# Research Note: Spur Pruning Leaving One Bud is an Interesting Viticultural Strategy to Control Bud Acrotony in Bolivian Vineyards


G. Gutiérrez-Gamboa[1], X. Pinedo[2], W. Villena[3,*], M. Araya-Alman[4,*], P. Pszczólkowski[5,*]

(1) Escuela de Agronomía, Facultad de Ciencias, Ingeniería y Tecnología, Universidad Mayor, Temuco, Chile.
(2) Bodegas y Viñedos La Concepción, Finca la Compañía Avilés.
(3) Departamento de Fitotecnia, Facultad de Ciencia Agrícolas y Forestales, Universidad Autónoma Juan Misael Saracho, Tarija, Bolivia.
(4) Departamento de Ciencias Agrarias, Campus "San Isidro", Universidad Católica del Maule, km 6 Camino Los Niches, Curicó, Chile.
(5) Private consultant, Santiago, Chile.



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**Bolivian viticulture is mostly found in the Central Valley of Tarija, which is characterised by a subtropical climate with high thermal oscillation in winter that results in low accumulation of chilling units. Such climatic conditions accentuate acrotony in vines, which affect budburst uniformity and, consequently, yield and bunch quality at harvest. The aim of this study was to evaluate the effect of different spur pruning strategies on the percentage of budburst and fertility of buds located in different nodal positions in both wine and table grape varieties growing in the Central Valley of Tarija. The results show that allocating spurs with fewer buds improved the budding of most of the distal buds studied. This was noted in both the wine and table grape cultivars, but mostly in the latter. Spur pruning leaving one bud improved the percentage of budburst and the fertility of the distal buds in Cabernet Sauvignon, Cardinal and Ribier, thereby preventing bud acrotony, compared to spur pruning leaving two buds. Spur pruning leaving two buds improved the budburst of latent buds in Cabernet Sauvignon. Therefore, to avoid acrotony patterns, viticulturists should perform pruning leaving one bud.**


## INTRODUCTION

An acrotonic budburst pattern in spring is characteristic of fruit species, particularly those growing under subtropical climatic conditions (Gutiérrez-Gamboa *et al*., 2021). Acrotony is the prevalent development of lateral axes in the distal part of a parent shoot that favours the apical control of terminal shoots (Barthélémy & Caraglio, 2007). Hence, lateral buds are inhibited by the distal shoots, resulting in the dominance of terminal buds and acrotonic branching (Cook *et al*., 2013). Acrotonic behaviour determinates plant architecture, relying on the dominance of the central axis in fruticulture trellis systems (Cook *et al*., 2013). In viticulture, however, the vertical shoot position trellis system in which cordons are positioned horizontally is commonly used to avoid acrotony. Acrotony is accentuated in subtropical climatic regions due to less chilling units being accumulated during the winter (Gutiérrez-Gamboa *et al*., 2020, 2021). Under such conditions, the chilling units required to break the dormancy of the buds is not achieved, increasing budburst heterogeneity and acrotonic branching (Anzanello *et al*., 2018; Pertille *et al*., 2021).

Sufficient accumulation of chilling after leaf fall at temperatures ranging from 0°C to 10°C results in the release of dormancy and uniform budburst as temperatures increase in the spring (Dokoozlian, 1999; Chervin & Fennell, 2019). The bud chilling requirement for grapevine bud break is genotype-specific within species, varying from 250 to 2 250 chilling units (CU) (Londo & Johnson, 2014). Based on this, Anzanello et al. (2018) reported that chilling requirements to overcome endodormancy in Chardonnay, Merlot and Cabernet Sauvignon vines growing in Veranópolis, Brazil was 136, 298 and 392 CU, respectively. In addition, it was reported that endodormancy was complete when 400 to 500 CU had been accumulated in cold-climate interspecific hybrid grapevines (North *et al*., 2021). Moreover, it has been shown that Listán Prieto and Gross Colman accessions growing under Chilean subtropical conditions completed


*Corresponding author: E-mail addresses: wilmarvillena@gmail.com; marayaa@ucm.cl; philippopsz49@gmail.com


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their endodormancy with chilling ranging from 36 to 75 CU (Poblete *et al*., 2016).

