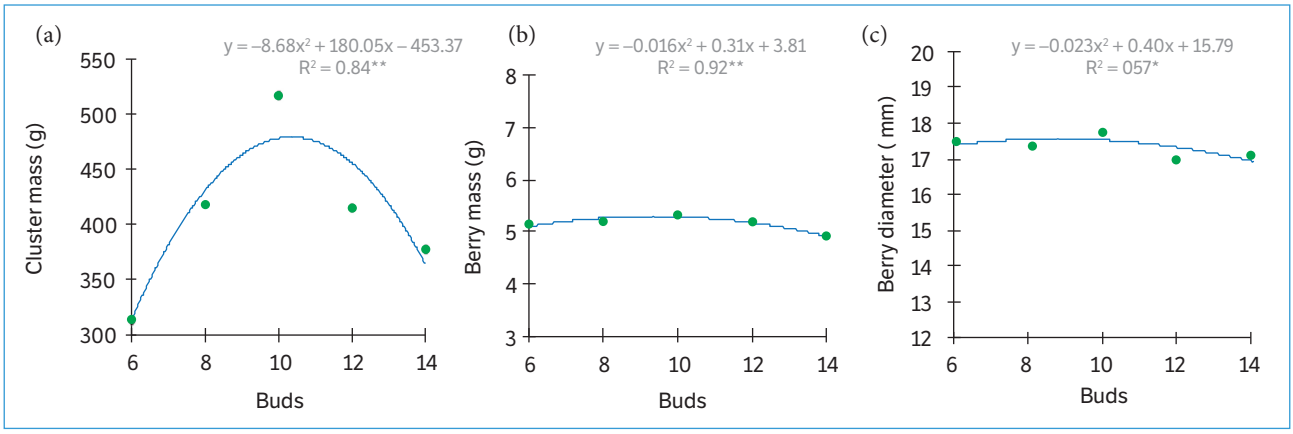

Figure 5. Influence of bud load on (a) cluster mass (g); (b) berry diameter (g); and (c) berry mass (g) in cv. Sugrathirteen (Midnight Beauty®) with different bud loads, during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Several researchers observed that increased bud load caused a reduction in mean cluster weight (Fawzi et al. 2015). However, other studies observed that cluster weight increased with the increase in number of buds per plant (Sabbatini et al. 2015).

According to Popescu (2012), who studied the effect of bud load in cultivar Victoria, there was a decrease in cluster mass with increased bud load in plants.

On the other hand, there was no significant effect in the interaction between factors on berry mass. However, the highest mean values were observed in 10 buds (5.33 g) and the lowest means were observed in pruning at 6 and 14 buds (5.13 g and 4.91 g, respectively) (Fig. 4b). Similar results were found by Abdel-Mohsen (2013), who observed that berry mass was significantly affected by different bud loads in cultivar Crimson Seedless, resulting in a higher berry mass in the 10-bud pruning.

According to Fawzi et al. (2015), berry mass significantly decreased with increased bud load in cultivar Superior Seedless®. The same authors observed, in 2010, higher berry weights (4.10 and 4.30 g) in cultivar Crimson Seedless with bud load of 13 buds·stick^{-1}, which is equivalent to 19.5 buds·m^{-1} in both years, respectively.

Cultivars of apirenic grapes (*Vitis vinifera* L.) usually have small-sized berries, and need adjustments in management to improve cluster quality. According to Souza et al. (2016), the increase in berries is characterized by a "double sigmoid" curve, which results from two consecutive growth stages, divided by a slow or nonexistent growth phase; the first phase starts right after flowering and lasts approximately four weeks. Growth drops sharply in the second phase, which lasts between two to three weeks. The third phase lasts between six to eight weeks, until harvest.

As shown in Table 4, there were significant differences in pruning seasons, with higher values in 2015 (17.83 mm) than in 2014 (16.85 mm). There was a significant effect of bud load on mean berry diameter, with a quadratic behavior, as shown in Fig. 5c.

