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RESEARCH PAPER

Maturation and quality of 'Isabel Precoce' grape grown on different rootstocks under semiarid conditions

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Abstract

P.L. de Oliveira Fernandes do Nascimento, P.L. Dantas de Morais, M. Ferreira Melo, T. Ramalho Neta, M.A. dos Santos Morais, and C.S. Azevedo Soares Silva. 2022. Maturation and quality of 'Isabel Precoce' grapes grown on different rootstocks under semiarid conditions. Int. J. Agric. Nat. Resour. 73-84. Grapes have been produced successfully in semiarid regions, but fruit quality may be affected by rootstock selection. In this study, the 'Isabel Precoce' grape variety was cultivated onto three different rootstocks ('IAC 572', 'IAC 766', and 'IAC 313'), and the physicochemical traits of fruits were evaluated at 14, 19, 21 and 28 days after veraison skin. The results showed that bunches increased significantly in weight and color until 19 days after veraison. In addition, grapes accumulated soluble solids, sugars, and anthocyanins during 28 days of ripening. Moreover, the rootstock used affected bunch length, pulp firmness, and the sugar and anthocyanin contents, but it did not influence skin coloring. In conclusion, 'Isabel Precoce' grapes reached maximum weight at 24 days after veraison and maximum soluble solids content, titratable acidity/soluble solids ratio, anthocyanins, and total soluble sugars at 28 days. Fruit on the 'IAC 313' and 'IAC 766' rootstocks had higher total soluble solids and anthocyanins at 28 days after veraison than 'IAC 572'. 'Isabel Precoce grapes' produced in semiarid conditions showed good quality for fresh marketing and for wine production.

Keywords: Anthocyanins, environmental conditions, fruit quality, *Vitis vinifera* × *Vitis labrusca.*

Introduction

Grapes (*Vitis* sp.) are grown worldwide, and approximately 74.3 tons of fruit are produced annually from 6.9 million ha (FAOSTAT, 2017). In addition to being destined for fresh consumption, grapes are processed to produce wine, raisins, juice, jam, concentrate, and seed oils (Reisch et al., 2012).

Although grapevines originated in temperate regions, they have been cultivated successfully in the Brazilian semiarid thanks to the use of technologies such as pruning, hydrogenated cy-

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anamide and garlic extract treatments to induce budding and mineral and vegetal oils to induce flowering (Lima, 2009; Carvalho et al., 2016; Leão et al., 2020).

Many cultivars have been developed around the world, allowing the production of grapes in tropical and subtropical regions. 'Isabel Precoce' cultivar is a spontaneous somatic mutation from the 'Isabella' cultivar, a natural hybrid between *Vitis vinifera* and *V. labrusca*. Developed and launched in 2004 by Empresa Brasileira de Pesquisa Agropecuária in Brazil, 'Isabel Precoce' shows a 33-day reduction in its vegetative cycle from flowering to harvesting compared to the 'Isabella' cultivar in subtropical and tropical regions of Brazil (Camargo, 2004). Additionally, it has vigor and high productive potential and can produce over two harvests per year, and the crop can be used for both fresh consumption and wine and juice production (Camargo et al., 2008, 2011).

To obtain quality fruit, grapes must be harvested at the ideal ripening point since they are not climacteric and do not ripen after harvesting. Generally, the harvesting point is determined by measuring the soluble solids content in the field. However, other attributes, such as acidity and sugar, anthocyanin and polyphenol contents, may also affect the quality of the wine and juice produced, as well as the organoleptic and functional qualities of fruits for fresh consumption (Fogaca & Daudt, 2015). Such characteristics depend on extrinsic factors such as climate (Xu et al., 2011) and intrinsic factors such as cultivars and hybrids (Ćurko et al., 2014; Tecchio et al., 2020).

Each grapevine phenological stage demands proper light, water, and heat intensity to develop and produce quality fruits (Guerra et al., 2005), which shows the strong influence of climate on the crop cycle and fruit ripening. The onset of ripening starts when berry color changes from green to purple, pulp starts softening, and ripening extends until harvest, when berries must be fully ripe (Coombe, 1995; Blouin, 2004; Dias, 2006). Such a period can extend from 30 to 70 days, depending on cultivar and edaphoclimatic conditions (Mota et al., 2006).