Bolivian viticulture is characterised by a subtropical climate with an accumulation of chilling hours varying from 285 to 325. The vineyards are mostly established at 1 650 to 2 800 meters above sea level in the Central Valley of Tarija (Gutiérrez-Gamboa *et al*., 2021). Hydrogen cyanamide has been identified as one of the most effective dormancy-breaking agents in several plant species and is usually applied when enough chilling units have not been accumulated (Or *et al*., 2000). Dormancy breakers can partially replace chilling to effectively promote budburst and are used widely in areas with warm winters (Liang *et al*., 2019). However, hydrogen cyanamide application in vineyards growing in the Central Valley of Tarija is not a viable option due to the frequency of spring frost damage and hail (Gutiérrez-Gamboa *et al*., 2021). Some strategies, such as garlic extracts (Botelho *et al*., 2007; Rady & Seif El-Yazal, 2014), ethanol (Chervin & Fennell, 2019) and cold plasma treatments (Mujahid *et al*., 2020), have been developed to replace this chemical due to its toxicity. Nonetheless, these strategies are difficult to perform in Bolivian vineyards due to the early spring frost and hail damage that characterise this viticulture, and economic and technical issues.

A reduced number of burst buds and uneven budburst after warm winter periods with insufficient accumulation of chilling is not only due to an inability of the buds to break, but also due to a correlative inhibition induced by the erratic early budburst (Lavee, 2000). Pruning and dormancy breakers promote growth stimuli and may produce more uniform budburst (Lavee, 1987).

The bud acrotonic pattern is of great concern for Bolivian grape growers, since it leads to more heterogenous budbreak, fruit maturation and early decline of the vineyard. Currently, very little information and technical strategies are available to avoid this problem in subtropical climates. Therefore, the aim of this study was to evaluate the effect of different pruning strategies on uniform budburst in different grapevine varieties growing in the Central Valley of Tarija.

## MATERIALS AND METHODS

### Plant material

The study was conducted in the 2008.2009 season in two experimental vineyards located in the Central Valley of Tarija, Tarija, Bolivia, where a subtropical climate predominates. To evaluate pruning treatments on wine grapes, a Cabernet Sauvignon vineyard situated in La Concepción, Avilés Province, Tarija Department, Bolivia was used. The vines were seven years old and grafted onto SO4 rootstocks. Grapevines were trained on a quadrilateral cordon, and planted at 2.4 × 1.6 m, accounting for a total of 2 604 vines/ha. A vineyard situated in El Portillo, Cercado Province, Tarija Department, Bolivia was used to evaluate the treatments on table grapes. The vines were six years old and ungrafted, and included the cultivars Italia (cv. Pirovano 65), Cardinal and Ribier. Grapevines were trained in a quadrilateral cordon using a double expansion and planted at 3.0 × 1.5 m, accounting for 2 222 vines/ha.

### Climatic conditions

The climate of the viticulture of the Central Valley of Tarija is defined as subtropical according to the Koopen classification (Gutiérrez-Gamboa *et al*., 2021). Data about the climatic conditions of this valley was obtained from an automatic weather station that has belonged to the Tarijean airport for 45 years (1962 to 2007). Based on the data, chilling unit accumulation reached a value of 337 h, whereas it accumulated an average of 269 h in the last ten years. Precipitation reached an annual accumulation of 604 mm, concentrated in summer – mainly in January, with an average of 135.3 mm in this month. The monthly average temperature varied from 13.1°C to 20.7°C, the average maximum temperature ranged from 23.8°C to 27.5°C, and the average minimum temperature varied from 2.3°C to 14.4°C.

### Treatments and evaluations

Pruning was done for the wine and table grapes in vine cordons pruned in spurs. Three treatments of pruning cuts were performed on wine grapes: a) spur pruning at *bourillon*; b) spur pruning leaving one basal bud; and c) spur pruning leaving two basal buds (Fig. 1). Two treatments of pruning cuts were performed on table grapes: a) spur pruning leaving one basal bud; and b) spur pruning leaving two basal buds (Fig. 1). Pruning treatments were displayed in a randomised block design, with three replicates. Blocks consisted of four individual vines that were pruned, leaving 30 *bourillons*, 30 one-bud spurs and 15 two-bud spurs, hance a similar number of buds. The treatments were performed to evaluate budburst percentage and bud fertility, expressed as the number of bunches per shoot and number of bunches per spur. The determinations were evaluated at each nodal position, starting from the distal bud of each shoot to the latent bud of the cordon (Fig. 2).

