 Doi: 10.33158/ASB.2018v4i2p59

Grape harvesting periods based on degree-days in Paraná state, Brazil

Wilian da Silva Ricce[1,*], Sergio Ruffo Roberto[2], Gláucia de Almeida Padrão[3] and Paulo Henrique Caramori[4]

[1]Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina, Rod. Admar Gonzaga, 1.347, Caixa Postal 502, CEP 88034-901, Florianópolis, SC, Brazil. [2]Universidade Estadual de Londrina, Departamento de Agronomia, CP 6001, CEP 86051-970, Londrina, PR, Brazil. [3]Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, Centro de Socioeconomia e Planejamento Agrícola, Rod. Admar Gonzaga, 1486, CEP 88034-001, Florianópolis, SC, Brazil. [4]Instituto Agronômico do Paraná, Ecofisiolologia, Rodovia Celso Garcia Cid, km 375, 86047-902, Londrina, PR, Brazil. *Corresponding author, E-mail: wilianricce@epagri.sc.gov.br.

ABSTRACT

Grape harvesting period can be decisive for greater profitability to vine growers and for production quality. Thus, the objective of this work was to evaluate grape harvesting periods based on degree-days (DD) during different pruning periods, and under the risk of frosts in the State of Paraná. Based on a series of maximum and minimum temperatures data from 21 conventional stations managed by IAPAR, from 1976 to 2010, this study evaluated the risk of frosts and the degree-days required to complete each cycle in several regions of the state. Results showed that the occurrence of frosts is a restrictive factor for vine crops pruning in regions with higher altitudes and latitudes. For cultivars with low degree-days needs, results showed that in the Northeast of the state harvest could occur from the second ten-day-period of September, with winter pruning by July 5, making the commercialization during periods of less grapes offer. In this same region, cultivars with more needs of degree-days could be harvested between the first and second ten-day period of November. For the Central, Southern and Eastern regions, the risk of frosts in the month of July is high and pruning may result in cold damages to new shoots and vines. Therefore, harvesting must occur from January to May in these regions.

Key words: Agroclimatic zoning, *Vitis* sp., commercialization, frost, pruning period.

INTRODUCTION

Harvesting period forecast or crop development estimate related to climate conditions helps crop planning and management. Particularly, the use of the degree-days and accumulated degree-days concept allow applications such as choice of genetic material compatible with the local degree-days regime, planting periods planning, harvest period estimates and pests infestation potential periods (Caramori 2006).

The degree-days concept assumes that the development of vegetal species is related to temperature, and there is a base temperature below which the plant does not develop or develops in a highly reduced scale (Pereira et al., 2002). The base temperature of 10°C has been used for vines (Hidalgo 1980).

Knowledge of the vine phenological behavior related to degree-days needs helps to understand crop development, determining the period of each development phase, rationalizing and optimizing cultural practices (Mandelli et al., 2004). This knowledge helps vine growers to predict crop development and periods of greater labor demand and crop management practices (Mullins et al., 1992).

Vine cultivation is an activity that has a high labor demand. The degree-days determination allows the estimation of the phenological phases and vines pruning-harvest cycle, favoring a better planning of agricultural activities (Santos et al., 2007). This knowledge helps vine growers to plan harvest according to their convenience aiming to obtain higher profitability. It also helps to plan when to hire more labor at the different phases of the culture, such as pruning times, shoots treatment, sprout thinning phytosanitary control and harvest, optimizing the whole production process.

The state of Paraná, located between 22 and 27°S of latitude, in a transition zone with high climate variability, with relief and soil variations that have a direct impact on temperature, evapotranspiration and local water balance, and with regions with tropical characteristics regions of transition to temperate climates. With the exception of the coast, temperatures in Paraná decrease from North to South and as the altitude increases. Although the state has a positive annual hydric balance for most regions, there is great temporal and precipitation distribution variation (IAPAR 2016).

MATERIALS AND METHODS

The study was conducted with data from 21 conventional weather stations of the IAPAR network in the state of Parana, with daily observations from1976 to 2010. Historical series of screen minimum temperatures below 1 ºC were used to calculate frost risks. The probabilities of occurrence of temperatures below 1 °C were determined for every 10 days, based on the distribution of extremes, and the values were adjusted to a regression equation with latitude, altitude and longitude. Regions with frost frequency below 20% in ten years were considered as low risk.

For the harvesting time estimation the study considered six vine pruning dates, defined as regular crop initial period: 05/07, 15/07, 25/07, 05/08, 15/08 and 25/08. Best pruning date was defined as when the risk of frost in the following ten-day-period was less than 20%.

To calculate the probable harvest date, the study considered nine production cycles based on different degree-days demands between pruning and harvest of different grapes cultivars: 1.025, 1.275, 1.325, 1.375, 1.450, 1.525, 1.625, 1.850 and 2.100 degree-days, according to values obtained by Ricce et al. (2013) and shown in Table 1.

The sum of degree-days (DD) from pruning to harvest was calculated by the following equations proposed by Villa Nova et al. (1972):

DD = $(MT - bT) + \frac{(MT-mT)}{2}$ for mT > bT;

DD = $\frac{(MT-bT)^2}{2(MT-mT)}$ for mT < bT;

and DD = 0 para bT > MT,

where: DD = degree-days; MT = maximum daily temperature (°C); mT = minimum daily temperature (°C); Bt = base temperature at 10 °C.

Table 1. Degree-days (°C day) for vine cultivars (*Vitis* spp.), from pruning to harvest (Ricce et al., 2013).

Degree-days	Cultivars
1.000 to 1.050	BRS Rúbea and Venus
1.250 to 1.300	Bordô, Cabernet Sauvignon, Chardonnay, Gewürztraminer, Isabel and Pinot Noir
1.300 to 1.350	Niagara Branca and Niagara Rosada
1.350 to 1.400	Concord, Gamay, Merlot and Riesling Itálico
1.450	BRS Clara, BRS Morena, Tannat and Thompson Seedless
1.500 to 1.550	BRS Linda, BRS Lorena, Cabernet Franc and Moscato Branco
1.600 to 1.650	Moscato Embrapa, Moscato Giallo and Trebbiano
1.700 to 2.000	Benitaka, Brasil, Itália and Rubi
2.100 to 2.200	Nero d'Avola, Palomino and Primitivo

Harvest dates were classified in probable ten-days-harvesting periods. By using the adjusted regression, frosts risk and probable ten-year harvesting periods were mapped based on the sum of the degree-days as a function of latitude, longitude and altitude for the state of Paraná, with resolution of 90m, using the SRTM - Shuttle Radar Topography Mission base (Miranda 2005).

This work was based only on the risk of frost to limit cultivation regions; however, other climate risks such as excessive humidity were taken into consideration when choosing the variety to be cultivated (Ricce et al., 2014).

Additionally, the amounts of table grapes commercialized by the Supply Centers of Parana (CEASA 2016) were verified in the units of Curitiba, Londrina, Maringá, Foz do Iguaçu and Cascavel, from 2005 to 2010.

To estimate the pattern seasonal behavior of the grapes price, this study used the average nominal monthly prices of fine table grapes published by the Secretariat of Agriculture and Supply of Parana (SEAB 2016), from January 1995 to December 2015 and corrected by the General Price Index-Internal Availability (IGP-DI). Moving averages and regression estimated and isolated deterministic seasonality throughout the year. The moving averages showed the seasonal index that represented the behavior of a series of prices throughout the year. Through the regression method, dummy seasonal variables were used, according to the equation $Y_t = T_t + S_t + \varepsilon_t$, where the trend can be represented by $T_t = \sum_{j=0}^{k} \beta_j t^j$. If the seasonality is deterministic, seasonal pattern shows no variation from one year to another and can be expressed by 12 constants, each one representing the months of the year. Seasonal dummies can be described by $S_t = \sum_{j=1}^{12} a_j d_{jt}$ where

$$d_{jt} = \begin{Bmatrix} 1 \;\; if\ the\ t\ period\ corresponds\ to\ j, j = 1,2,\dots,12 \\ 0 \quad otherwise \end{Bmatrix}.$$

Prices pattern seasonal behavior allows to analyze the possibility of profitability increase, in case grape harvest is planned based on degree-days. Therefore, by knowing the prices seasonal behavior, the grower's decision-making process is more efficient, since through seasonal factors it is possible to have a numeric measure that expresses the intensity of seasonality of the each period.

