Scientia Horticulturae 201 (2016) 78–83

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Phenology of 'Tupy' and 'Xavante' blackberries grown in a subtropical area

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ARTICLE INFO

Article history:
Received 24 August 2015
Received in revised form 18 January 2016
Accepted 21 January 2016

Keywords:
Rubus spp.
Chilling hours
Thermal demand
Fruit development

ABSTRACT

The objective of this study was to evaluate the duration of phenological stages of 'Tupy' and 'Xavante' blackberries grown under subtropical conditions with the goal of optimizing the production system. The experiment was conducted at the Experimental Station, Agricultural Research Center, Londrina State University, PR, Brazil, during two consecutive seasons: 2013 and 2014. A completely randomized design was used with five plot replications, with each composed of five plants. The duration (in days) of each phenological stage was recorded for both cultivars through visual observations at the following times: the onset of bud sprouting, the onset of flowering, the onset of fruit maturation, the beginning of fruit harvest, the end of flowering, and the end of fruit harvest. The duration (in days) of the following fruit development stages was also recorded: flower bud, full open flower, unripe green berry, ripening pink berry, and ripe berry. The phenological development of 'Tupy' and 'Xavante' blackberries was directly influenced by the subtropical winter conditions with changes in bud sprouting, flowering and fruit harvesting periods. In the 2013 season, 'Tupy' had a later start of the growth cycle than 'Xavante', but fruit harvest for both ended at the same time in early summer. In the 2014 season, 'Xavante' maintained its characteristic early start, and 'Tupy' also resumed the growth cycle, which was earlier than the previous season. The duration of fruit development was similar for both cultivars. 'Tupy' and 'Xavante' grown in subtropical mild winter conditions demonstrated unique phenology, with earlier and shorter growth cycles than in temperate regions; thus, growing blackberries as two annual crops to optimize the production system is proposed.

1. Introduction

In recent years, small fruits such as blackberries (*Rubus* subgenus *Rubus* Watson) have caught the attention of researchers, fruit growers and consumers due to presence of basic nutrients, fiber, essential micronutrients, such as minerals and vitamins, and various phenolic compounds (Harborne and Williams, 2000; Souza et al., 2014).

Blackberries belong to the Rosaceae family and were previously considered a wild fruit, but cultivation of this species has become important in several countries (Clark and Finn, 2014). Blackberries are a shrubby plant with an erect or climbing stem; the plant is native to Asia, Europe and America, and it is well-suited to regions with a well-defined winter (Moore, 1984). They are considered a good cultivation option for small-scale growers because of the low cost of development and maintenance of orchards, minimal levels of insect and disease damage and high nutritional value (Antunes et al., 2000; Antunes, 2002; Hussain et al., 2014).

'Tupy' and 'Xavante' are the most important cultivars in some temperate areas. The 'Tupy' blackberry is the result of a cross between the 'Uruguay' and 'Comanche' cultivars (Santos and Raseira, 1988) and is considered an important global cultivar due to its high yield and fruit quality (Volk et al., 2013). This cultivar produces black fruits and has creeping, vigorous, thorny stems with a prostrate habit that requires support.

The 'Xavante' blackberry is derived from seeds collected in Clarksville, Arkansas, USA, from a cross between the A1620 and A1507 varieties and is therefore the second generation of this cross. It has vigorous, upright stems without thorns and is a low-chilling cultivar that has good production. The berries have an elongated

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http://dx.doi.org/10.1016/j.scienta.2016.01.036
0304-4238/

shape, medium firmness and a sweet-acid flavor (Botelho et al., 2009). Under the temperate conditions of southern Brazil, flowering begins in September and extends to October, and harvesting occurs in early November and ends in early February (Antunes and Raseira, 2004).

However, the phenology of these cultivars under subtropical conditions has not been well studied. Phenology is the study of cyclic and seasonal natural phenomena, which depends on genetic factors and environmental and climatic conditions. Thus, the phenological characterization of blackberries describes the details of the plant growth cycle, allowing determination of the optimal time to carry out cultivation practices or verification of the occurrence of an important event such as frost or drought associated with well-defined stages (Fenner, 1998; Carew et al., 2000; Sato et al., 2008; Tadeu et al., 2015).

Air temperature is an important climatic factor for temperate plants that influences the duration of phenological stages in the blackberry, which can vary depending on the local annual accumulation of chilling hours (Clark et al., 2005) that promote the end of dormancy, the onset of sprouting and uniform flowering in the spring (Fear and Meyer, 1993). The growth cycle can be significantly different, particularly under subtropical conditions, and it can also vary annually due to the accumulation of growing degree-days, the accumulated difference between the average air temperature and the base temperature, which a plant needs to complete the various stages of its development cycle. Below this temperature, no development occurs (Black et al., 2008).

Given these considerations, the objective of this work was to evaluate the duration of the phenological stages for 'Tupy' and 'Xavante' blackberries under subtropical conditions with the goal of optimizing the system of production.