Moreover, rootstocks may influence plant development and thereby the postharvest quality of fruit (Silva et al., 2018). Rootstocks were developed from North American species, including *V. riparia*, *V. rupestris*, and *V. berlandieri*, and have focused on providing protection against phylloxera and nematodes as well as adaptation to high or low pH and water-stressed conditions (Reisch, 2012). Thus, the objective of this research was to evaluate the maturation and quality of 'Isabel Precoce' grape grown on different rootstocks under semiarid conditions.

Materials and methods

Experimental area and crop management

Vines were evaluated from December 2014 to March 2015 at the Rafael Fernandes Experimental Farm, Federal Rural University of Semiarid (UFERSA), Mossoró city, Rio Grande do Norte state, Brazil (5°11'S, 37°20'W, 18 m above sea level). The soil in the experimental site was classified as a Red Yellow Argisolic Sandy Latosol (Santos et al., 2018), and the climate was classified as 'BSh' according to the Köppen classification. Climatic data during the experiment were recorded by the weather station located at the experimental farm (Table 1).

The experiment consisted of an orchard of 'Isabel Precoce' (*Vitis vinifera* × *Vitis labrusca*) grapevines grafted onto three different rootstocks: 'IAC 313' Tropical (*V. riparia* × *V. rupestris* × *V. cinerea*), 'IAC 572' Jales (*V. caribaea* × 101-14 Mgt), and 'IAC 766' Campinas (106-8 Mgt × *V. caribaea*). The cultivars are retained by Empresa Brasileira de Pesquisa Agropecuária and Instituto Agronômico de Campinas, Brazil. The bunches used for this research were harvested after eight years of installation of the orchard.

Table 1. Climatic data during the experiment in Mossoró city, Brazil.

Year	Month	Relative Humidity (%)	Temperature (°C)	Rainfall (mm)
2014	December	61.3	28.2	0.00
	January	60.0	28.41	4.57
2015	February	68.0	27.76	13.87
	March	73.0	26.78	45.88

Plants were trained in the "y" trellis system under three wires, north–south oriented, with 3 × 2 m spacing (1,667 plants ha^{-1}) and irrigated by a microsprinkler system. During vegetative growth, plants were pruned, leaving two main shoots and 10 lateral shoots each.

Fruit pruning was performed on December 18, 2014. Subsequently, branch lashing, top trimming, and branch, inflorescence and berry thinning were performed during crop growth to train the canopy and to achieve good fruit production (Lima, 2009). Additionally, 5% hydrogenated cyanamide (Dormex®) was applied to shoots to induce bursting.

Plants were fertilized with five tons of organic compost per hectare and chemical fertilizer (Fosfitotal Ultra Abs, Intercuf, Campinas, Brazil). The fertilizer is composed of 600, 42, 30, 6, 1, 6, 35, 1, 1, and 60 g kg^{-1} phosphorus, calcium, magnesium, boron, cobalt, copper, manganese, molybdenum, nickel, and zinc, respectively. Moreover, plants were fertigated with 2.0 kg of urea for seven days after pruning.

Weed control was performed by weeding and mowing in addition to the application of straw mulch [*Copernicia prunifera* (Miller) H.E. Moore leaves] in the rows, aiming to reduce weed infestation, maintain soil moisture and improve soil microbiology. Powdery mildew and mildew control was performed using Dimetomorph (Forum®, BASF) and benzimidazole (Viper®, IHARABRAS), respectively, at the minimum level recommended by the manufacturer, with a 15-day interval between the first and second applications.

Fruits were harvested at different ripening stages to evaluate ripening evolution from veraison. Five growth stages were identified after pruning (Coombe & Coombe, 1995): shoot and inflorescence development (S1), flowering (S2), berry development (S3), fruit ripening (S4), and senescence (S5). Into maturation, the stage veraison corresponds to the onset of ripening. Therefore, fruit was harvested at 14, 19, 21 and 28 days after veraison and then transported to the Physiology and Postharvest Laboratory at UFERSA for physicochemical trait evaluation.