RESULTS AND DISCUSSION

The risk of frosts is the key factor that limits vine cultivation throughout the year in the cold regions of Paraná (Figure 1). In the South, in the municipalities of Clevelândia and Palmas, frosts can occur from May 20 to the end of August. The risk diminishes as latitude and altitude decrease. In the Southwestern and central parts of the state, the risk period is above the threshold of 20% in the second and third ten-day period of July. In the Southwest, West, Northwest, North and Ribeira Valley and the Coast the risk of frosts is below 20%.

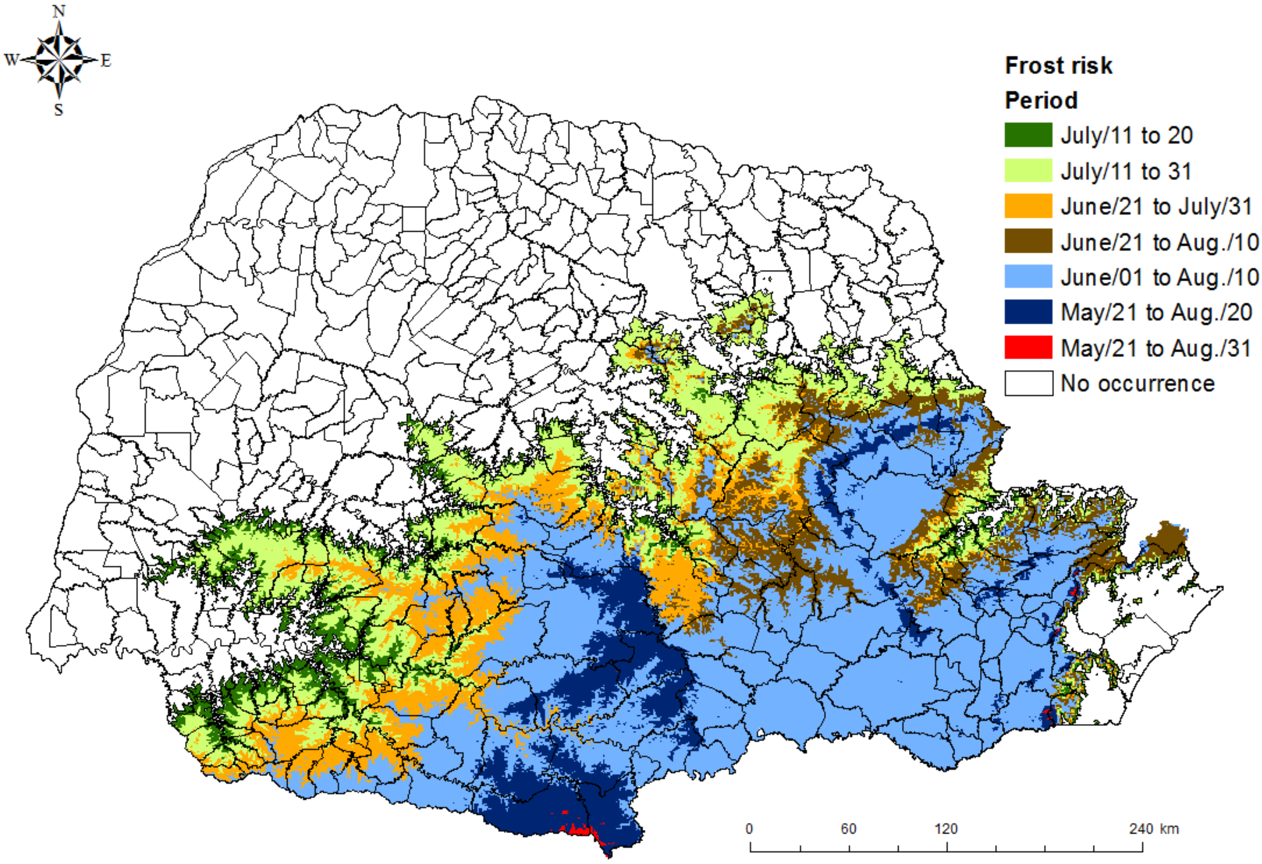

Figure 1. Periods with frost risk above 20% in Paraná state, Brazil.

Based on the risks of frosts for pruning and degree-days accumulation, this study verified grapes cultivars harvest forecast in function of their thermal demand, for the six defined pruning periods (Figures 2 to 10). The earliest pruning periods resulted in harvest anticipation; however, this practice is not advisable in the regions where the risk is high. During the July pruning, the Central, South and East showed high risk of frosts. In August, the first pruning period (05/08) presents high risk in the South and East, the second period (15/08) only in the areas with high altitude, and for the last period, the risk was low all over the state. The pruning period depends on several factors including the cultivar, vine size, terrain topography (risk of late frosts), qualified labor availability, competition with other activities in the property, soil humidity and production objectives (industry or table) (Embrapa 2003).

The wide range of cultivars available helps vine growers to choose the ones that meet final product expectations and offer both fruit for processing or fresh consumption. For grapes with low degree-days demand, between 1.000 and 1.050 degree-days, such as BRS Rúbea and Venus, there is possibility of harvest from the second ten-day period of September in the North, with winter pruning on June 05, allowing commercialization possible when there is little fruit offer in the market (Figure 2). In this same region, cultivars with more degree-days needs, such as Itália and its mutants, would be harvested between the first and second ten-day- period of November (Figure 9). In the North of Paraná, winter pruning on July 15, of cultivars with degree-days demand between 1.700 and 2.000, such as Itália and its mutations, results in harvests until December (Figure 9), making summer pruning possible for an off - season production.

For the coldest regions, the risk of frost in July is high, and pruning in this period may burn the new shoots and cause damages to the vines. Thus, in these regions, cultivars with less degree-days demand pruned from August 25 would be harvested in January (Figure 2), and those with higher demand only in May (Figure 10), making summer pruning difficult for an off-season production due to climate risks.