### Statistical analysis

The statistical analysis was performed using Statgraphics Centurion XVI.I (Statgraphics Technologies Inc., Virginia, USA) and all data was subjected to the Shapiro-Wilk normality test and Levene chi-square test, followed by one-way ANOVA. The significance of the differences was determined by Duncan's test ($p$-value ≤ 0.05).

## RESULTS

### Pruning effects on budburst percentage and bunch number in Cabernet Sauvignon vines grafted onto SO4

Table 1 shows the effects of different pruning strategies on the budburst percentage (%) of buds of different nodal positions with respect to the apex in Cabernet Sauvignon vines. As spur pruning was defined by fewer buds, the budburst percentage is higher in most of the distal buds studied. Pruning strategies involving *bourillon* and one bud favoured the percentage of budburst of *bourillon* compared to two-bud pruning in spurs (Table 1). The budburst percentage of basal bud was improved by *bourillon* pruning, compared to the one- and two-bud pruning strategies (Table 1). Two-bud spur pruning improved the percentage of budburst of latent, second apical and third apical buds compared to the rest of the pruning strategies (Table 1).

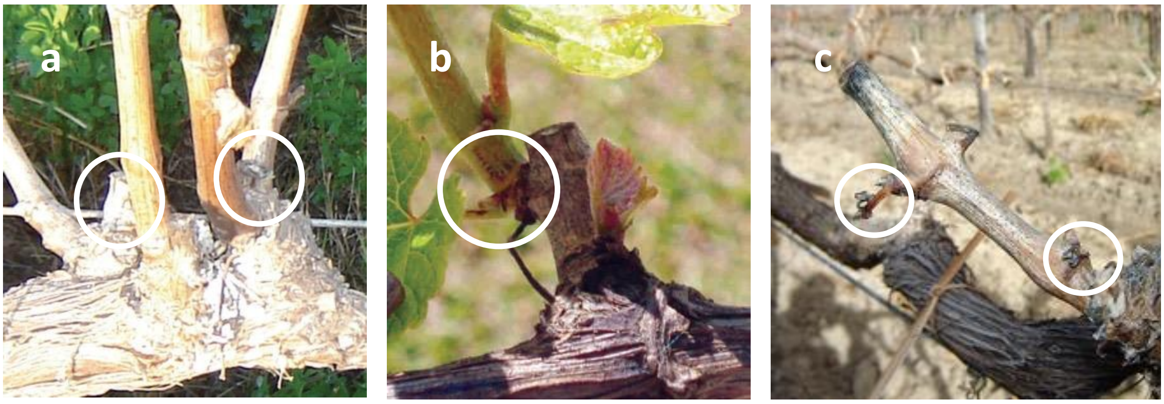


FIGURE 1
Pruning strategies in table and wine grapes: a) spur pruning at *bourillon*; b) spur pruning leaving one basal bud; and c) spur pruning leaving two basal buds. Circles show the buds left at pruning.

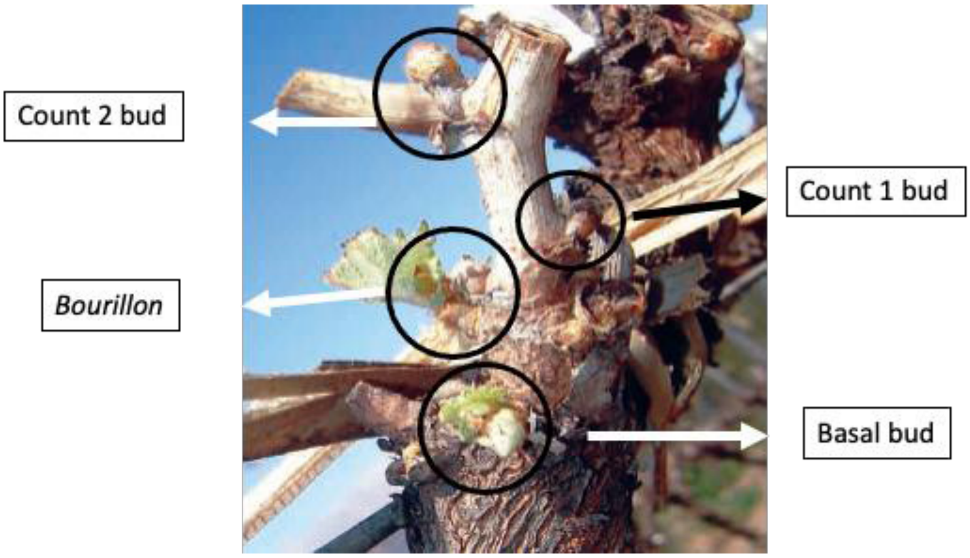


FIGURE 2
Nodal positions evaluated in this trial, starting from the distal bud of each shoot to the latent bud of the cordon. In this trial, the apical first is the terminal bud from the basal one when it was pruned to one or two buds in spurs.