Physicochemical trait evaluation

Bunch weight (g) was determined using an analytical scale, and bunch length (cm) and diameter (cm) were determined using a digital caliper. Additionally, the number of berries per bunch was counted.

Samples of ten berries from the upper, lower, and middle regions of each bunch were taken, and skin color was determined using a colorimeter positioned at the equatorial region of each berry. The CIELCH space was used, where L* is the luminosity, C is the chroma, and H is the Hue angle. Additionally, the color index for red table grapes (CIRG) was calculated using the formula [CIRG=(180-H)/(L*+C)] proposed by Carreño et al. (1995).

Additionally, a sample of 10 berries per bunch was used to determine firmness (N) using a texture analyzer (TA. XTExpress, Stable Micro Systems, Surrey, United Kingdom) equipped with a 2-mm cylindrical plunger. The equipment was programmed to insert a plunger to an 8-mm distance at a 2-mm s^{-1} speed test and a 5-g trigger force.

Subsequently, the berries were processed in a kitchen blender to obtain pulp and determine the pH, soluble solids content (SS, expressed in % fresh weight), titratable acidity (TA, expressed as a percentage of tartaric acid), taste index (SS/TA), total soluble sugars (TS, expressed as g per 100 g^{-1} fresh weight), and anthocyanin content (ANT, expressed as g per 100 g^{-1} fresh weight).

The pH was determined directly by a potentiometer (Tecnal®, Piracicaba, SP, Brazil) with automatic temperature adjustment; SS was determined by direct refractometry of the grape must in a digital refractometer with automatic temperature compensation (Palette, Atago®, Tokyo, Japan) (Horwitz 2010); and titratable acidity was obtained by titration with 0.1 N NaOH using 1.0% phenolphthalein as a color indicator (Zenebon et al., 2008).

The total soluble sugars were determined according to Yemm & Willis (1954). The absorbance values at 620 nm were compared with those obtained with a calibration curve of glucose in a spectrophotometer (UV-1600 Pro-Tools, Pró-Análise, Porto Alegre, RS, Brazil). The anthocyanin content was determined according to Francis (1982). The absorbance values obtained in the spectrophotometer at 535 nm were used to calculate the anthocyanin content (absorbance × dilution factor/98.2). Total extractable polyphenols were determined by the Folin-Ciocalteu colorimetric method (Larrauri et al., 1997).

Table 2. Analysis of variance for physicochemical traits during ripening in 'Isabel Precoce' grape cultivated onto different rootstocks in the Brazilian semiarid.

SV	DF	BuW	BL	BD	NBB	BeW	Firm
Block	5	128.70$^{ns\ 2}$	61.99^{ns}	18.01^{ns}	4.05^{ns}	2.09^{ns}	0.37^{ns}
Rootstock (Root)	2	719.40*	507.26*	40.93^{ns}	74.39^{ns}	7.48^{ns}	0.53^{ns}
Error a	10	174.00	76.31	13.51	53.26	2.81	0.16
Ripening (Rip)	3	5690.60***	1530.78***	225.13***	382.72***	26.14***	33.69***
Root x Rip	6	118.80^{ns}	463.38***	20.82^{ns}	90.48^{ns}	21.43***	0.75**
Error b	45	337.20	72.91	19.24	50.26	2.81	0.19
SV	DF	SS	pH	L*	C	H	CIRG
Block	5	0.33^{ns}	0.00^{ns}	0.09^{ns}	0.02^{ns}	110.80^{ns}	0.24^{ns}
Rootstock (Root)	2	1.27^{ns}	0.01*	0.53*	0.19^{ns}	84.40^{ns}	0.34^{ns}
Error a	10	0.32	0.00	0.08	0.05	87.80	0.19
Ripening (Rip)	3	102.08***	0.39***	9.41***	3.77***	17990.80***	38.78***
Root x Rip	6	0.59^{ns}	0.02***	0.18*	0.07^{ns}	213.90^{ns}	0.57*
Error b	45	0.28	0.00	0.07	0.04	105.50	0.22
SV	DF	TA	TI	DF	ANT	DF	TS
Block	5	0.01^{ns}	0.97^{ns}	2	7.64^{ns}	3	2.42^{ns}
Rootstock (R)	2	0.11*	9.31**	2	276.73*	2	7.05^{ns}
Error a	10	0.02	0.84	4	18.79	6	2.47
Ripening (r)	3	2.15***	213.64***	3	3059.25***	3	74.06***
Rxr	6	0.14***	4.12***	6	108.14***	6	3.26^{ns}
Error b	45	0.01	0.68	18	8.64	27	2.22