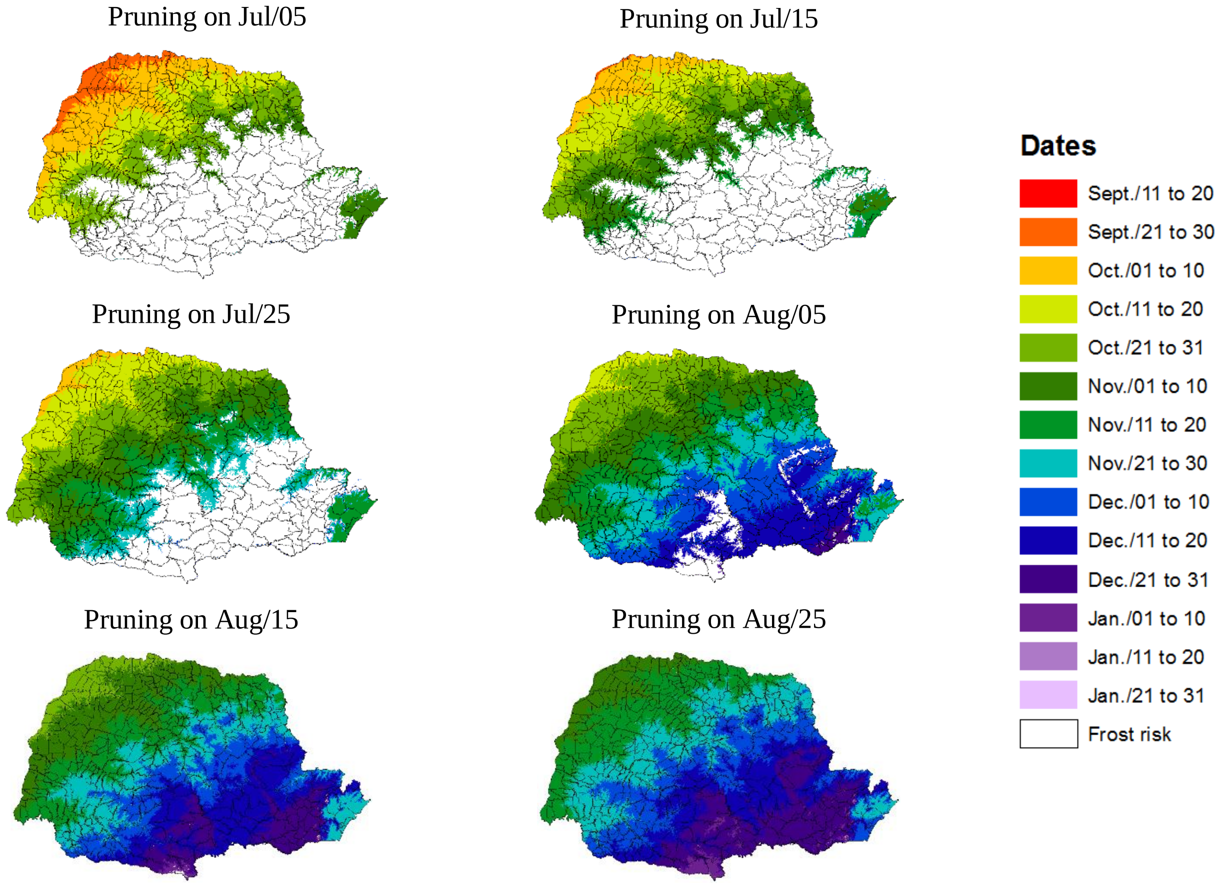

Figure 2. Probable ten-day harvest period for cultivars with degree-days demand between 1.000 and 1.050, in function of pruning periods in Paraná state, Brazil.

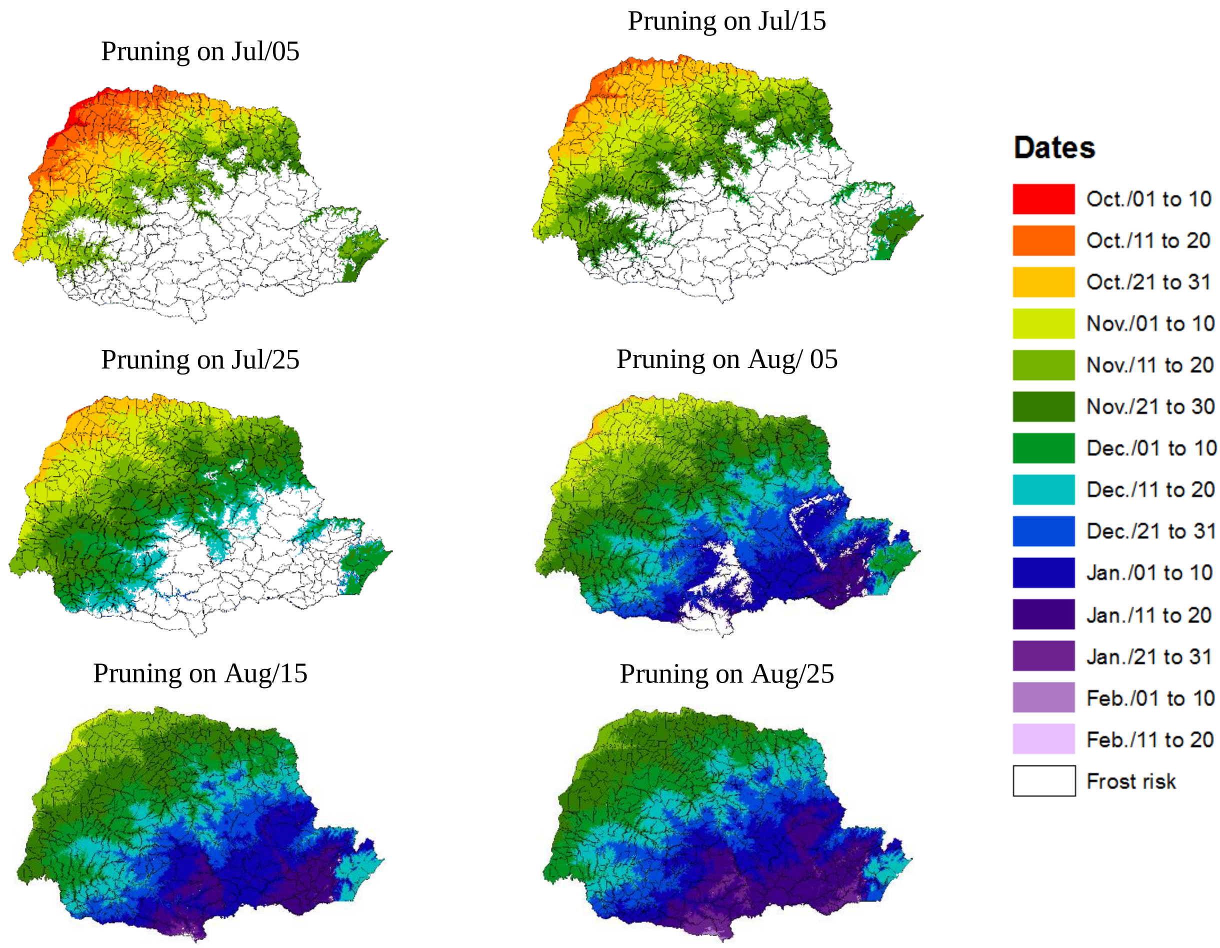

Figure 3. Probable ten-day harvest period for the cultivars with degree-days demand between 1.250 and 1.300, in function of pruning periods in Paraná state, Brazil.