2. Material and methods

The research was conducted at the Experimental Station, Agricultural Research Center, Londrina State University, PR, Brazil (latitude 23°23′S, longitude 51°11′W and elevation 566 m), during two consecutive seasons: 2013 and 2014. According to the Köppen classification, the climate of the region is Cfa (subtropical climate), with an average temperature in the coldest month below 18 °C (mesothermal), an average temperature in the hottest month above 22 °C, and an average annual rainfall of 1507 mm (Koyama et al., 2014). The texture of the soil is 81% clay, 8% silt and 11% sand.

Nursery plants of 'Tupy' and 'Xavante' blackberries (*Rubus* sp.) were produced according to the methodology of Villa et al. (2003) and obtained from stock plants belonging to Embrapa Temperate Climate, Pelotas, Brazil. A completely randomized design was used with five plot replications; each plot comprised five plants of each cultivar. The spacing of nursery plants was 3 m between rows and 1 m between plants during November 2012. The plants were trained on a double cordon of two wires (parallel twin wires) on eucalyptus "T" poles spaced 60 cm apart at a height of 90 cm above ground level (Antunes and Raseira, 2004).

During the experiment, identical cultivation practices were employed for both cultivars. Irrigation of the experimental plants was performed with a drip system, under agroecological management without the use of synthetic inputs, and with regular manual weed control. Farmyard manure was applied one week after pruning.

In the 2013 and 2014 seasons, pruning was undertaken in late winter on August 9th and August 6th, respectively, leaving an average of five stems per plant up to the second wire of the cordon. In this step, branches were trimmed to a height of 10 cm above the second support wire and the side branches were eliminated; 10 representative branches per plot were identified for phenology assessments.

The duration (in days) of each phenological stage in each plot was evaluated through visual observations according to the classification of Childers and Lyrene (2006) as follows: onset of bud sprouting, onset of flowering (when greater than 5% of flowers had opened), onset of fruit maturation, beginning of fruit harvest, end of flowering (when 90% of flowers had opened), and end of harvest. Diagrams were then prepared representing the duration of each phenological stage (in days) for both cultivars during each season.

In addition, because blackberry flowering and harvest stages occur continuously over several weeks (Takeda et al., 2002) in the 2014 season, the time required for the fruit development of each cultivar was also assessed. Ten dormant buds per plot were identified for fruit phenology assessments, and the duration (in days) of the following important fruit development stages were evaluated: flower bud, full open flower, unripe green berry, ripening pink berry, and ripe berry (Fig. 1).

To quantify the thermal demand required by blackberry cultivars to complete their growth cycle, an automatic micrometeorological station (iMetos®, Plessl Instruments, Austria) was installed in the experimental area to obtain temperature data. The thermal demand, expressed in degree-days (DD), was calculated using the sum of DD accumulated from the onset of bud sprouting to the end of harvest: $\Sigma DD = \Sigma(Ta - Tb)$, where Ta = daily average temperature, and Tb = base temperature (10 °C) (Arnold, 1960; Black et al., 2008).

In addition, it was also possible to obtain the number of chilling hours during each winter season for each cultivar (the number of hours when air temperature was ≤7.2 °C), which represents the minimum period of cold weather after which a fruit-bearing plant will blossom (Allan, 1999).

3. Results and discussion

At the experimental site, the winter of 2013 was longer than the winter of 2014, and it was frosty with 111 chilling hours accumulated (Table 1); there was also a dry period during August, and the mean minimum temperature recorded was lower than normal. In contrast, the winter of 2014 was characterized by a reduced accumulation of low temperatures compared with 2013 (52 chilling hours), a large swing between high and low temperatures, no frost in August, and an increase in temperature and precipitation after early August. Higher temperatures were observed during the summer, and a tendency towards increased temperature was observed once the number of chilling hours was fulfilled.

Like other small fruit crops, blackberries grown in a temperate climate with well-differentiated seasons require a number of chilling hours during the dormant period for uniform budburst and flowering in the spring (Fear and Meyer, 1993). The chilling hour requirement varies among cultivars (Dale et al., 2003), and it has been described as a basic climate factor for flowering and fruit set

Table 1
Accumulated chilling hours and thermal demand in degree-days for 'Tupy' and 'Xavante' blackberries, seasons 2013 and 2014.

Cultivar	Chilling hours[a]		Degree-days[b]	
	2013	2014	2013	2014
Tupy	111	52	1252.6	1374.4
Xavante			1450.9	1439.7

Note: base temperature (Tb) = 10 °C.

[a] Accumulated sum of hours with air temperature ≤7.2 °C during the winter season.

[b] Accumulated degree-days from the onset of bud sprouting to the end of harvest.