SV: source of variation; DF: degrees of freedom; BuW: bunch weight; BL: berry length; BD: berry diameter; NBB: number of berries per bunch; BeW: berry weight; Firm: firmness; SS: soluble solids content; pH: hydrogen potential; L*: luminosity; C: chroma; H: hue angle; CIRG: color index for red table grapes; TA: titratable acidity; TI: taste index (SS/TA); ANT: anthocyanin content; TS: total soluble sugars.

*, **, and ***: significant at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$, respectively, by the F test.

^{ns}: nonsignificant.

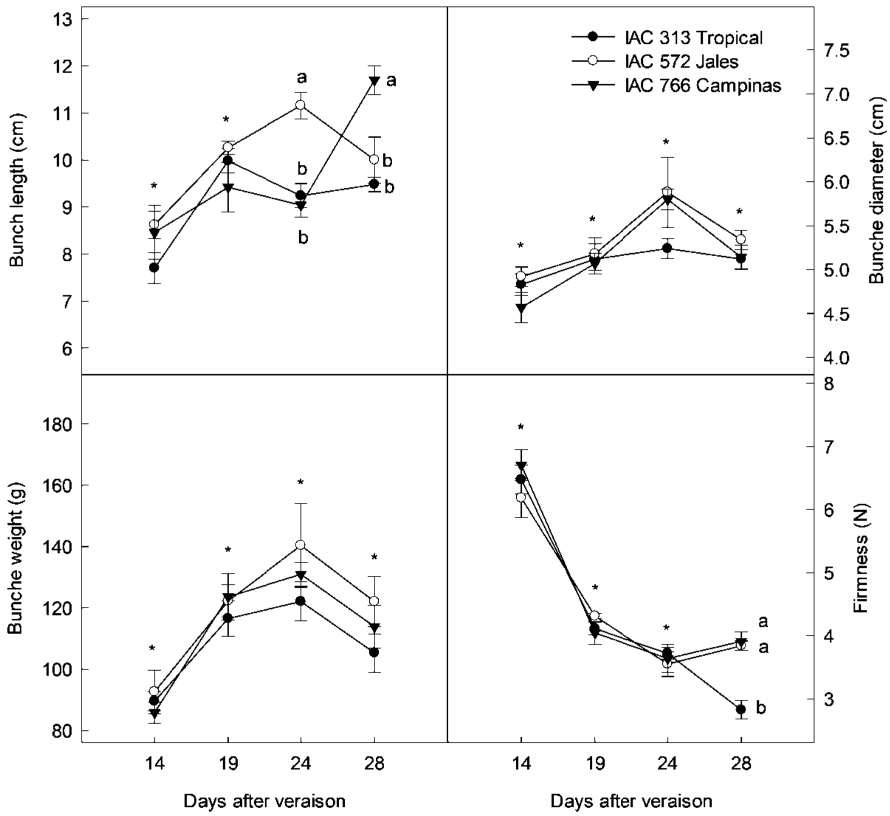

Figure 1. Changes in bunch length, diameter and weight and firmness during ripening in Isabel Precoce grapes cultivated onto different rootstocks in the Brazilian semiarid. Different letters indicate significant differences among rootstocks on each day (Tukey, $p \leq 0.05$); *: nonsignificant.

