Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online

WINTER COLD DEFICIT IN LOW SUBTROPICAL CLIMATE REGION AND BLACKBERRY VARIETIES PHENOLOGY

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SAP 23610 Received: 20/06/2019 Accepted: 25/09/2019
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 19, n. 1, jan./mar., p. 66-71, 2020

ABSTRACT - In the western region of Paraná, the subtropical climate prevails, with little accumulation of hours of cold in the winter, making the fruit species not go into complete dormancy. Given the above, the objective of this study was to evaluate the effect of chemical defoliant on blackberry varieties, aiming at their complete defoliation and induction of numbness. The work was conducted at Unioeste, Marechal Cândido Rondon *Campus*, in a four-year-old orchard of plants, spaced 3 x 0.5 m, simple spreader with two wire strands at a height of 120 cm from the ground, and 20 plants per grow crops. The experimental design used was randomized blocks, where two treatments related to the application of defoliant (with and without) on 7 cvs were evaluated blackberry, containing three replicates and three plants in each cultivar. Was used as a defoliant lime sulfur applied in August pruning then held 25 days after application. Regarding fruit quality, Caigangue and Tupy varieties showed the highest SS/AT ratio, indicating the best flavor of their fruits for fresh consumption. The cultivars Brazos and Guarani showed lower SS/AT ratio, indicating more acidic fruits. Higher levels of ascorbic acid were found in fruits of cvs. Guarani and Cherokee. The application of defoliant reduced the total number of blackberry fruits of the cultivars Comanche and Guarani. The use of defoliant did not interfere in the physicochemical characteristics of the blackberry fruits of the evaluated cultivars.
Keywords: *Rubus* spp., small fruits, dormancy, defoliant.

RESUMO - Na região oeste do Paraná predomina o clima subtropical, com pouco acúmulo de horas de frio hibernal, fazendo com que as espécies frutíferas não entrem em completa dormência. Diante do exposto, objetivou-se com o presente trabalho avaliar o efeito de desfolhante químico sobre cvs. de amoreira-preta, visando à completa desfolha das mesmas e indução de dormência. Conduziu-se o trabalho na Unioeste, *Campus* Marechal Cândido Rondon, em pomar de plantas de quatro anos, com espaçamento 3 x 0,5 m, espaldeira simples com dois fios de arame a uma altura de 120 cm do solo, e 20 plantas por cultivar. O delineamento experimental utilizado foi blocos ao acaso, onde se avaliaram dois tratamentos relativos à aplicação de desfolhante (com e sem) sobre 7 cvs. de amoreira-preta, contendo três repetições e três plantas em cada cultivar. Como desfolhante utilizou-se calda sulfocálcica aplicada em agosto, seguida da poda, realizada 25 dias após sua aplicação. Em relação à qualidade de frutos, as cvs. Caigangue e Tupy foram as que apresentaram maior relação SS/AT, indicando melhor sabor de seus frutos para consumo *in natura*. As cultivares Brazos e Guarani apresentaram menor relação SS/AT, indicando frutos mais ácidos. Maiores teores de ácido ascórbico foram encontrados nos frutos das cvs. Guarani e Cherokee. A aplicação de desfolhante reduziu o número total de frutos de amoreira-preta das cultivares Comanche e Guarani. O uso de desfolhante não interferiu nas características físico-químicas dos frutos de amoreira-preta das cultivares avaliadas.
Palavras-chave: *Rubus* spp., pequenos frutos, dormência, desfolhante.

INTRODUCTION

The blackberry, along with other small fruits, has been gaining worldwide attention by technicians and producers, but in Brazil, it is less widespread, with a total cultivated area of approximately 450 ha (GONÇALVES et al., 2011). This cultivation grows year by year because it is a crop with a low cost of implantation and maintenance, due to its rusticity, high productivity, nutritious fruits and also for its beneficial health effects, anticancer activity, antioxidant and anti-inflammatory (HUSSAIN et al., 2016).