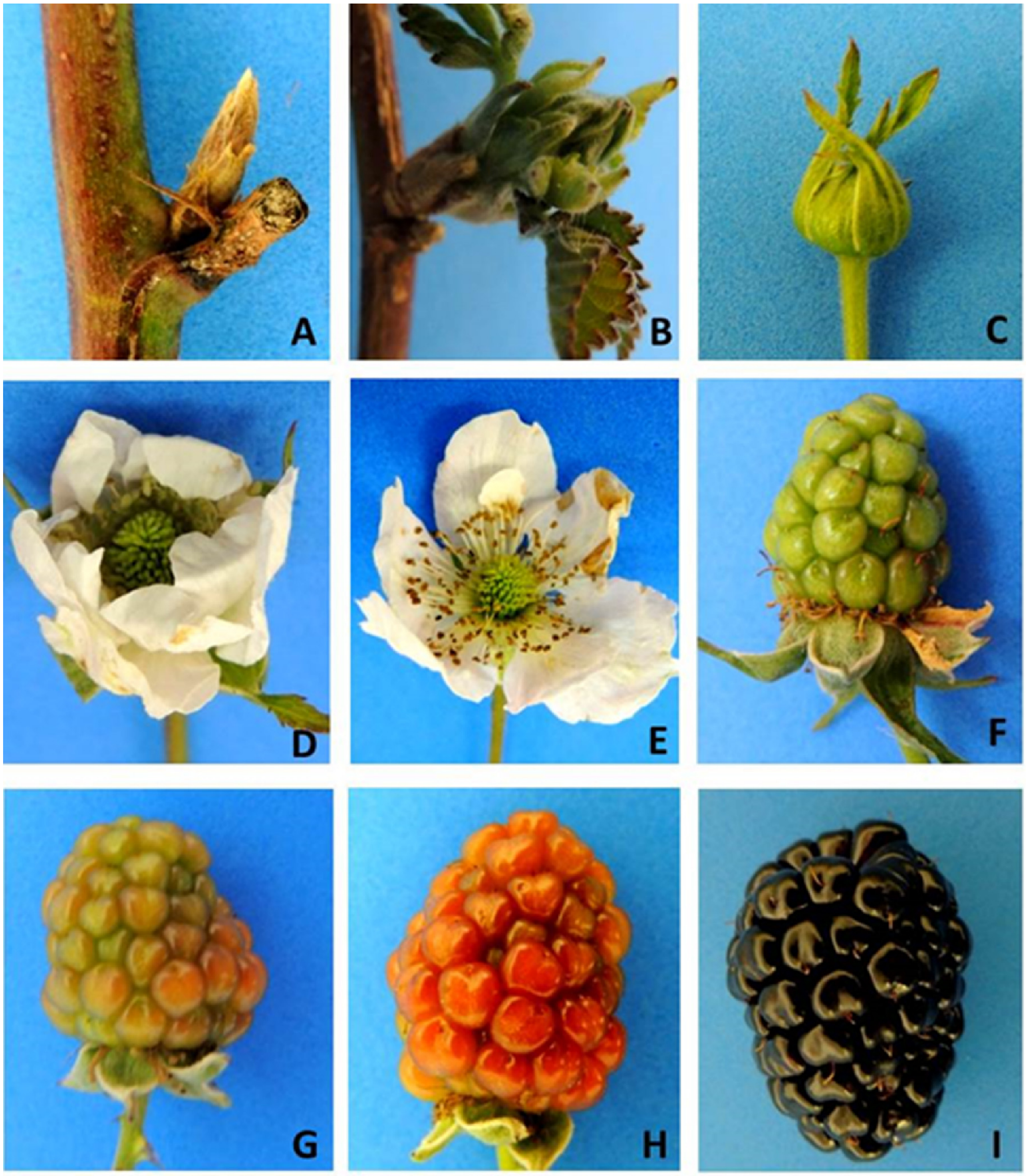

Fig. 1. Phenological stages of blackberry fruit development. (A) Dormant buds; (B) bud sprouting; (C) flower bud; (D) half open flower; (E) full open flower; (F) unripe green berry; (G) early ripening pink berry; (H) ripening pink berry; I: Ripe berry.

(Elloumi et al., 2013) that has a strong effect on phenological stages (Javanshah, 2010).

In subtropical areas, which are colder than the tropics and warmer than temperate zones, it is documented that winter is usually mild to cool and has unpredictable temperatures and no distinct dry season (Lyrene, 2005). Thus, inconsistent winter conditions may result in a different accumulation of chilling days over multiple years at the same location (Scariotto et al., 2013), which may hasten or delay the initiation of new growth of blackberries. However, at the onset of winter, a cessation of shoots extensions and new growth occurs, whereas from late winter to early spring, the temperature increases more rapidly causing the onset of reproductive bud development and development of the floral organs of blackberries (Takeda et al., 2002).