Statistical analysis

The experiment was arrayed in a completely randomized block design in a split-plot scheme (3 × 4) with six plants as replicates. Factors corresponded to rootstocks in the plot and evaluation day in the subplot. Data were submitted to two-way analysis of variance by the F test ($p \leq 0.05$), and means were grouped by Tukey's test ($p \leq 0.05$). Statistical analysis was performed in R version 4.0 (RStudio Team, 2020).

Results

Physical traits

The rootstock used affected bunch weight and length, pH, acidity, taste index, anthocyanin content, and skin luminosity (L). Additionally, the interaction between rootstock and ripening was significant for bunch length, berry weight, firmness, pH, acidity, taste index, anthocyanin content, skin luminosity, and CIRG (Table 2).

Bunches reached maximum weight (130 g average) at 19 days after veraison, while firmness declined from 6.5 N to 4.2 N, which made the fruit softer (Fig. 1). At 28 days, among the rootstocks used, 'IAC 766' produced bunches with longer lengths (117 mm). Additionally, firmness in fruits from 'IAC 31'3 was lower (2.8 N) at 28 days than in the other rootstocks (3.9 N) (Fig. 1).

Color index

The luminosity (L*) and hue angle (H) values significantly decreased during ripening, while chroma

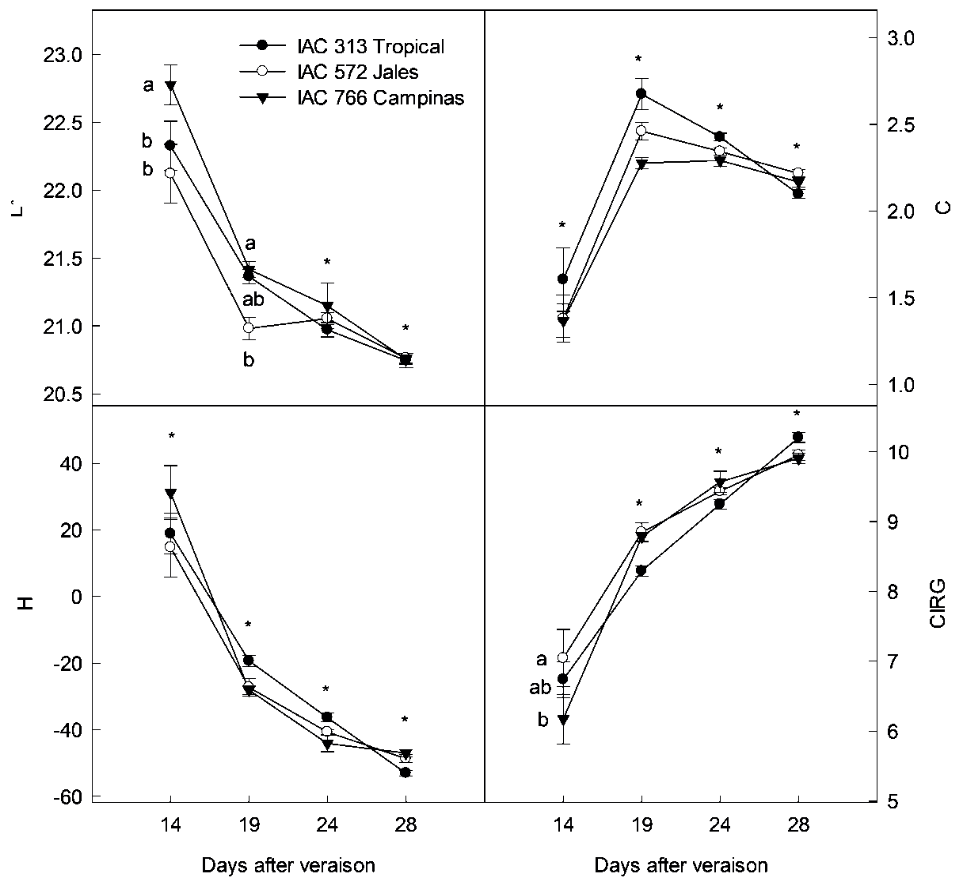

Figure 2. Changes in luminosity (L*), chroma (C), hue angle (H), and color index for red table grapes (CIRG) during ripening in 'Isabel Precoce' grapes cultivated onto different rootstocks in the Brazilian semiarid. Different letters indicate significant differences among rootstocks on each day (Tukey, $p \leq 0.05$); *: nonsignificant.