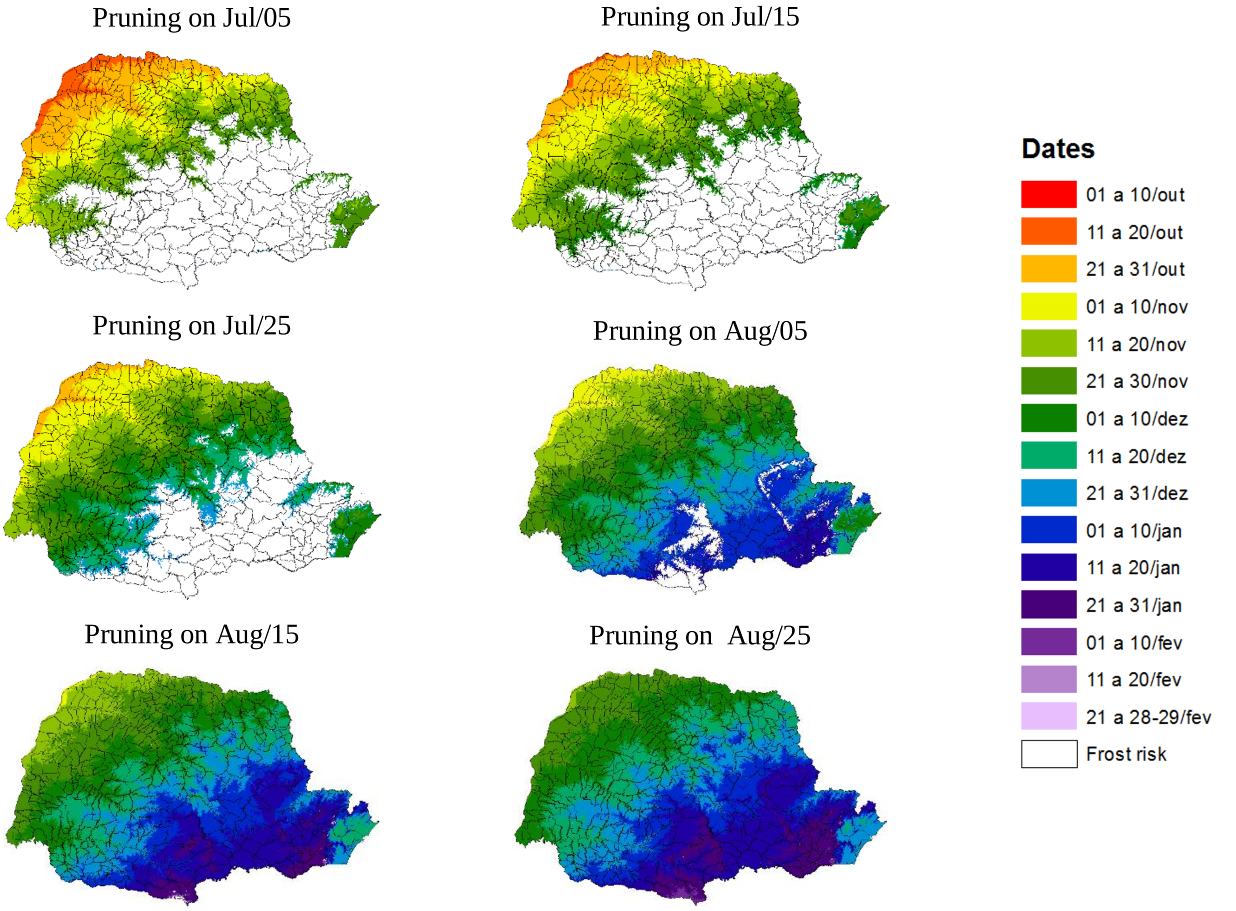

Figure 4. Probable ten-day harvest period for the cultivars with degree-days demand between 1.300 and 1.350, in function of pruning periods in Paraná state, Brazil.

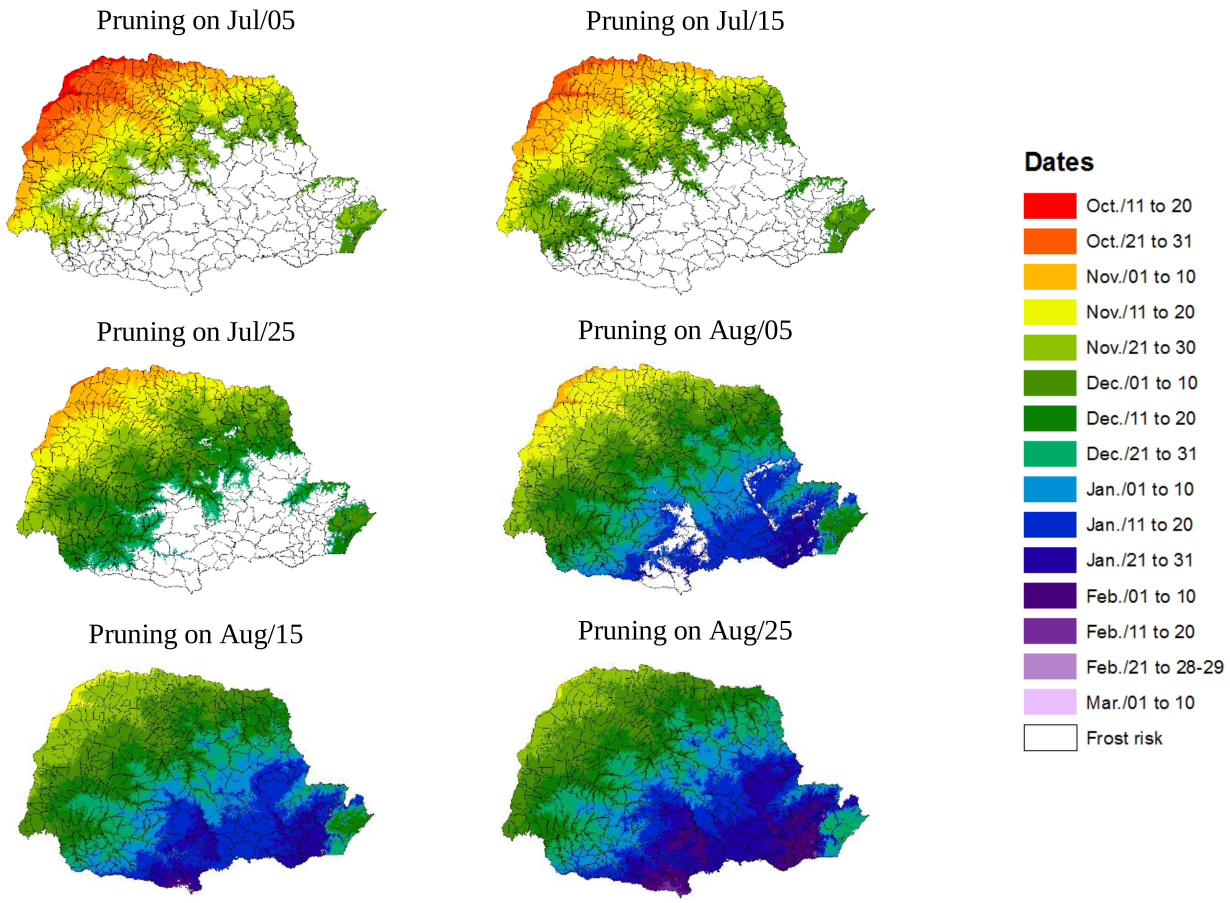

Figure 5. Probable ten-day harvest period for the cultivars with degree-days demand between 1.350 and 1.400, in function of pruning periods in Paraná state, Brazil.