Under subtropical conditions, temperate fruit cultivars may exhibit significant variability in their growth cycle, and their adaptability to this new environment requires close attention. In 2013, the cycle of the 'Tupy' blackberry from the onset of bud sprouting to the end of harvest was 100 days, from September 16th to December 26th (Fig. 2A). 'Xavante' showed a longer cycle of 121 days, from August 26th and December 26th (Fig. 2B). During this season, it was verified that 'Xavante' began new growth approximately 21 days earlier than 'Tupy', but the end of harvest period was similar for both cultivars.

In addition to these findings, there was little variation in the duration of the different phenological periods when the cultivars are compared. The primary difference observed was from the

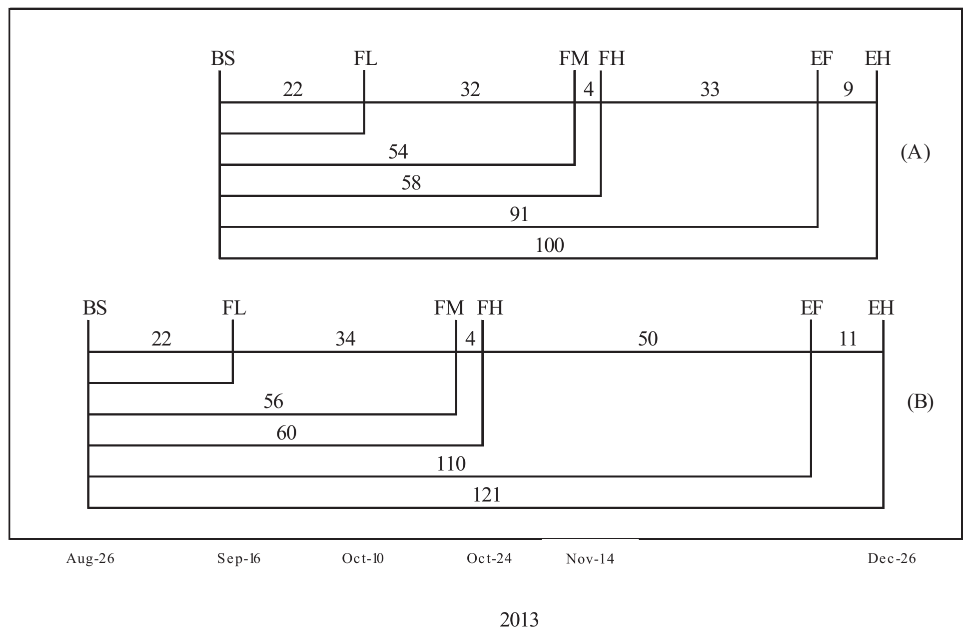

Fig. 2. Duration (in days) of phenological stages for 'Tupy' (A) and 'Xavante' (B) blackberries during the 2013 season. BS: onset of bud sprouting, FL: onset of flowering, FM: onset of fruit maturation, FH: beginning of fruit harvest, EF: end of flowering, EH: end of harvest.

beginning to the end of fruit harvest, which was 42 and 61 days for 'Tupy' and 'Xavante', respectively.

Winter conditions have a significant influence on different phases of the annual growth cycle of blackberries, particularly on flower bud initiation, uniformity of bud sprouting, flowering and the timing and duration of fruiting harvesting (Takeda et al., 2002). Thus, the choice of cultivars with low chilling requirements and tolerance of high temperatures during flowering make production more consistent in subtropical regions.

The lower accumulation of chilling hours observed during the 2014 season and the early increase in temperature at the end of winter had a strong influence on blackberry phenology. In general, the milder winter conditions observed during 2014 advanced the start of bud sprouting for both cultivars. The cycle of 'Tupy' was 108 days, from September 6th to December 23rd, showing a growth cycle that began 10 days earlier (September 6th) than in 2013. The period from the beginning to the end of fruit harvest (49 days) was one week longer than in 2013 (42 days) (Fig. 3A). Under warm winter conditions, temperate fruit cultivars with set chilling requirements, show immense variability in the flowering period from year to year (Petri et al., 2008). In addition, high temperatures reportedly promote the rapid growth of canes in red raspberries, causing the canes to reach the flowering stage earlier (Hoover et al., 1989).

However, for 'Xavante', the cycle in 2014 was similar to 2013 and lasted 114 days; the onset of bud sprouting occurred on August 24th, and the end of harvest occurred on December 18th. 'Xavante' maintained its characteristic earliness and the onset of flowering was 7 days earlier (September 10th) than in the previous season (September 17th), whereas it took 8 more days from onset of flowering to the onset of fruit maturation when compared with the 2013 season (42 and 34 days, respectively). A similar fruit harvest period, from the beginning to the end of fruit harvest, was recorded for 'Xavante' (51 days) and 'Tupy' (49 days) during the 2014 season (Fig. 3B).