The plants belong to the genus *Rubus*, family Rosaceae and, containing more than three hundred species, native to Europe, Africa, Asia and America. The blackberry has a arbust growth habit, erect or creeping, and aggregate type fruits with acid to sweet-acid flavor and black color, but rarely reddish, white or green (CURI et al., 2015; CAMPBELL et al., 2017), can be consumed *in natura* or industrialized (ANTUNES et al., 2014).

Studies on this small fruit, related to edaphoclimatic adaptations are still incipient, but recent works have generated important information about the behavior of cultivars in regions where predominate the

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subtropical area (ROTILI et al., 2019; CAMPAGNOLO & PIO, 2012a; VILLA et al., 2014).

Except for the regions of Brazilian temperate climate, some other regions where the blackberry is cultivated do not have enough cold winter hours to cause the total fall of the leaves, being this important process for the entry into dormancy of these plants, phenomenon which in temperate fruit confers the ability to survive at inappropriate temperatures (HAWERROTH et al., 2010), in addition to influencing vegetative development and reproductive capacity.

The blackberry needs temperatures below 7.2°C for a period of 100 to 1000 h, depending on the cultivar, so that it can overcome dormancy (SHAKER & ANTONIOLLI, 2009). The overcoming of dormancy in regions with insufficient cold accumulation is the main factor limiting this type of fruit specie. For regions of subtropical and/or tropical climate, there are cultural practices that, in a way, supply this deficit of cold hours, such as chemical defoliation (HEIDE & SONSTEBY, 2011).

Being the Marechal Cândido Rondon municipality (Paraná, Brazil) is situated in a subtropical climate area, the necessity of inducing the blackberry leaves fall into dormancy is necessary. In view of the above, the objective of this study was to evaluate the use of defoliant in blackberry varieties, replacing the winter cold deficit, your phenology and production.

MATERIAL AND METHODS

The experiment was carried out at the Experimental Farm "Prof. Antônio Carlos dos Santos Pessoa", belonging to the State University of the West of Paraná (Unioeste), located at 472 m altitude, in the parallels 24º35'42" south latitude and 53º59'54" west longitude. According to the Köppen classification, the climate is *Cfa* (humid subtropical zone), with average maximum annual temperature of 29ºC and minimum of 17ºC. The soil where the matrix plants are installed is of the Eutrophric Red Latosoil type.

The experimental orchard consisted of seven blackberries cultivars (4 years old) being 'Guarani', 'Arapaho', 'Brazos', 'Cherokee', 'Comanche', 'Caigangue' and 'Tupy'. These were installed in spacing 3.0 x 0.5 m, conducted in a simple espalier, with two wire strands at a height of 120 cm of the soil, in number of 20 plants per cultivar.

For the application of the treatments, the plants were separated with bamboo cuttings and black tarpaulins. The product used as defoliant was the sulphocalcic product, with the commercial name of Sulfertilizante® (9% calcium and 20% sulfur). The dilution of the product for application occurred in the proportion of 1 L of the commercial product to 6 L of water. The product was applied at the beginning of August/2017, with a costal sprayer, so that it reached the entire foliar surface of the plants. Plant pruning and pruning were performed 25 days after application of the defoliant in both treatments. The experimental design was randomized blocks, in a 7 x 2 factorial scheme (cultivars x with and without defoliant), containing three replicates and three plants in each treatment.

Periodic monitoring of the plants was carried out, aiming at the evaluation of the phenological parameters of bud sprouting (1st visible sprouting) and flowering (1st open flower). Harvesting was done by hand, with only fruits of bright black color, indicative of complete maturation. Fifteen crops were obtained every 3 days, the first one being held on November 9 and the last on December 21.