(C) increased exponentially in the first five days and then decreased slightly during ripening. This change implicated an increase in CIRG values, denoting the color change. Therefore, it can be observed that there was a great change in color that was more accentuated at 19 days after veraison. Rootstocks did not affect the skin color change during ripening (Fig. 2).

Physicochemical traits

Changes in physicochemical attributes were significantly correlated during fruit ripening (Table 3), and only C with TS and C with ANT were not correlated.

In addition to color change, there were intense accumulations of soluble solids, sugars, and grape anthocyanins during ripening. Conversely, acidity was reduced, which thus reduced the pH and increased the taste index (Fig. 3). As a result, in addition to becoming purple and softer, the grapes became sweeter and tastier after 28 days of ripening. Moreover, the 'IAC 313' rootstock provided fruits with higher pH and lower anthocyanin content than the 'IAC 766' and 'IAC 572' rootstocks. At 28 days, the other physicochemical attributes were not significantly affected by the type of rootstock used, although some differences were observed during ripening (Fig. 3).

Table 3. Pearson correlation analysis (r) among physicochemical traits during ripening in 'Isabel Precoce' grape cultivated in the Brazilian semiarid region.

	L*	C	H	CIRG	SS	pH	TA	TI	TS
C	-0.75**								
H	0.93**	-0.74**							
CIRG	-0.94**	0.69**	-1.00**						
SS	-0.85**	0.60**	-0.90**	0.92**					
pH	-0.72**	0.43**	-0.75**	0.77**	0.77**				
TA	0.74**	-0.52**	0.77**	-0.78**	-0.85**	-0.83**			
TI	-0.79**	0.50**	-0.84**	0.86**	0.93**	0.86**	-0.96**		
TS	-0.63**	0.38ns	-0.68**	0.69**	0.73**	0.64**	-0.72**	0.75**	
ANT	-0.65**	0.25ns	-0.71**	0.74**	0.85**	0.66**	-0.73**	0.86**	0.70**

L*: luminosity; C: chroma; H: Hue angle; CIRG: color index for red table grapes; SS: soluble solids content; pH: hydrogen potential; TA: titratable acidity; TI: taste index (SS/TA); TS: total soluble sugars; ANT: anthocyanin content.
**: significant at $p \leq 0.01$.
ns: nonsignificant.