Temperate fruit crops are grown under different environmental conditions using different cultivation techniques, and studies concerning the chilling and heat requirements for cultivars are valuable tools to avoid an incomplete termination of dormancy or abnormal flowering (Alburquerque et al., 2008). The duration of the phenological stages is usually related to the thermal conditions of the specific area where the crop is grown, and air temperature has a close relationship with the onset of bud sprouting and flowering, thus influencing the crop production cycle (Black et al., 2008). The effective heat requirements of fruit tree cultivars are associated with various factors, such as the amount of chilling required, light, nutritional status, genetic factors, the type of buds (flower or vegetative) and latitude (Jacobs et al., 2002; Powell, 1987).

The thermal demand, expressed in degree-days (DD), between the onset of bud sprouting and the end of fruit harvest was 1252.6 and 1374.4 DD for 'Tupy' in the 2013 and 2014 seasons, respectively, whereas for 'Xavante' the demand was1450.9 and 1439.7, respectively (Table 1). The thermal demand for 'Xavante' was higher than 'Tupy' in both seasons, perhaps because its longer cycle requires more heat.

When a new temperate fruit cultivar is introduced to a subtropical area, phenology plays an important role as it allows the duration of developmental stages to be characterized in relation to climate, particularly in relation to seasonal variation, and it is used to interpret the impact of different climatic regimes on the crop (Fenner, 1998). The observed cycle for 'Tupy' and 'Xavante' blackberries grown under temperate conditions in Brazil was 160 and 150 days (Antunes et al., 2000), respectively, which is significantly longer than the cycles observed in this study under subtropical conditions.

The characterization of blackberry phenological stages is essential to achieve high fruit quality and yield because a number of management practices such as pruning and the application of bioregulators, fertilizers and pesticides relies on the recognition of certain phenological stages (Salinero et al., 2009). However, as shown previously, blackberry flowering and harvest stages occur continuously across several weeks (Takeda et al., 2002), and it is difficult to identify the exact period needed for complete fruit development because within a single plant, it is common to observe fruits at different stages of ripening at the same time. For this reason, phenological information combined with other existing data are also important to evaluate the adaptability of blackberry cultivars to subtropical conditions.

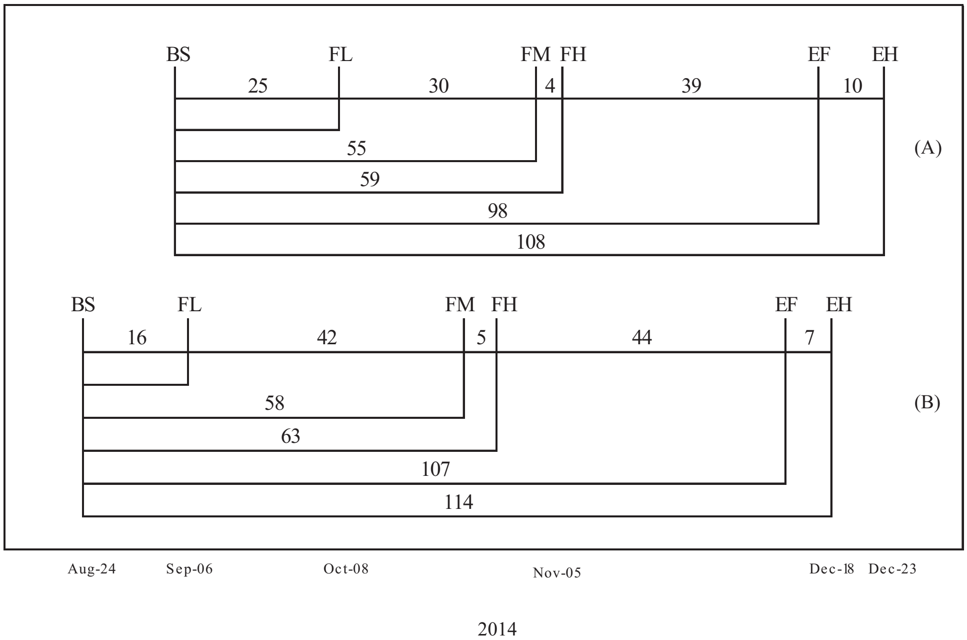

Fig. 3. Duration (in days) of phenological stages for 'Tupy' (A) and 'Xavante' (B) blackberries during the 2014 season. BS: onset of bud sprouting, SF: onset of flowering, FM: onset of fruit maturation, FH: beginning of fruit harvest, EF: end of flowering, EH: end of harvest.

Table 2
Duration of phenological stages (in days) of blackberry fruit development for 'Tupy' and 'Xavante' blackberries, season 2014.

Cultivar	Phenological stage duration (days)				
	FB-OF	OF-GB	GB-PB	PB-RB	FB-RB
Tupy	2.0 ± 0.5	6.7 ± 0.5	15.9 ± 1.4	5.0 ± 0.5	29.6 ± 1.1
Xavante	2.0 ± 0.5	4.6 ± 0.8	20.4 ± 0.8	4.0 ± 0.7	31.0 ± 0.8

FB: Flower bud, OF: Full open flower, GB: Unripe green berry; PB: Ripening pink berry; RB: Ripe berry.