At each harvest the fruits were separated by treatment and repetition, placed in plastic trays duly identified and taken to the Laboratory of Food Production Technology belonging to Unioeste, for the evaluation of physical and chemical parameters. The number and fresh biomass of fruits were evaluated by repetition and treatment. The longitudinal and transverse diameters were obtained through the selection of five fruits per repetition, measured with digital caliper and repeated in all harvests.

To obtain pH values and soluble solids, the five previously selected fruits were ground for total homogenization of the sample. The pH was obtained by means of bench pH meter and the soluble solids content by analog bench refractometer, with results expressed in ºBrix. Titratable acidity was determined by titration and the results expressed as percentage (%) citric acid, according to the physico-chemical methods manual of the Instituto Adolfo Lutz (IAL, 1985). For the determination of vitamin C, the standard AOAC method (BENASSI and ANTUNES, 1988) was used.

The data were submitted to analysis of variance, and the means were compared by Scott-Knott's test, at 5% probability of error, with the aid of the statistical program Sisvar (FERREIRA, 2011).

RESULTS AND DISCUSSION

The sulphocalcium product showed no significant effect on the defoliation of black mulberry plants evaluated. As for the start of sprouting, all cultivars, except 'Tupy', showed the first sprouting visible in the first half of September (Table 1).

Campagnolo et al. (2012b), Hussain et al. (2016) and Martins et al. (2019) also reported the proximity between the sprouting start dates of blackberry and raspberry cultivars, respectively, in subtropical and tropical climates, emphasizing the importance of these data, from the point of view of the allocation of these fruits in locations with conditions similar to the west of Paraná State.

The beginning of flowering of the cultivars studied occurred in October (Table 1). Brazos and Caigangue were the first to present open flower, followed by Guarani, Cherokee and Comanche. Arapaho and Tupy obtained late flowering. These results contrast with those presented by Antunes et al. (2010), who verified in Minas Gerais State, that the same cultivars began flowering in September.

TABLE 1 - Sprout start dates (1st visible sprout) and flowering start (1st open flower) of blackberry varieties, without defoliant (WD) and with application of defoliant (AD).

Blackberry varieties	Sprouting start		Flowering start	
	WD	AD	WD	AD
Guarani	12/09	12/09	05/10	05/10
Arapaho	15/09	15/09	08/10	08/10
Brazos	12/09	12/09	03/10	03/10
Cherokee	14/09	14/09	06/10	06/10
Comanche	13/09	13/09	07/10	07/10
Caigangue	15/09	15/09	03/10	03/10
Tupy	16/09	16/09	08/10	08/10

The delay in sprouting and flowering of blackberry cultivars in Marechal Cândido Rondon municipality (Paraná) can not be attributed to the use of sulphocalcium product, since this event was verified in both treatments. These flowering variations may be linked, in addition to other factors, to pruning times, conduction systems, climatic factors such as accumulation of cold hours, photoperiod and start date of higher temperatures, which favor the resumption of growth and development of plant, as well as, particular characteristics of each cultivar. All factors mentioned above may alter the intrinsic characteristics of the cultivar studied, thus modifying the productive and physiological pattern of the plant.

According to meteorological data obtained, the accumulation of cold hours for the western region of Paraná State (Brazil), in 2017, with temperatures below 7.2°C, was 180 h, insufficient to meet the minimum requirement of most blackberry cultivars, thus affecting the plants physiological processes. The phenological aspects of blackberry vary from year to year, due to the requirement in cold hours to be satisfied or not (ANTUNES et al., 2010).

Regarding the total number of fruits, there was a significant interaction between treatments, where Comanche and Guarani cultivars who received the application of sulphocalcium product, presented lower number of fruits per plant in relation to the plants that did not receive the treatment (Table 2).

TABLE 2 - Means of the total number of blackberry varieties, without defoliant (WD) and with application of defoliant (AD).