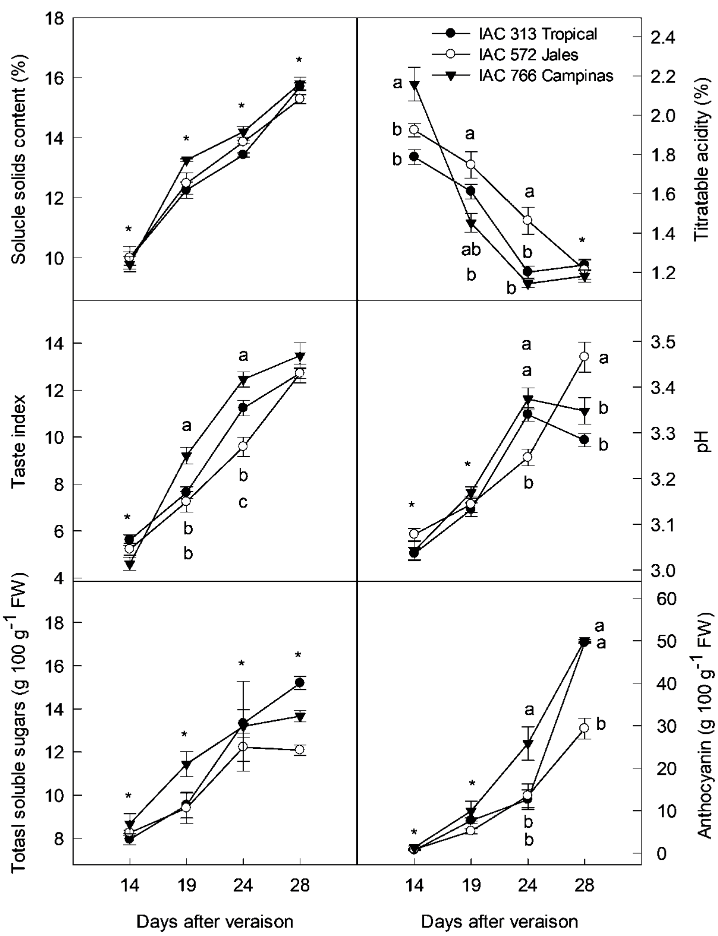

Figure 3. Changes in physicochemical traits during ripening in fruits of Isabel Precoce grapevines cultivated on different rootstocks in the Brazilian semiarid region. Different letters indicate significant differences among rootstocks on each day (Tukey, $p \leq 0.05$); *: nonsignificant.

Discussion

Pulp firmness decreases during ripening in response to cell wall degradation and water loss (Lima, 2009). Pulp firmness is maintained by calcium (Ca) and magnesium (Mg) pectate in the cell wall and middle lamella, which are hydrolyzed during fruit ripening, releasing pectic acid, Ca^{2+} and Mg^{2+} ions (Pires & Pommer, 2003). Pectates consolidate cell walls (Santana et al., 2008), and their hydrolysis causes fruit softening, which consequently reduces pulp firmness. Fava et al. (2011) reported higher pulp firmness (4.9 N) in 'Isabel Precoce' grapes than those found in this study, which can be explained by the different climatic conditions of cultivation.

The change in skin color from green to purple in grapes is attributed to the accumulation of anthocyanins during ripening, which increased the CIRG value (r=0.74). The anthocyanin concentration was negatively correlated with L* and H but positively correlated with CIRG (Table 1). Anthocyanin is a pigment responsible for the blue and purple colors in many fruits, and in addition to its use as a natural dye, these colored pigments are potential pharmaceutical ingredients that have various beneficial health effects for humans, possess antioxidant and antimicrobial activities, improve visual and neurological health, and protect against various nontransmissible diseases (Khoo et al., 2017). Synthesis is stimulated by solar radiation and temperature (Lima & Choudhury, 2007), which are typical climatic conditions present in semiarid regions.

L* decreased due to epicuticular wax (pruine) synthesis on the berry skin surface during ripening. This wax layer decreases light reflection, which decreases luminosity and gives a matte appearance to the berry surface. Luminosity is more important for table grape cultivars since fruit appearance is most attractive to consumers. As 'Isabel Precoce' grape can be destined both for fresh consumption and juice production, luminosity must also be considered as a fruit quality indicator. Outer appearance features related to luminosity and skin color were similar in grapes produced on the 'IAC 572', 'IAC 766', and 'IAC 313' rootstocks in the Brazilian semiarid.

The soluble solids content (SS) increased during ripening due to sugar accumulation (r=0.73) (Fig. 3), which is the main component of solutes in grapes. In addition, water loss during fruit ripening concentrates solutes in fruits and thus contributes to increasing SS (Pires & Pommer, 2003; Roberto et al., 2004; Lima & Choudhury, 2007). Grapes were harvested with 15.6% SS on average, which is above the 15% SS recommended for grapes commercialized in Brazil (Albuquerque, 1996; Choudhury, 2001). However, higher SS was found in 'Isabel Precoce' (21.0%), 'BRS Coroa' (22.6%) (Ribeiro et al., 2012), 'Romana', 'Niágara Rosada', and 'Corvina' cultivars (16 to 22%) (Versari et al., 2001; Silva et al., 2008), which supports that this attribute depends on the grape cultivar, crop management, and climatic conditions, mainly temperature and solar radiation.