In Fig. 5c we can observe a significant effect on the diameter of the berries in relation to the load of yolks, presenting a quadratic behavior, it is also verified that the number of yolk that maximizes a greater diameter of berries is estimated, from the regression curve, in approximately 8.7 buds, in this way, we can indicate that pruning with 9 buds is the most effective and lowest pruning value with 14 buds. Similar results were found by Abdel-Mohsen (2013), who observed that there was a higher berry size in pruning at 10 buds.

Diameter, which is the most important variable in seedless grapes, since the minimum diameter of 18 mm is typically required for exportation (Technical cultivation recommendations, Sugrathirteen (Midnight Beauty®), Sun World, Brazil, 2012), had mean value below 18 mm in all treatments in both harvests (Table 4). However, as described in some packaging manuals such as TESCO, Dauge Brazil and Primafruit™, the minimum diameter required for seedless grape exportation is determined by market and by the marketed cultivar, and this value might lie between 14 and 17 mm.

The number of clusters is one of the main components of yield and might be determined by pruning severity and bud fertility. There were no significant differences in the number of clusters·plant^{-1} between pruning seasons in the →

analysis of variance in both study periods. This is due to the standardization previously performed right after fruit ripening. In all treatments, the mean numbers of clusters were 48.6 and 49.4 clusters·plant^{-1} in 2014 and 2015 harvests, respectively (Table 4). This was an attempt to standardize the use of drain in all treatments.

The number of clusters per plant, as well as cluster size or mass, is directly related to vineyard yield, a variable of great importance for hybrid and rustic cultivars, as high yields are essential for production to be feasible (Hernandes et al. 2010). Neis et al. (2010) indicate that the number of clusters per plant had significant influence in production.

Despite the fact that the interactive effect between bud load and seasons was evident in number of clusters, as shown in Table 5, number of clusters did not influence final quality and yield, nor did it influence any variables evaluated.

Figure 6 also shows a significant interaction between factors in cluster length. In cultivar cv. Sugrathirteen (Midnight Beauty®), linear and quadratic regression equations were adjusted to the two cycles, respectively.

There was an increasing trend in clusters in 2014 with the increase in number of buds·branch^{-1}. However, this increasing trend only occurred up to 10 buds in 2015, and there was a decrease from 12 buds onwards (Fig. 6). The lowest cluster length was observed in 6 buds, (22.43 cm and 22.07 cm in 2014 and 2015, respectively). The highest values were observed in pruning at 14 buds in 2014 (26.67 cm) and in 10 buds in 2015 (24.83 cm).

In a similar study, different results were found by Fawzi et al. (2015), in cultivar Superior Seedless®; as the bud load increased in the plant, cluster length decreased, and the lowest cluster lengths (17.33 cm and 18.90 cm) were observed in the pruning with 15 buds·stick^{-1}, whereas the highest values were found with 9 buds·stick^{-1} (31.16 cm and 33.10 cm) in the two studied years.

Almanza-Merchán et al. (2014) observed that pruning is performed to limit the number and length of clusters, thus providing an adequate balance between plant vigor and yield.

Evaluating only bud load individually, and comparing both seasons, statistical differences were only observed in 14 buds, (26.67 cm and 22.82 cm in 2014 and 2015, respectively); there was no significant difference in the other bud loads (Fig. 6).