The time elapsed between the flower bud and ripe berry stages of 'Tupy' and 'Xavante' blackberries was quite similar, 29.6 and 31 days, respectively (Table 2). The duration of other phenological sub-stages showed little or no difference between cultivars, except for the time elapsed from unripe green berry to ripening pink berry in which 'Tupy' took almost 5 fewer days than 'Xavante' (15.9 and 20.4, days, respectively). The phenological stage scale for blackberry fruits development proposed in this work (Fig. 1) is a useful tool that could help growers and breeders to better predict, for example, the end of harvest based on the occurrence of the last flush of flowering.

The phenological study of blackberries grown under subtropical conditions has commercial importance, as the onset of flowering, the growth development and the reproductive cycle differs among cultivars due to environmental variation (Takeda et al., 2002). In temperate climates, blackberries present defined phenological stages (Carew et al., 2000; Antunes and Raseira, 2004), but the same blackberry cultivar may show phenological variation depending on the intensity and duration of winter, with moderate winters favoring the early resumption of the growth cycle in spring (Takeda et al., 2002). The occurrence of bud sprouting and flowering may vary from year to year due to the variable cycle and chill accumulation by plants (Glozer and Ingels, 2006). The rate of reproductive bud development and differentiation in blackberries are dependent on climate, and the timing of floral bud differentiation and blooming are variable (Moore and Caldwell, 1985).

Blackberry production in the temperate zones of Brazil ranges from October to February (Antunes et al., 2000; Segantini et al., 2011), whereas in the United States the fruiting season ranges from May to August, with flowering occurring after 2 months of bud differentiation (Clark et al., 2005; Strik et al., 2008; Takeda et al., 2008). Hoover et al. (1989) considered temperature to be the cause of variation in the growth cycle at different locations within North America; in addition, Takeda et al. (2008) stated that freezing injury is the limiting factor at the northern latitudes. These observations emphasize why 'Tupy' and 'Xavante' were directly influenced by winter conditions in subtropical areas; these conditions influenced bud sprouting, flowering and the duration of the fruit harvesting period.

Based on the results obtained from this research, it is proposed that the possibility exists, not only for blackberry harvest during the summer but also for off-season blackberry production during the autumn, as has been established for table grape production in some subtropical areas. Due to the mild subtropical winter and the use of budburst stimulators in summer, it is possible to produce two crops of table grapes per year (regular and off-season crops). The regular crop begins with the end of grapevine dormancy in late winter, and harvest occurs during the summer. Where no risk of frost exists, a new cycle is initiated immediately following harvest; the grapevines are pruned and forced to sprout again by applying budburst stimulators, and an off-season crop is obtained during the autumn (Ricce et al., 2013; Khamis et al., 2015; Yamamoto et al., 2015).

In temperate areas, blackberries typically produce one crop per year due to the long period of low temperatures during autumn–winter and the higher probability of late frost compared with a mild winter. Under a two crop per year system, it is proposed that the growing season for first or regular crop would start in late winter (early August) when the plants are pruned, and the harvest would end in early summer (late December). The second or off-season growing season would start in early summer (early January) when the plants are again pruned and a budburst stimulator, such as hydrogen cyanamide, is applied to the canes, and the harvest would end in middle autumn (mid-May) when the air temperature is still favorable for fruit development.

It is known that budburst stimulators can be used to promote uniform sprouting of blackberry cultivars (Segantini et al., 2011) by modifying the flowering and fruit maturation periods of several temperate fruit species (George et al., 2002; Hawerroth et al., 2009). Thus, the second crop could allow a 3–5 month expansion of blackberry production under warmer subtropical conditions.

The expansion of blackberries to subtropical areas where the climatic conditions allow the production of two crops a year will result in an efficient use of land and manpower. Moreover, it may create the opportunity to obtain better prices by using the most suitable cultivars with expanded dates of harvest, a prolonged production season and early harvesting. The two annual crop systems also may allow growers to produce fresh blackberries year-round and to meet higher demand from processed markets.

Moreover, the cultivation of blackberry cultivars with a low chilling requirement in mild winter regions allows the harvest of fruits before the traditional harvesting period of temperate growing areas. This has an important market impact because it makes commercialization of blackberries possible during periods of lower supply.

In conclusion, 'Tupy' and 'Xavante' blackberries grown under subtropical mild winter conditions have a unique phenology, with earlier and shorter growing cycles than in temperate regions. This will improve blackberry production for consumption as fresh or processed fruits, and knowledge of how rapidly the fruit completes its ripening from flowering to harvest will allow better planning for harvesting and storage infrastructure.