Table 2 shows the effect of different pruning strategies on the bunch number of buds of different nodal position with respect to the apex in Cabernet Sauvignon vines. Pruning to *bourillon* promoted the highest number of bunches of the *bourillon* and basal buds (Table 2). In addition, pruning at *bourillon* favoured reaching the lowest number of bunches of the second apical buds (Table 2). Pruning spurs to one bud led to a lower number of bunches of the latent buds, and of the second and third apical buds compared to pruning to two buds (Table 2). This strategy resulted in a smaller number of bunches of *bourillon* compared to pruning to one bud (Table 2).

**Pruning effects on budburst percentage and bunch number in different table grapes**

Table 3 shows the effects of different pruning strategies on the percentage (%) of budburst of the buds at different nodal positions in relation to the apex in Italia, Cardinal and Ribier vines. As the pruning was defined by fewer buds on the spurs, the budburst percentage was higher in most of the distal buds studied. Pruning to one bud favoured a higher budburst percentage of the first count, *bourillon* and basal compared to pruning to two buds in Italia (Table 3). In contrast, pruning to two buds favoured a higher percentage of budburst of the second and third apical buds compared to pruning to one bud in Italia (Table 3). Pruning to one bud favoured a higher budburst percentage of the first count and *bourillon* compared to pruning to two buds in Cardinal (Table 3). In contrast, pruning to two buds favoured a higher budburst percentage of third apical buds compared to pruning to one bud in Cardinal (Table 3). Pruning to one bud favoured a higher budburst percentage of the first count and the *bourillon* compared to pruning to two buds in Ribier (Table 3).

Table 4 shows the effect of different pruning strategies on the bunch number of buds at different nodal positions

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TABLE 1

Effects of pruning strategies of spurs (at *bourillon*, one bud and two buds) on budburst percentage (%) of buds at different nodal positions with respect to the apex in Cabernet Sauvignon vines grafted onto SO4 rootstock.

| Spur pruning strategy | *Bourillon* | Basal bud | Latent bud | First apical bud | Second apical bud | Third apical bud |
|---|---|---|---|---|---|---|
| At *bourillon* | 96.5 b | 68.6 b | 19.2 a | 96.5 a | 68.6 a | 19.2 a |
| At one bud | 85.2 b | 14.8 a | 14.8 a | 96.6 a | 85.2 b | 14.8 a |
| At two buds | 39.7 a | 11.8 a | 35.2 b | 98.3 a | 95.5 c | 39.7 b |

All the parameters are given with their standard error (n = 4). For each parameter, different letters indicate significant differences between treatments (Duncan test: $p$-value ≤ 0.05). For *bourillon* pruning, the first, second and third apical buds correspond to *bourillon*, the basal bud and the latent bud, respectively. For one-bud pruning, the first, second and third apical buds correspond to count 1, *bourillon* and basal buds, respectively. For two-bud pruning, the first, second and third apical buds correspond to count 2, count 1 and *bourillon* buds, respectively.

TABLE 2

Effects of pruning strategies in spurs (at *bourillon*, one bud and two buds) on bunch number of buds of different nodal position with respect to the apex in Cabernet Sauvignon vines.

| Spur pruning strategy | *Bourillon* | Basal bud | Latent bud | First apical bud | Second apical bud | Third apical bud |
|---|---|---|---|---|---|---|
| At *bourillon* | 1.19 c | 0.57 b | 0.10 ab | 1.19 a | 0.57 a | 0.10 ab |
| At one bud | 0.94 b | 0.12 a | 0.05 a | 1.17 a | 0.94 b | 0.05 a |
| At two buds | 0.40 a | 0.09 a | 0.17 b | 1.34 a | 1.21 c | 0.17 b |

All the parameters are given with their standard error (n = 4). For each parameter, different letters indicate significant differences between treatments (Duncan test: $p$-value ≤ 0.05). For *bourillon* pruning, the first, second and third apical buds correspond to *bourillon*, the basal bud and the latent bud, respectively. For one-bud pruning, the first, second and third apical buds correspond to the count 1, *bourillon* and basal buds, respectively. For two-bud pruning, the first, second and third apical buds correspond to the count 2, count 1 and *bourillon* buds, respectively.