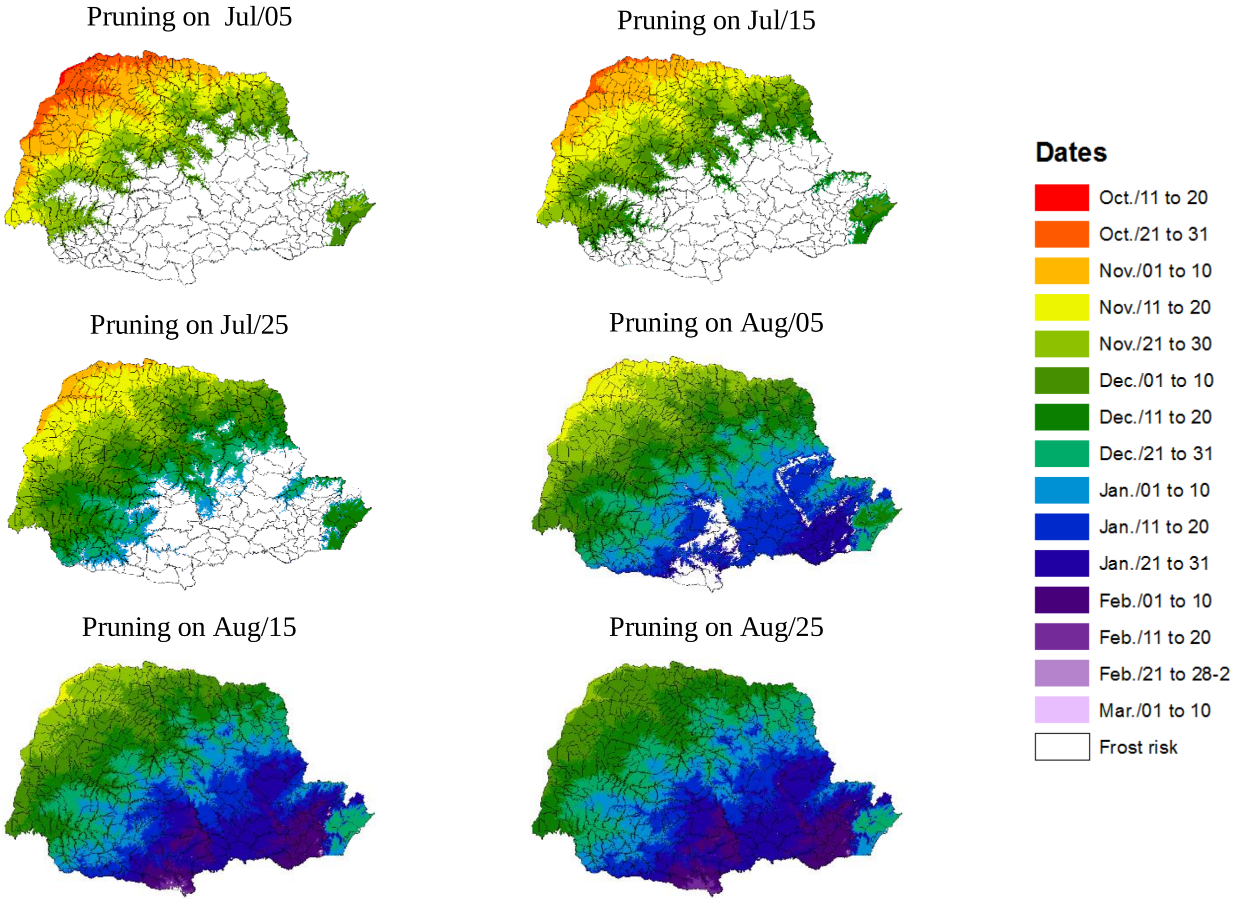

Figure 6. Probable ten-day harvest period for the cultivars with degree-days demand of 1.450, in function of pruning periods in Paraná state, Brazil

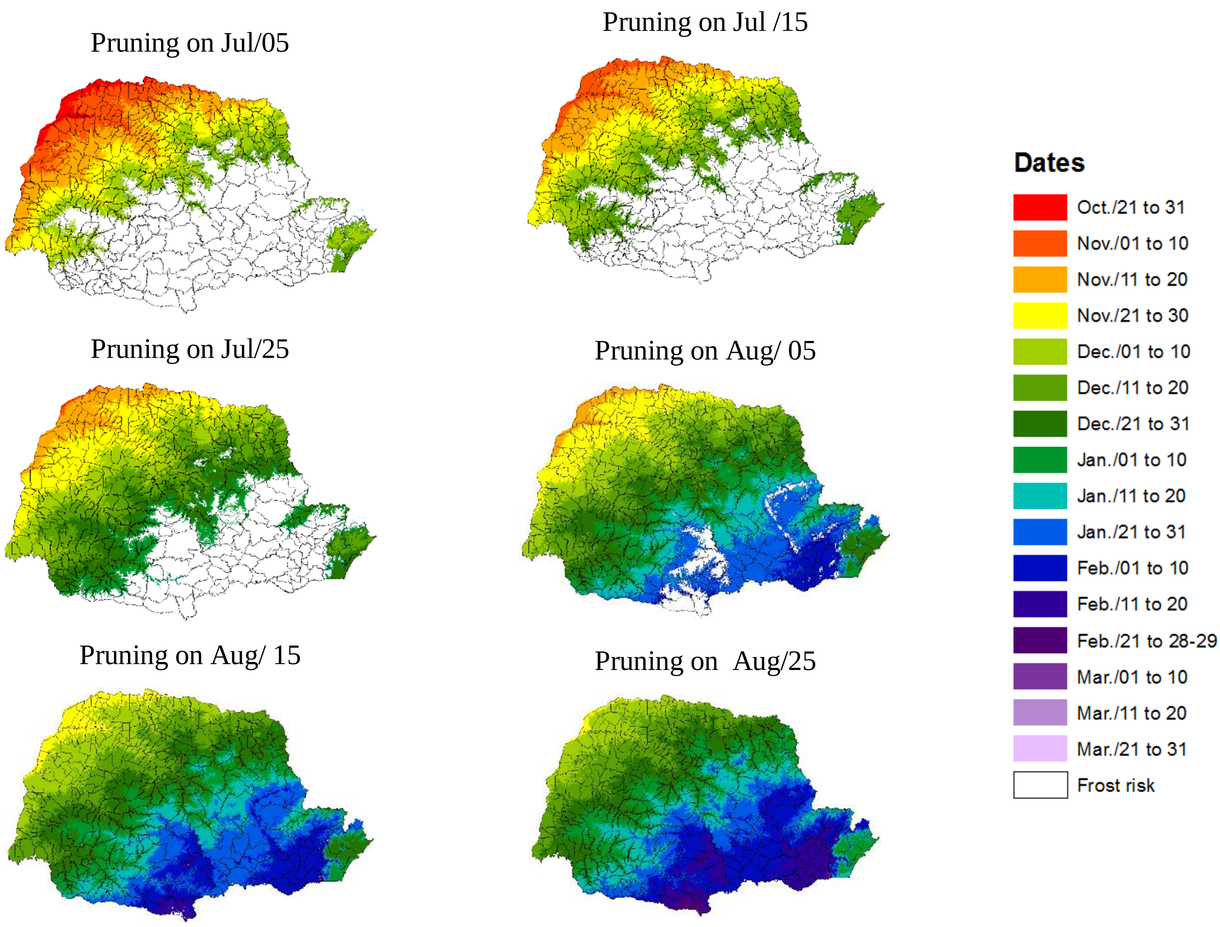

Figure 7. Probable ten-day harvest period for the cultivars with degree-days demand between 1.500 and 1.550, in function of pruning periods in Paraná state, Brazil.