Acknowledgments

The authors thank Brazilian National Council for Scientific and Technological Development (CNPq) and The World Academy of Sciences (TWAS) for financial support.

References

Alburquerque, N., Garcia, M.F., Carrillo, A., Burgos, L., 2008. Chilling and heat requirements of sweet cherry cultivars and the relationship between altitude and the probability of satisfying the chill requirements. Environ. Exp. Bot. 64, 162–170.

Allan, P., 1999. Measuring winter chilling in areas with mild winters. Deciduous Fruit Grow. 49, 1–10.

Antunes, L.E.C., 2002. Blackberry: a new crop option to Brazil. Cienc. Rural 32, 151–158.

Antunes, L.E.C., Raseira, M.C.B., 2004. Aspectos técnicos da cultura da amora-preta. Pelotas: Embrapa Clima Temperado., 54 (documentos, 122).

Antunes, L.E.C., Chalfun, N.N.J., Regina, M.A., Hoffmann, A., 2000. Blossom and ripening periods of blackberry varieties in Brazil. J. Am. Pomol. Soc. 54, 164–169.

Arnold, C.Y., 1960. Maximum–minimum temperatures as a basis for computing heat units. J. Am. Soc. Hortic. Sci. 76, 682–692.

Black, B., Frisby, J., Lewers, K., Takeda, F., Finn, C., 2008. Heat unit model for predicting bloom dates in *Rubus*. HortScience 43, 2000–2004.

Botelho, R.V., Pavanello, A.P., Broetto, D., Scisloski, S.D.F., Baldissera, T.C., 2009. Phenology and yield of thornless blackberry cv: Xavante in the region of Guarapuava-PR. Sci. Agrar. 10, 209–214.

Carew, J.G., Gillespie, T., White, J., Wainwright, H., Brennan, R., Battey, N.H., 2000. Techniques for manipulation of the annual growth cycle in raspberry. J. Hortic. Sci. Biotechnol. 75, 504–509.

Childers, N.F., Lyrene, P.M., 2006. Blueberries for Growers, Gardeners, Promoters. E. O Painter Printing Company, Florida, 266p.

Clark, J.R., Finn, C.E., 2014. Blackberry cultivation in world. Rev. Bras. Frutic. 36, 46–57.

Clark, J.R., James, N.M., Jose, L.Z.M., 2005. 'Prime-Jan' ('APF-8') and 'Prime-Jim' ('APF-12') primocane-fruiting blackberries. HortScience 40, 852–855.

Dale, A., Sample, A., King, E., 2003. Breaking dormancy in red raspberries for greenhouse production. HortScience 38, 515–519.

Elloumi, O., Ghrab, M., Kessentini, H., Benmimoun, M., 2013. Chilling accumulation effects on performance of pistachio trees cv. mateur in dry and warm area climate. Sci. Hortic. 159, 80–87.

Fear, C.D., Meyer, M.D.L., 1993. Breeding and variation in *Rubus* germplasm for low winter chill requirement. Acta Hortic. 352, 295–304.

Fenner, M., 1998. The phenology of growth and reproduction in plants. Perspect. Plant Ecol. Evol. Syst. 1, 78–91.

George, A.P., Broadley, R.H., Nissen, R.J., Ward, G., 2002. Effects of new rest breaking chemicals on flowering: shoot production and yield of subtropical tree crops. Acta Hortic. 575, 835–840.

Glozer, K., Ingels, C., 2006. Effect of dormant application timing in 'Bartlett' pear. HortScience 41, 1031.

Harborne, J.B., Williams, C.A., 2000. Advances in flavonoid research since 1992. Phytochem 55, 481–504.

Hawerroth, F.J., Petri, J.L., Herter, F.G., Leite, G.B., Leonetti, J.F., Marafon, A.C., Simões, F., 2009. Phenology: budbreak and apple fruit production by hydrogen cyanamide and mineral oil application. Bragantia 68, 961–971.

Hoover, E., Luby, J., Bedford, D., Pritts, M., Hanson, E., Dale, A., Daubeny, H., 1989. Temperature influence on harvest date and cane development of primocane-fruiting red raspberries. Acta Hortic. 262, 297–303.

Hussain, I., Assis, A.M., Yamamoto, L.Y., Koyama, R., Roberto, S.R., 2014. Indole butyric acid and substrates influence on multiplication of blackberry 'Xavante'. Cienc. Rural 44, 1761–1765.

Jacobs, J.N., Jacobs, G., Cook, N.C., 2002. Chilling period influences the progression of bud dormancy more than does chilling temperature in apple and pear shoots. J. Hortic. Sci. Biotechnol. 77, 333–339.

Javanshah, A., 2010. Global warming has been affecting some morphological characters of pistachio trees (*Pistacia vera* L.). Afr. J. Agric. Res. 5, 3394–3401.