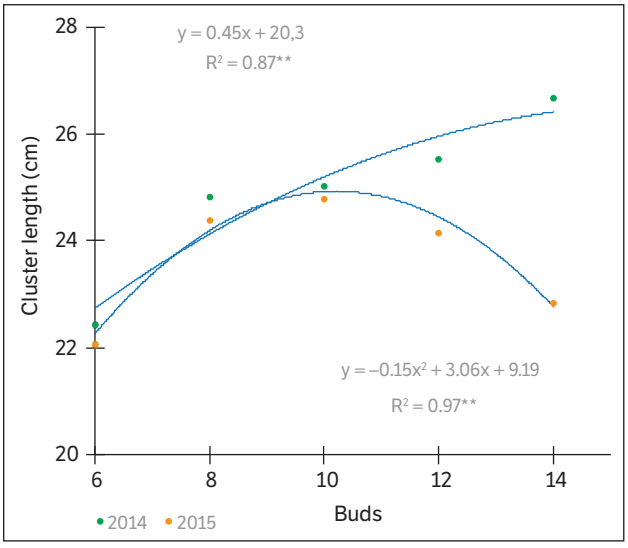

Figure 6. Interaction between pruning seasons in cluster length (cm) on cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Table 5. Interaction between pruning seasons in number of clusters·plant^{-1} in cv. Sugrathirteen (Midnight Beauty®) submitted to different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Seasons	6 buds (17 buds·m^{-2})	8 buds (23 buds·m^{-2})	10 buds (29 buds·m^{-2})	12 buds (34 buds·m^{-2})	14 buds (40 buds·m^{-2})	Equation
2014	48.75 A	48.50 A	48.40 A	48.6 A	48.75 A	$y = 0.01x^2 - 0.38x + 50.35$ $R^2 = 0.92^{ns}$
2015	49.05 A	49.65 A	49.00 A	49.6 A	49.75 A	$y = 0.006x^2 - 0.06x + 49.31$ $R^2 = 0.38^{ns}$

Means followed by the same letter in the column do not differ using Tukey's test with 5% probability.

Table 6. Interaction between pruning seasons in cluster width (cm) of cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Seasons	6 buds (17 buds·m^{-2})	8 buds (23 buds·m^{-2})	10 buds (29 buds·m^{-2})	12 buds (34 buds·m^{-2})	14 buds (40 buds·m^{-2})	Equation
2014	9.64 B	10.99 B	10.43 B	11.55 B	11.85 B	$y = 0.25x + 8.40$ $R^2 = 0.83$
2015	14.19 A	15.02 A	15.20 A	13.95 A	14.58 A	y = ns

Means followed by the same letter in the column do not differ using Tukey's test with 5% probability.

There was interaction between factors related to cluster width; Table 6 shows a linear growth according to bud load in the first study year, with the highest values in 14 buds (11.85 cm), i.e., there was a gradual increase in cluster width with increased bud load. In the second study year, this significance did not occur for bud load.

However, considering seasons within each bud load, the largest cluster width was always obtained in the second study year regardless of the number of buds.

Different results were found by Fawzi et al. (2015) for cluster width with cultivar Superior Seedless®; the highest values were found in pruning at 9 buds·stick^{-1} (21.76 cm and 22.22 cm), and they obtained a reduction in cluster width (16.93 cm and 18.03 cm) in pruning at 15 buds·stick^{-1} in both periods, respectively.

The yield of a grapevine might be determined by the percentage of bud fertility, which is a quantitative measure of a plant's potential to produce fruits, or an indication of the number of clusters that will be harvested in the next season. However, yield is also associated to a considerable number of factors, among which the genetic potential of the cultivar, the technological standard used, vineyard age, climatic conditions, and phytosanitary state are worth mentioning (Melo and Ribeiro 2011).

Vineyards might reach a great development in their natural environment. In these conditions, yield is not constant and clusters are small and have low quality. By limiting the number and length of shoots, pruning provides a rational balance between vigor and yield.

If we compare load individually between both seasons in Table 7, we see there were significant differences from 10 buds onwards, with higher values in 2014.

Table 4 shows the result of yield tests of bud load treatments between two pruning seasons, showing that there were significant statistical differences of 30.10 t.ha^{-1} and 25.71 t.ha^{-1} between 2014 and 2015, respectively. Pruning season is one of the factors of greatest relevance in grape yield (Neis et al. 2010).