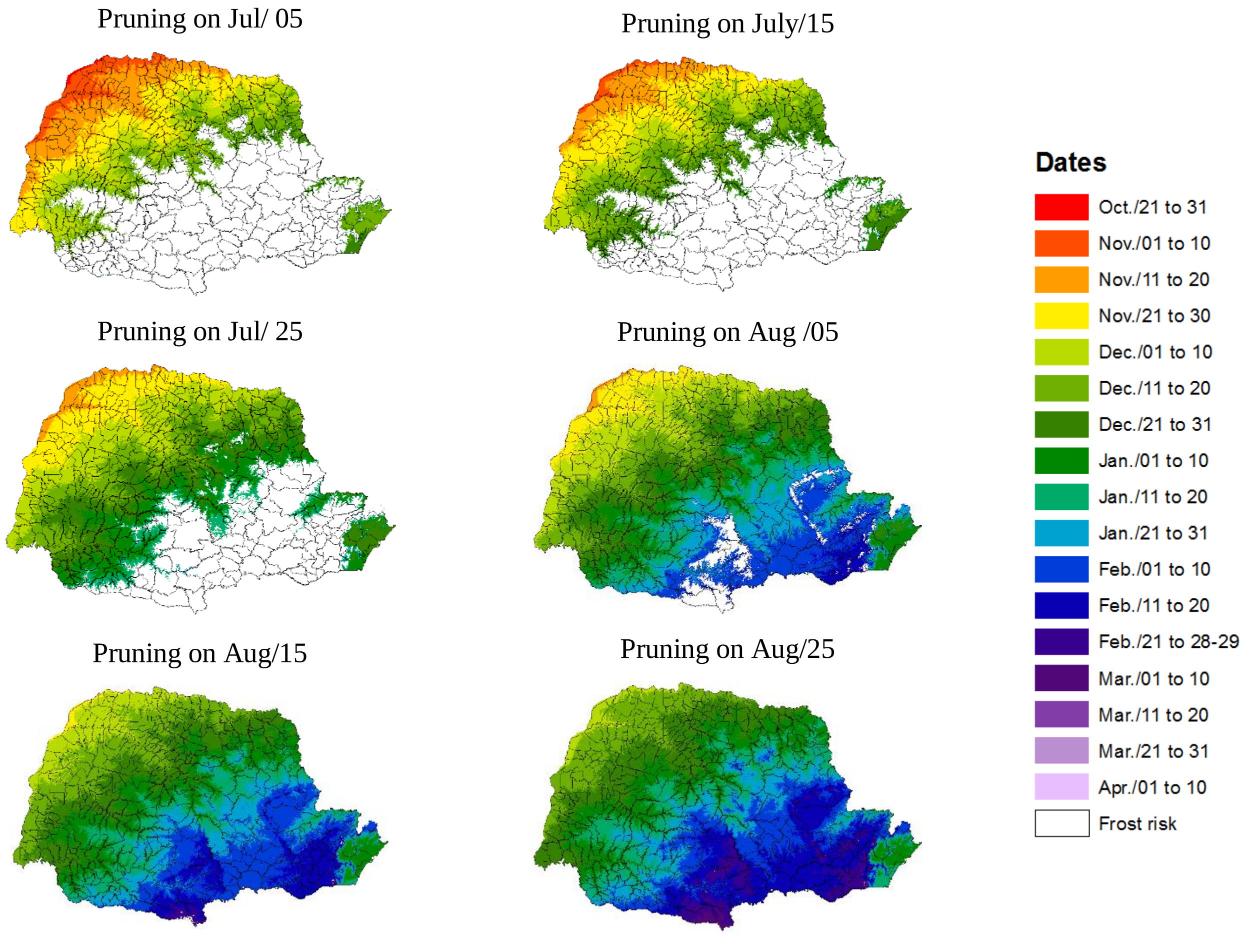

Figure 8. Probable ten-day harvest period for the cultivars with degree-days demand between 1.600 and 1.650, in function of pruning periods in Paraná state, Brazil.

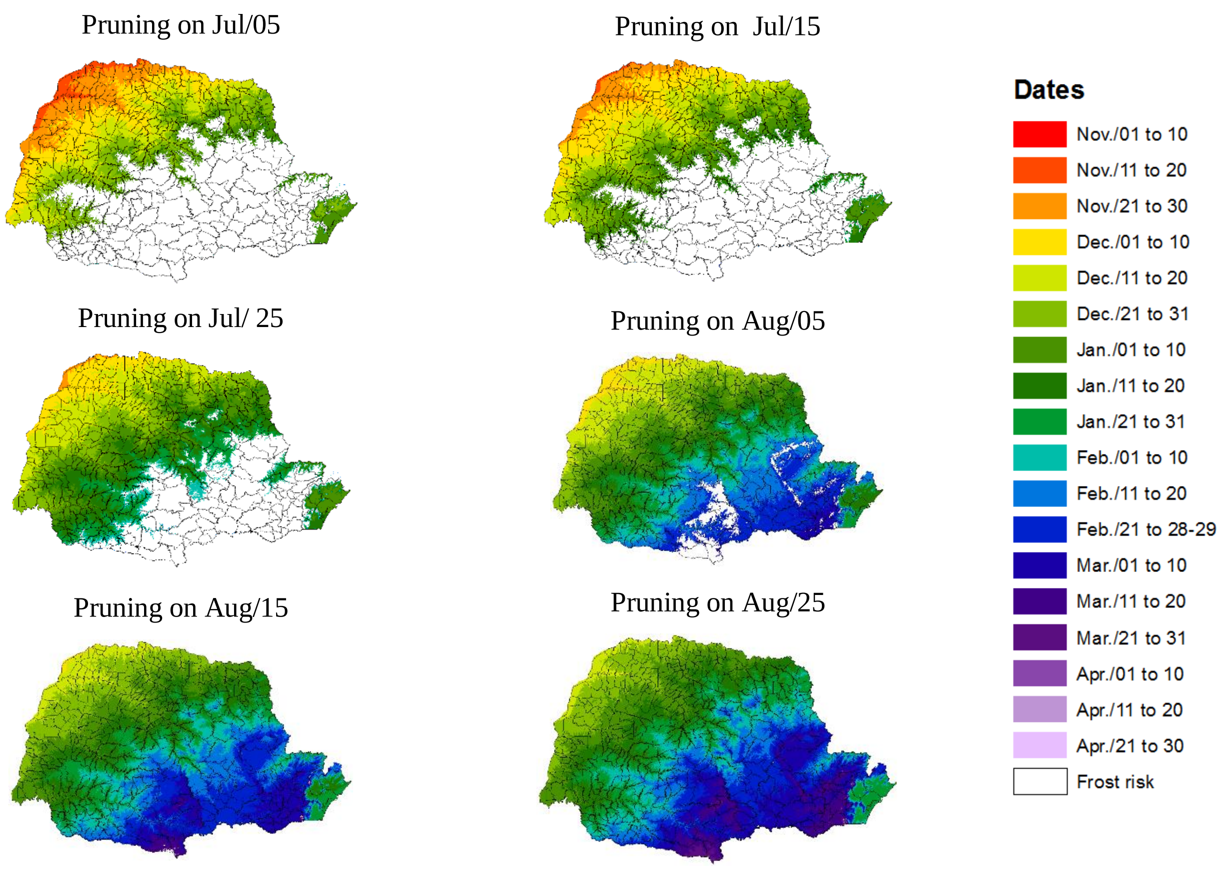

Figure 9. Probable ten-day harvest period for the cultivars with demand degree-days between 1.700 and 2.000, in function of pruning periods in Paraná state, Brazil.