Khamis, Y., Roberto, S.R., Chiarotti, F., Koyama, R., Hussain, I., Souza, R.T., 2015. Control of Botrytis mold of the new seedless grape 'BRS Vitoria' during cold storage. Sci. Hortic. 193, 316–321.

Koyama, R., Assis, A.M., Yamamoto, L.Y., Borges, F.W., Borges, R.S., 2014. Exogenous abscisic acid increases the anthocyanin concentration of berry and juice from 'Isabel' grapes (*Vitis labrusca* L.). HortScience 49, 460–464.

Lyrene, P.M., 2005. Breeding low chill blueberries and peaches for subtropical areas. HortScience 40, 1947–1949.

Moore, J.N., 1984. Blackberry breeding. HortScience 19, 183–185.

Moore, J.N., Caldwell, J.D., 1985. *Rubus*. In: Halevy, A.H. (Ed.), CRC Handbook of Flowering, 4. CRC Press, Boca, Raton, Fla, pp. 226–238.

Petri, J.L., Hawerroth, F.J., Leite, G.B., 2008. Phenology of wild apple species like pollinators of Gala and Fuji cultivars. Rev. Bras. Frutic. 30, 868–874.

Powell, L.E., 1987. Hormonal aspects of bud and seed dormancy in temperate-zone woody plants. HortScience 22, 845–850.

Ricce, W.S., Caramori, P.H., Roberto, S.R., 2013. Climatic potential for grape production under double annual pruning system in the State of Parana, Brazil. Bragantia 72, 408–415.

Salinero, M.C., Vela, P., Sainz, M.J., 2009. Phenological growth stages of kiwifruit (*Actinidia deliciosa* 'Hayward'). Sci. Hortic. 121, 27–31.

Santos, A.M., Raseira, M.C.B., 1988. Lançamento de Cultivares de Amoreira-Preta. EMBRAPA-CNPFT, Pelotas, p. 7 (informativo, 23).

Sato, A.J., Jubileu, B.S., dos Santos, C.E., Bertolucci, R., Silva, R.A.L., Carielo, M., Guiraud, M.C., Fonseca, I.C.B., Roberto, S.R., 2008. Phenology and thermal demand of 'Isabel' and 'Rubea' grapevines on different rootstocks in North of Parana. Semina 29, 283–292.

Scariotto, S., Citadin, I., Raseira, M.C.B., Sachet, M.R., Penso, G.A., 2013. Adaptability and stability of 34 peach genotypes for leafing under Brazilian subtropical conditions. Sci. Hortic. 155, 111–117.

Segantini, D.M., Leonel, S., Ripardo, A.K.S., Auricchio, M.G.R., 2011. Growth regulators use for dormancy breaking and influence in blackberry. Rev. Bras. Frutic. 33, 275–280.

Souza, V.R., Pereira, P.A.P., Silva, T.L.T., Oliveira Lima, L.C., Pio, R., Queiroz, F., 2014. Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry red raspberry, strawberry, blueberry and sweet cherry fruits. Food Chem. 156, 362–368.

Strik, B., Clark, J.R., Finn, C.E., Buller, G., 2008. Management of primocane-fruiting blackberry to maximize yield and extend the fruiting season: proc. IX. international *Rubus* and *Ribes* symposium. Acta Hortic. 777, 423–428.

Tadeu, M.H., Souza, F.B.M., de Pio, R., Valle, M.H.R., do Locatelli, G., Guimarães, F.F., Silva, B.E.C., 2015. Drastic summer pruning and production of blackberry cultivars in subtropical areas. Pesqui. Agropecu. Bras. 50, 132–140.

Takeda, F., Strik, B.C., Peacock, D., Clark, J.R., 2002. Cultivar differences and the effect of winter temperature on flower bud development in blackberry. J. Am. Soc. Hortic. Sci. 127, 495–501.

Takeda, F., Demchak, K., Warmund, M.R., Handley, D.T., Grube, R., Feldhake, C., 2008. Row covers improve winter survival and production of western trailing 'Siskiyou' blackberry in the Eastern United States. HortTechnology 4, 575–582.

Villa, F., Pio, R., Chalfun, N.N.J., Gontijo, T.C.A., Dutra, L.F., 2003. Propagation of blackberry using of woody cutting. Cienc. Agrotecnol. 27, 829–834.

Volk, G.M., Olmstead, J.W., Finn, C.E., Janick, J., 2013. The ASHS outstanding fruit cultivar award: a 25-year retrospective. HortScience 48, 4–12.

Yamamoto, L.Y., Assis, A.M., Roberto, S.R., Bovolenta, Y.R., Nixdorf, S.L., García-Romero, E., Gómez-Alonso, S., Hermosín-Gutiérrez, I., 2015. Application of abscisic acid (*S*-ABA) to cv. Isabel grapes (*Vitis vinifera* × *Vitis labrusca*) for color improvement: effects on color, phenolic composition and antioxidant capacity of their grape juice. Food Res. Int. 77, 572–583.