Blackberry cultivars	WD	AD
Guarani	356.33 bA*	193.66 cB
Arapaho	91.66 c	113.00 c
Brazos	633.66 a	743.00 a
Cherokee	389.66 b	286.33 c
Comanche	784.00 aA	458.00 bB
Caigangue	229.00 c	228.00 c
Tupy	696.33 a	670.66 a
CV (%)	22.44	

*Averages followed by lowercase letters differ from each other in the column and capital letters on the line, by Scott-Knott's test, at 5% error probability. CV (%) = coefficient of variation (%).

Considering that the treatment with sulphocalcium product acted negatively on the production of blackberry's fruits, based on only the treatment without syrup application, the Comanche, Tupy and Brazos cultivars obtained better results in total fruit/plant production. Campagnolo & Pio (2012b), in the productive cycle 2009/10, observed higher production of Brazos, followed by Comanche and Guarani cultivars.

Table 3 shows the number of fruits/plant, fruit fresh biomass, production and yield of blackberry plants, without significant interaction between the cultivars and the defoliant, with significance only for cultivars. Brazos was the cultivar that obtained greater production and also greater caliber of fruit, followed by Tupy and Comanche cultivars. Antunes et al. (2010) also verified the superiority of Brazos cultivar in southern Minas Gerais State, followed by Guarani, Tupy and Comanche. In relation to fruit biomass, the same authors also proved superiority of the Brazos cultivar in Pelotas municipality (Rio Grande do Sul State, Brazil).

TABLE 3 - Number of fruits/plant (NFP), fruit fresh biomass (FFB), production (PROD) and productivity (PRODT) of blackberry varieties.

Blackberry cultivars	NFP	FFB (g)	PROD (kg)	PRODT (kg ha^{-1})
Guarani	91.67 b*	4.79 c	0.44 c	2917.56 c
Arapaho	34.11 c	4.10 c	0.14 c	923.32 c
Brazos	229.45 a	6.80 a	1.56 a	10379.40 a
Cherokee	112.66 b	3.64 c	0.41 c	2721.47 c
Comanche	207.01 a	4.97 c	1.03 b	6865.01 b
Caigangue	76.17 b	4.20 c	0.32 c	2117.67 c
Tupy	227.83 a	5.57 b	1.27 b	8437.58 b
CV (%)	27.50	16.13	32.99	33.02

*Averages followed by lowercase letters differ from each other in the column, by Scott-Knott's test, at 5% error probability. CV (%) = coefficient of variation (%).

Table 4 shows soluble solids (SS), pH, titratable acidity (TA) and SS/AT ratio, showing only significant difference between cultivars. The cultivars that presented lower pH's and more acidic fruits were Brazos, Cherokee, Comanche, Caigangue and Tupy. Guedes et al. (2013) obtained a more acidic values (range 2.88 to 2.96) in Lavras municipality (Minas Gerais State) for these cultivars in relation to this work, with only the Choctaw and Comanche cultivars having pH above 3.0.

TABLE 4 - Soluble solids (SS expressed in ºBrix), pH, titratable acidity (TA expressed as % citric acid) and SS/TA ratio in blackberry fruits.

Blackberry cultivars	pH	SS	TA	SS/TA	TA
Guarani	3.33 a*	7.73 c	1.41 a	5.49 d	57.05 a*
Arapaho	3,35 a	8,37 c	1,28 b	6,56 c	48,39 c
Brazos	3,25 b	8,27 c	1,44 a	5,75 d	52,84 b
Cherokee	3,27 b	10,01 a	1,45 a	6,93 c	59,85 a
Comanche	3,20 b	9,15 b	1,36 a	6,77 c	54,02 b
Caigangue	3,25 b	10,70 a	1,24 b	8,61 a	52,38 b
Tupy	3,19 b	9,93 b	1,25 b	7,45 b	53,41 b
CV (%)	2,11	6,26	4,68	8,54	4,97

*Averages followed by lowercase letters differ from each other in the column, by Scott-Knott's test, at 5% error probability. CV (%) = coefficient of variation (%).