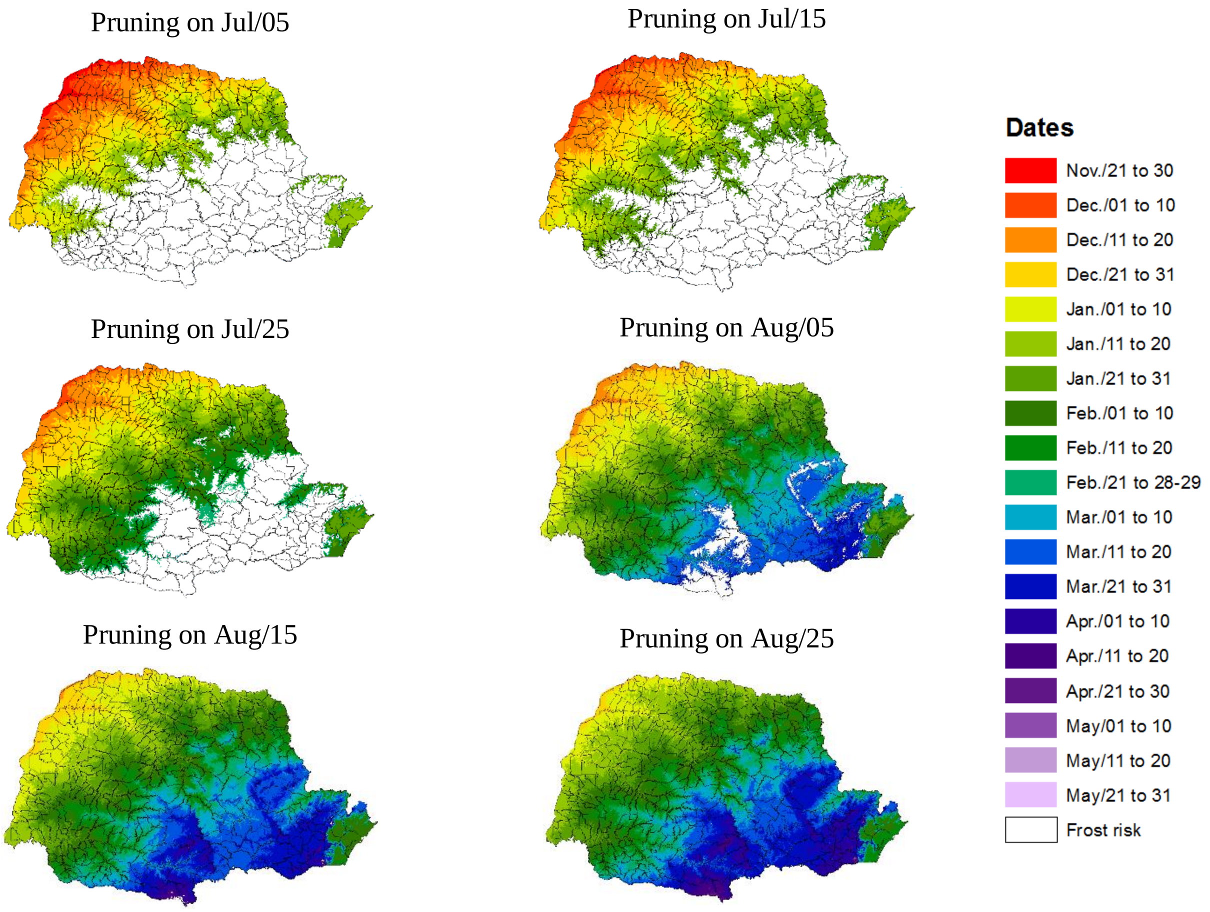

Figure 10. Probable ten-day harvest period for the cultivars with the degree-days demand above 2.000, in function of pruning periods in Paraná state, Brazil.

The possibility of having annual double crops does not necessarily indicate the need for cultivation in two periods. It may indicate the possibility of having an extra crop during a period of better prices and when the offer of fine table grapes is low, and the benefits brought by the production displacement to a period in which climate conditions are more favorable, such as with fine grapes for wine making (Jubileu et al., 2010).

In addition, new technologies applied to fine table grapes production may anticipate harvest time. Yamamoto et al. (2011) observed that the use of a plastic cover helps anticipate harvest in relation to netted shade of ‘BRS Clara’ vine in Northern Paraná.

It is important to emphasize the fact that the degree-days concept takes into consideration only the thermal factor involved in vegetal growth (Pereira et al., 2002). Braga (1995) also emphasizes that this concept includes an approximately constant numerical value for each phenological stage and, based on the sum of the daily values, determine when a given phenological stage is complete. Smart and Coombe (1983) observed that excessive irrigation delays maturation due to continuous growth and excessive emission of branches. On the other hand, hydric stress accelerates maturation.

Figure 11 shows the amount of monthly commercialization of grape cultivars in the CEASA units of Paraná. For the ‘Itália’ and ‘Rubi’ grapes, the greatest commercialized volumes are in December, January and March for the CEASA unit of Curitiba, with the highest total commercialization volume. In Maringá, the greatest volumes are in February and March, from August to October and December. For the ‘Niágara Rosada’, the greatest volumes are in January and March and ‘Benitaka’ from August to December and in May.

Periods with great commercialization volumes tend to be those with the lowest prices, and, therefore, growers should produce during the gaps with low commercialization. Sato et al. (2004) analyzed the fine grapes average seasonal price index for the State of São Paulo in the period from 1995 to 2002, and observed that they reach maximum peak in the months of April and November. In June, the index reaches the lowest level due to the beginning of the harvest in Paraná, and from December to March, period of the São Paulo harvest, which also shows a decreased in prices.

Prices seasonal behavior for the state of Paraná is shown in Figure 12. Price oscillations are above average between September and March. In the months of October, November, February and March the prices can be up to 20% higher than the yearly average. Similar results are displayed in Table 2, showing that in January, June and

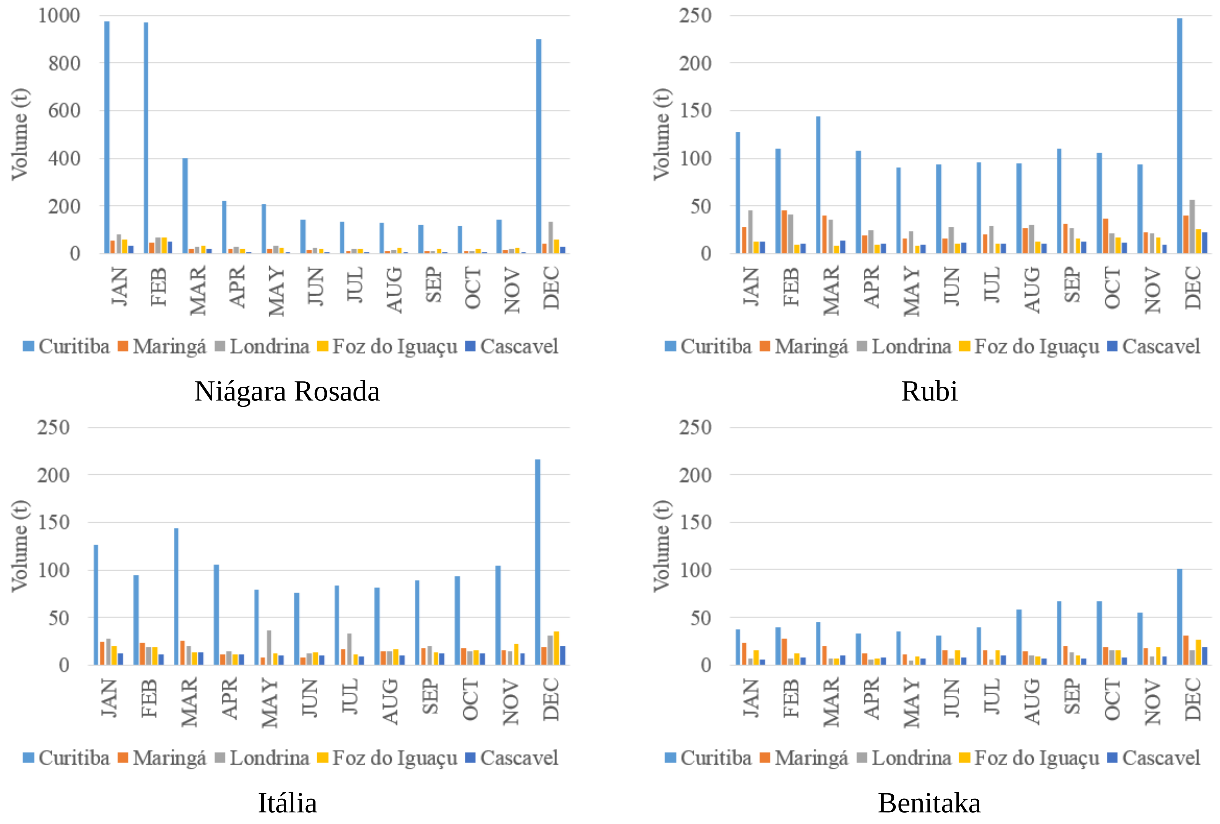

Figure 11. Monthly average volumes commercialized (t) for the Niágara, Rosada, Rubi, Italy and Benitaka grapes in the Curitiba, Londrina, Maringá, Foz do Iguaçu and Cascavel CEASA Paraná units, from 1994 to 2015 (CEASA 2016).

July grape prices remained below average and above average in the other months. It is important to emphasize that, from September to December, greater positive variation was identified in relation to the average by the regression method, confirming the results obtained by the calculation of the seasonal pattern by moving averages. All coefficients were significant at 1% by the t student test, showing that prices variations throughout the year tend to repeat a seasonal pattern.