TABLE 3

Effects of pruning strategies in spurs (at one bud and two buds) on budburst percentage (%) of buds of different nodal positions with respect to the apex in table grape vines.

| Spur pruning strategy | Count bud 1 | *Bourillon* | Basal bud | Latent bud | First apical bud | Second apical bud | Third apical bud |
|---|---|---|---|---|---|---|---|
| ***Italia*** | | | | | | | |
| At one bud | 97.2 b | 79.6 b | 4.3 b | 25.1 a | 97.2 a | 79.6 a | 4.3 a |
| At two buds | 86.6 a | 7.2 a | 1.1 a | 28.3 a | 97.7 a | 86.7 b | 7.2 b |
| ***Cardinal*** | | | | | | | |
| At one bud | 92.9 b | 63.4 b | 6.5 a | 34.5 a | 92.9 a | 63.4 a | 6.5 a |
| At two buds | 72.1 a | 12.2 a | 5.6 a | 38.4 a | 93.2 a | 72.1 a | 12.2 b |
| ***Ribier*** | | | | | | | |
| At one bud | 95.3 b | 56.9 b | 2.3 a | 32.3 a | 95.3 a | 56.9 a | 2.3 a |
| At two buds | 63.2 a | 4.2 a | 0.9 a | 28.2 a | 94.8 a | 63.2 a | 4.2 a |

All the parameters are given with their standard error (n = 4). For each parameter, different letters indicate significant differences between treatments (Duncan test: $p$-value ≤ 0.05). For *bourillon* pruning, the first, second and third apical buds correspond to *bourillon*, the basal bud and the latent bud, respectively. For one-bud pruning, the first, second and third apical buds correspond to the count 1, *bourillon* and basal buds, respectively. For two-bud pruning, the first, second and third apical buds correspond to the count 2, count 1 and *bourillon* buds, respectively.

with respect to the apex in Italia, Cardinal and Ribier vines. Pruning strategies did not affect the bunch number in Italia (Table 4). Pruning to one bud favoured a higher bunch number of the first count and *bourillon* compared to pruning to two buds in Cardinal (Table 4). Pruning to one bud favoured a higher bunch number of the first count and latent buds compared to pruning to two buds in Ribier. In contrast, pruning to two buds favoured a higher bunch number of the third apical buds compared to pruning to one bud in Ribier.

## DISCUSSION

Based on the results above, *bourillon* and one-bud spur pruning reduced the occurrence of bud acrotony in Cabernet Sauvignon vines growing under subtropical conditions, since they favoured a homogeneous and high percentage of budburst and high productivity (Tables 1 and 2). Similarly, pruning to one bud resulted in a homogeneous budburst and increased productivity in Cardinal and Ribier (Tables 3 and 4).

Dormancy release in subtropical conditions is uneven due to the lack of chilling units that are needed to promote dormancy release in vines (Dokoozlian, 1999; Chervin & Fennell, 2019). The lack of chilling in the Central Valley of Tarija is due to the high thermal oscillation that occurs in winter, which means that buds accumulate less chilling units. The lack of chilling results in slower and erratic budburst, and the inhibition of distal shoot parts is accentuated (Cook & Jacobs, 1999), which leads to heterogenous maturity of bunches on the vine (Gutiérrez-Gamboa *et al*., 2021a). In addition, a reduction in budburst along canes due to high growth polarity and apical dominance can also affect the whole vine, causing a decline of the arms in cordon-trained vines (Lavee, 2000; Gutiérrez-Gamboa *et al*., 2023). Pruning, particularly spur pruning, considerably affects budburst in grapevines (Gutiérrez-Gamboa *et al*., 2021a,b; Lavee, 2000). Based on this, pruning during the deep dormancy stage can result in delayed and heterogenous budburst. In contrast, late pruning during the slow endogenous release from dormancy can result in early bud opening (Lavee, 1987, 2000). Spur pruning to one bud allowed an increase in the percentage of budburst, improving yield, compared to two-bud spur pruning (Tables 1 to 4). Because of the polar growth under subtropical conditions, the excess vigour is mostly expressed by marked elongation of the annual growing shoots (Lavee, 2000), which is accentuated in those emerging from the distal nodal positions.