Factors such as climatic conditions and harvesting point may affect fruit pH values. The intensity of the solar luminosity on the plants can also affect these values and consequently, the fruits acidity. Lavras municipality (Minas Gerais State) is located in a region with high altitude, which gives it a higher incidence of ultraviolet radiation, a factor that may have influenced the greater acidity of blackberry fruits grown in this region. Soil type and nutritional deficiencies also affect the physiological development of plants and their nutritional reserves, which may affect the quality of their final product.

The soluble solids content was higher in the Caigangue and Cherokee cultivars, followed by Tupy and Comanche. Campagnolo & Pio (2012a) obtained similar results, in the 2009/10 production cycle, for Caigangue and Cherokee cultivars, with levels of 10.1 and 9.2° Brix, respectively. Raseira et al. (2004) describes that soluble solids contents found in Guarani fruits vary from 8 to 10° Brix on average, so that the variation of the values found for this parameter can be explained, with climatic differences between the two production cycles, hours of cold and precipitation.

For titratable acidity, the cultivars that presented the lowest percentage of citric acid were Caigangue, Tupy and Arapaho. Acidity and soluble sugars are important parameters used for the blackberry fruits market, and can serve as a reference for classifying fruit pulps and juice processing (HIRSCH et al., 2013).

The relationship between soluble solids and titratable acidity was higher for the Caigangue, followed by the Tupy cultivar, indicating a better flavor for *in natura* consumption of these fruits, corroborating Campagnolo & Pio (2012a), which affirm that Tupy and Caigangue cultivars are the best options for this. Brazos and Guarani showed lower relation between soluble solids and titratable acidity, characterizing more acidic taste to their fruits.

Table 4 shows the ascorbic acid content (vitamin C), where only the cultivars showed significance. Higher levels of ascorbic acid were found in Guarani and Cherokee fruits, corroboring Gündoğdu et al. (2016). Purgar et al. (2012) studied several cultivars in different regions of Mexico. These authors stated that the levels of total acidity, ascorbic acid, soluble solids, antioxidant capacity and polyphenols depend on the cultivars studied, and not only on the climatic conditions. The antioxidant properties, besides being related to the cultivars, may also depend on the conditions of plant cultivation and degree of maturity at harvest (VIZZOTTO et al., 2012; GUEDES et al., 2017; GÜNDEŞLI et al., 2019).

From the results presented, it can be observed that the use of sulphocalcium product as defoliant, in the concentration of 1 L to 6 L of water, did not have a positive effect on the cultivars of blackberry in none of the analyzed parameters. It is thus necessary to test new concentrations or products as defoliants in the blackberry instead of the winter cold deficit. It was also verified the good adaptation of Brazos to subtropical climates, as already mentioned by other authors in the literature, obtaining a high production considering the other cultivars tested in this work.

From the above, can say that the cultivation of blackberry in subtropical and tropical climates of altitude is possible and profitable. However, there is a need to carry out new work, so that the shortage of cold hours in these regions can be somehow supplied, so that the plants are completely dormant. The study of new concentrations or products for use as defoliants, replacing the winter cold deficit, besides helping dormancy of temperate fruit, can also provide uniformity of budding and flowering and quality of fruits, among other benefits.

The use of the sulphocalcium product does not replace the winter cold deficit in the region, and does not interfere in the fruits physicochemical characteristics. The Comanche and Guarani cultivars that received the defoliant had lower number of fruits. Greater productivity was obtained in Brazos cultivar. Fruits of Caigangue and Tupy cultivars are indicated for *in natura* consumption. Fruits of Brazos and Guarani cultivars were more acids.

CONCLUSIONS

The application of defoliant reduced the total number of blackberry fruits of the cultivars Comanche and Guarani.

The use of defoliant did not interfere in the physicochemical characteristics of the blackberry fruits of the evaluated cultivars.

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