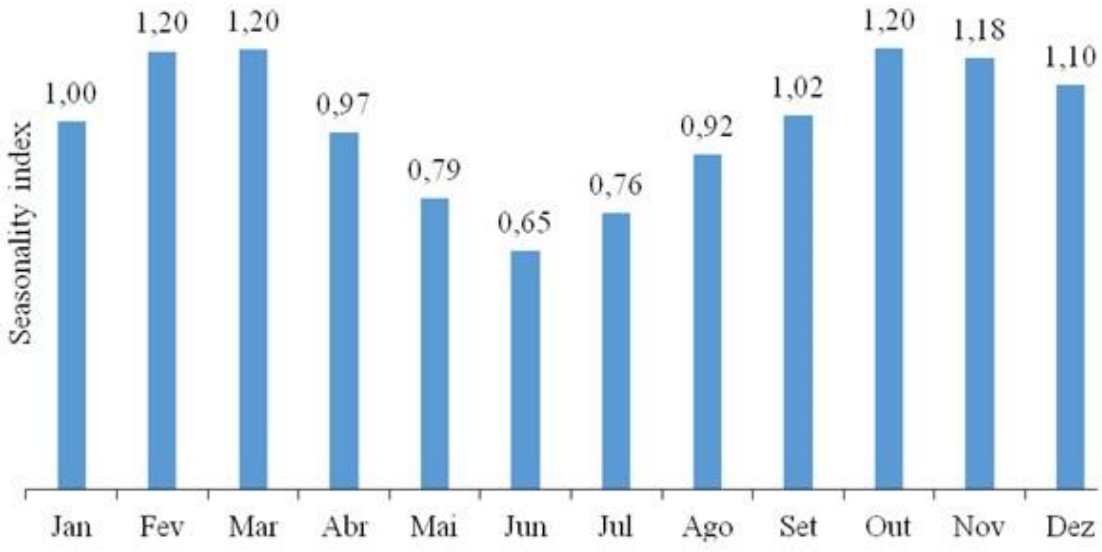

Figure 12. Table grape prices seasonal index in Paraná, Jan. 1995 to Dec. 2015.

Table 2. Regression coefficients to identify deterministic seasonality pattern using dummy variables for all the months of the year

Variable	Coefficient	t
D01	0.9576	4.13***
D02	1.1118	4.80***
D03	1.1681	5.04***
D04	1.1802	5.09***
D05	1.0292	4.44***
D06	0.8708	3.76***
D07	0.9743	4.20***
D08	1.1974	5.16***
D09	1.3222	5.70***
D10	1.4704	6.34***
D11	1.5391	6.64***
D12	1.2799	5.52***

Note: Calculated coefficient pattern error is equal to 0.2318. *** Significance level of 1% for the Student t test.

Such results indicate that knowledge of prices behavior is fundamental as a planning tool. Growers who plan their harvest to commercialize during the months with higher prices can increase their profitability margin. The association of this knowledge with the harvest planning based on the number of degree-days, growers can anticipate harvest and access the market when prices are favorable. In addition, the choice of cultivar according to the specificities of each region allows the grower to anticipate harvest, increasing the offer during off season and market high prices.

Based on the results in this work, it is possible to estimate harvest periods for several grape cultivars in each region of Paraná, based on their degree-days needs and climate risks, to guarantee the profitability and sustainability of this important agricultural sector for the state.

CONCLUSIONS

For grapes with low degree-days demand, between 1.000 and 1050, such as the BRS Rúbea and Venus, harvest possibility from the second ten-day period in September is observed for the Northwest, when pruning is done on July 5, with the possibility of being commercialized during periods of low fruit offer. In this same region, more degree-days demanding cultivars such as Itália and its mutants (1.800 degree-days) would be harvested between the first and second ten-day period of November. These months were identified by the seasonal behavior pattern when prices are above average, as shown by the seasonal factors analysis of grape average prices in the state of Parana. For the coldest regions, such as the Central, South and East, where the risk of frost determines pruning only after August 25, grapes would be harvested between the months of January and May.

The accumulation of degree-days to predict harvest for each cultivar and the prices behavior pattern for the state of Paraná help harvest planning and sales with greater profit margin for the grower.

REFERENCES

Braga HJ (1995) Previsão agrícola: uma nova abordagem - Uso de scanner aerotransportável e redes neurais. Tese, Universidade Federal de Santa Catarina.

Caramori PH (2006) Escopo da bioclimatologia vegetal. In: Anais do 4th Congresso Brasileiro de Biometeorologia. Fapesp, Ribeirão Preto, 1 CD-ROM.

Ceasa (2016) Serviços : Informações sobre Produtos Hortigranjeiros: Volumes Comercializados nas Unidades Atacadistas. Centrais de Abastecimento do Paraná - CEASA/PR. http://celepar7.pr.gov.br/ceasa/evolucao_das_unidades.asp. Acesso 20 set 2016.

Embrapa (2003) Uvas Americanas e Híbridas para Processamento em Clima Temperado. Embrapa Uva e Vinho. Sistema de Produção, 2: Versão Eletrônica. http://sistemasdeproducao.cnptia.embrapa.br. Acesso 10 dez. 2011.

Hidalgo L (1980) Caracterizacion macrofisica del ecosistema médio-planta em los viñedos españoles. Instituto Nacional de Investigaciones Agrarias, Madrid, 255p.

Iapar (2016) Agrometeorologia: Cartas Climáticas. http://www.iapar.br. Acesso 10 nov. 2016.

Jubileu BS, Sato AJ and Roberto SR (2010) Caracterização fenológica e produtiva das videiras 'Cabernet Sauvignon' e 'Alicante' (*Vitis vinifera* L.) produzidas fora de época, no norte do Paraná. Revista Brasileira de Fruticultura 32(2): 451-462.

Mandelli F, Tonietto J, Camargo UA and Czermainski ABC (2004) Fenologia e necessidades térmicas da videira na Serra Gaúcha. In: Anais do 18th Congresso Brasileiro de Fruticultura. Sociedade Brasileira de Fruticultura, Florianópolis, CD-ROM.

Miranda EE (2005). Brasil em Relevo. Embrapa Monitoramento por Satélite, Campinas. http://www.relevobr.cnpm.embrapa.br. Acesso 28 January 2016.

Mullins MG, Bouquet A and Williams LE (1992) Biology of the grapevine. University Press, Cambridge, 239p.

Pereira AR, Angelocci LR and Sentelhas PC (2002) Agrometeorologia: fundamentos e aplicações práticas. Agropecuária, Guaíba, 478p.

Ricce WR, Caramori PH and Roberto SR (2013) Potencial climático para a produção de uvas em sistema de dupla poda anual no Estado do Paraná. Bragantia 72(4): 408-415.

Ricce WR, Carvalho SLC, Caramori PH and Roberto SR (2014) Zoneamento agroclimático da cultura da videira no Estado do Paraná. Semina: Ciências Agrárias 35(4): 2327-2336.

Santos CE, Roberto SR, Sato AJ and Jubileu BS (2007) Caracterização da fenologia e da demanda térmica das videiras ‘Cabernet Sauvignon’ e ‘Tannat’ para a região norte do Paraná. Acta Scientiarum 29(3): 361-366.

Sato GS, Martins VA and Bueno CRF (2004) Sazonalidade dos preços de uva fina para mesa no estado de São Paulo. Informações Econômicas 34(8): 37-40.

Seab (2016) Produção Agropecuária. DERAL. Secretaria da Agricultura e do Abastecimento do Paraná, Curitiba. http://www.agricultura.pr.gov.br. Acesso 12 Sep. 2016.

Smart RE and Coombe BG (1983) Water relations of grapevines. In: Kollowski (Ed.) Water deficits and plant growth. Academic Press, New York, p. 137-196.

Villa Nova NA, Pedro Júnior MJ, Pereira AR and Ometto JC (1972) Estimativa de graus-dia acumulados acima de qualquer temperatura base em função das temperturas máxima e mínima. Ciência da Terra 30: 1-8.

Yamamoto LY, Assis AM, Morais H, Souza FS, Miotto LCV, Sato AJ, Souza RT and Roberto SR (2011) Evolução da maturação da uva ‘BRS Clara’ sob cultivo protegido durante a safra fora de época. Bragantia 70(4):825-831.

Received: July 05, 2017.
Accepted: October 24, 2017.
Published: May 11, 2018.