As there was a significant interaction between the factors, it can be observed in Table 4 that in the year 2014 as a function of the yolk load, a quadratic effect occurred, it is verified that the number of yolk that maximizes the production is estimated from of the regression curve, in approximately 11 buds, which would result in a maximum yield of 34.53 t·ha^{-1}, and the highest production value was obtained close to 10 buds (36.22 t·ha^{-1}), showing become more efficient. In the year of 2015 we can verify that the behavior was similar to the year 2014, with values obtained through derivation of the equation, it was in pruning with 10 buds, resulting in an estimated production of 29, 41 t·ha^{-1}.

It was observed in the pruning with 10 gems the equivalent of 29 buds.m^{-2} a greater productive potential and an excellent quality of the grape, due to a good relation between the vegetative vigor and the production, resulting in a greater balance of source/drain. According to Abdel-Mohsen (2013), the highest yields in cultivar Crimson Seedless occurred in pruning at 8 and 10 buds in both study years, compared to 6 buds.

Fawzi (2010) observed that yield significantly increased with bud load increase in cultivar Crimson Seedless. The highest yields were 13.25 and 13.57 kg·plant^{-1}, and 15.28 and 16.14 kg·plant^{-1}, i.e., 104 buds·plant^{-1}, which is equivalent to 17.3 buds·m^{-2} and 117 buds·plant$^{-1,}$, which is equivalent to 19.5 buds·m^{-2}.

Yield decreased in 2014 and 2015 in prunings at 6 and 14 buds (22.7 t·ha^{-1} and 30.06 t·ha^{-1}, and 21.02 t·ha^{-1} and 22.6 t·ha^{-1}, respectively). There was a higher yield (12.44 kg·plant^{-1}) with 12 sticks·plant^{-1} compared to 16 and 20 sticks·plant^{-1} (10.78 and 10.45 kg·plant^{-1}, respectively).

Kohale et al. (2013) reported that maximum yield (18.92 t·ha^{-1}) in cv. Sharad Seeless was in the pruning →

Table 7. Interaction between pruning seasons and yield (t·ha^{-1}) in cv. Sugrathirteen (Midnight Beauty®) with different bud loads during the seasons 2014 and 2015, Petrolina, Pernambuco, Brazil.

Seasons	6 buds (17 buds·m^{-2})	8 buds (23 buds·m^{-2})	10 buds (29 buds·m^{-2})	12 buds (34 buds·m^{-2})	14 buds (40 buds·m^{-2})	Equation
2014	22.65 A	29.63 A	36.22 A	31.93 A	30.06 A	$y = -510x^2 + 1105x - 2537$ $R^2 = 0.91$
2015	21.02 A	30.01 A	28.57 B	26.20 B	22.68 B	$y = -464x^2 + 9256x - 1674$ $R^2 = 0.82$

Means followed by the same letter in the column do not differ using Tukey's test with 5% probability.

\at 8 buds·stick^{-1}, whereas maximum yield was 18.26 t·ha^{-1} in pruning at 6 buds·stick^{-1}, and 17.25 t·ha^{-1} in 4 buds·stick^{-1}. It is well known that balance can be maintained in the ratio source/drain by using vineyard management techniques, such as pruning, leaf removal, or cluster thinning (Fredes et al. 2010).

Apparently, vigor induced by pruning at 6 buds was excessive, thus compromising yield.

CONCLUSION

Our findings lead us to conclude that pruning at 6 buds (17 buds·m^{-2}) in cv. Sugrathirteen (Midnight Beauty®) cultivated in the Semiarid region of the São Francisco River Valley showed a lower potential bud fertility, and consequently, increased vegetative vigor and yield. Thus, pruning of production in cv. Sugrathirteen (Midnight Beauty®) should be directed with 10 stick^{-1} buds, with a yolk load of 29 m^{-2} buds, presenting adequate strength, maintaining balance between vegetation and fruiting of plants.

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