Subtropical climatic conditions enhance the acrotonic budburst pattern in spring vines (Gutiérrez-Gamboa *et al*., 2021a), inducing the development of lateral axes in the distal part of a parent shoot, and favouring the apical control of terminal shoots (Barthélémy & Caraglio, 2007). As a result, budburst heterogeneity and the acrotonic pattern increase as bud chilling is not fulfilled during the winter (Cook & Jacobs, 1999). Empirically, the acrotonic pattern is higher in a long shoot of moderate to low vigour than in vigorous shoots in which distal buds are more developed. Ezzili and Bejaoui (2000) report that, at the level of the cane, the percentage of buds that have not burst does not only depend on the diameter of the cane, but also on its fixing on the carrier axis. Based on this, it is possible that the acrotony pattern is due mainly to the anticipated growth of shoots than to their position on the cane. Thereby, if a vertical shoot establishes a decreasing vigour gradation towards the base, shoot development will be more uniform when the shoot is placed horizontally and directed mainly downwards. Based on these explanations, spur pruning leaving the most basal buds could promote a homogeneous budburst and control bud acrotony patterns.

From budburst, the acrotony pattern is delayed and budburst is more uniform in non-tipping shoots for the

TABLE 4
Effects of pruning strategies in spurs (to one bud and two buds) on bunch number of buds at different nodal positions in respect to the apex in table grapes vines.

| **Spur pruning strategy** | **Count bud 1** | ***Bourillon*** | **Basal bud** | **Latent bud** | **First apical bud** | **Second apical bud** | **Third apical bud** |
|---|---|---|---|---|---|---|---|
| ***Italia*** | | | | | | | |
| At one bud | 0.75 a | 0.56 a | 0.28 a | 0.19 a | 0.75 a | 0.56 a | 0.28 a |
| At two buds | 0.69 a | 0.54 a | 0.00 a | 0.18 a | 0.75 a | 0.69 a | 0.54 a |
| ***Cardinal*** | | | | | | | |
| At one bud | 1.10 b | 0.65 b | 0.52 a | 0.27 a | 1.10 a | 0.65 a | 0.52 a |
| At two buds | 0.65 a | 0.16 a | 0.29 a | 0.15 a | 1.08 a | 0.65 a | 0.16 a |
| ***Ribier*** | | | | | | | |
| At one bud | 1.13 b | 0.72 a | 0.50 a | 0.50 b | 1.13 a | 0.72 a | 0.50 a |
| At two buds | 0.91 a | 0.63 a | 0.75 a | 0.38 a | 1.16 a | 0.91 b | 0.64 a |

All the parameters are given with their standard error (n = 4). For each parameter, different letters indicate significant differences between treatments (Duncan test: $p$-value ≤ 0.05). For *bourillon* pruning, the first, second and third apical buds correspond to *bourillon*, the basal and the latent buds, respectively. For one-bud pruning, the first, second and third apical buds correspond to the count 1, *bourillon* and basal buds, respectively. For two-bud pruning, the first, second and third apical buds correspond to the count 2, count 1 and *bourillon* buds, respectively.

following reasons: a) the distal or terminal buds are more developed in a pruned shoot; b) the buds activated in advance by root stimuli are concentrated in the distal zone; and c) because of the lack of vascular connection in the basal buds. In this way, the acrotonic difference in a same cane is accentuated when distal or terminal buds start to burst, which is clearly observed between buds located on the same line of the phloematic or orthostatic elements.

Tarija has increased the surface area planted with vineyards in recent years. Based on the results, vineyard establishment under such conditions should be performed on the basis of agronomical guidelines. In this way, grapevine varieties with low chilling requirements and high fertility in the basal buds can be cultivated, and adequate viticultural management to control bud acrotony can be determined, especially in terms of pruning.

## CONCLUSIONS

Pruning to one bud could be the most convenient pruning strategy under the subtropical conditions of the Central Tarija Valley. Pruning to one bud allows the acrotonic bud pattern to be controlled, improving bud percentage and fertility compared to pruning to two buds. The high percentage of bursting of the *bourillon*, the most developed of the basal buds, would allow the shoot emerging from the *bourillon* to be used as a spur in the following season. Pruning leaving only the *bourillon* could be detrimental for viticulturists, since there would be little renewal material for pruning in the next season. It could also affect the productivity of the vine in the event of spring frost.

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