Acidity decreases during ripening because acids may be consumed by respiration and thereby converted into other compounds (Assis et al., 2011). Consequently, the pH increased (r=-0.83), which may also be attributed to the increase in potassium concentration in fruits (Manfroi et al., 2004; Favero, 2011). The pH values in this study (3.2) are in agreement with those reported by Rizzon & Link (2006) and Mascarenhas et al. (2010). Grapes presented 1.2% TA similar to that reported by Pereira et al. (2008), who harvested grapes with 0.8 to 1.7% TA in 'Folha de Figo', 'Alwood', 'Concord', 'BRS Rúbea', and 'Isabel Precoce' grapes cultivated in Minas Gerais, Brazil. In the same region, Abe et al. (2007) harvested grapes with 0.7 to 1.1% TA from the 'Niagara Rosada', 'Folha de Figo', 'Syrah', 'Merlot', and 'Moscato' cultivars. According to Guerra et al. (2009), this acidity level is higher than that recommended for grapes intended for juice production.

The taste index (SS/TA) is a quality attribute that characterizes cultivars from a region and determines the ideal point for harvesting (Sachi & Biasi, 2008). The ideal ripening point is the one at which the grape has visual quality and has a very good balance between acidity and sweetness. However, the use of this index as a grape ripening point should be done carefully since an increase in sugar concentration does not always correspond to a decline in acidity (Rizzon & Miele, 2004; Manfroi et al., 2004).

The increase in TS was in accordance with the SS increase (8.3 to 13.6%), of which TS is the main constituent (Coombe, 1992). Grape cultivars (*V. vinifera*) destined for processing, such as 'Cabernet Sauvignon' and 'Tannat', have greater potential for sugar production than American grapes (*V. labrusca*), such as 'Isabel Precoce'. This feature, coupled with the higher residual acidity, allows high potential for vinification (González-Neves et al., 2004; Abe et al., 2007). In this study, however, 'Isabel Precoce' showed a high potential for wine production due to its high acidity and sugar content, which favors fermentation and the production of good quality wine.

In addition to being responsible for skin color, anthocyanins and phenolic compounds act in plant antioxidant systems. Additionally, these bioactive compounds help to prevent chronic diseases such as cardiovascular diseases and cancers in humans. The anthocyanin content in this study (50 mg 100 g^{-1} FW) was lower than that reported by Soares et al. (2008) (82.15 mg 100 g^{-1} FW) but higher than those reported by (Rombaldi et al., 2004) in the 'Isabel' cultivar grown under a conventional production system (13.8 to 27.8 mg 100 g^{-1} FW) and under a conservationist production system (14.4 to 28.4 mg 100 g^{-1} FW), which uses fungicides with low environmental impact.

The ANT content was negatively correlated with TA (r=-0.73), suggesting that a decline in fruit acidity may be related to the conversion of acids into anthocyanins during fruit ripening (Cabrita et al., 2000). However, the total extractable polyphenol content did not vary among the rootstocks used during fruit ripening, suggesting that the maximum level of these bioactive compounds is produced before veraison and is little affected afterward.

Conclusion

Isabel Precoce grapes reached maximum weight at 24 days after veraison and maximum quality regarding soluble solids content, titratable acidity/soluble solids ratio, anthocyanins and total soluble sugars at 28 days.

Grapevines grafted onto 'IAC 313' and 'IAC 766' rootstocks produced grapes with more total soluble sugars and anthocyanins at 28 days after veraison than those grafted on 'IAC 572'.

Isabel Precoce grapes produced in semiarid conditions showed good quality for fresh marketing and for wine production.

Resumen

P.L. de Oliveira Fernandes do Nascimento, P.L. Dantas de Morais, M. Ferreira Melo, T. Ramalho Neta, M.A. dos Santos Morais, y C.S. Azevedo Soares Silva. 2022. Maduración y calidad de la uva 'Isabel Precoce' cultivada sobre diferentes portainjertos en condiciones de semiárido. Int. J. Agric. Nat. Resour. 73-84. Se han producido uvas con éxito en regiones semiáridas, pero la calidad de la fruta puede verse afectada por el porta injerto utilizado. La uva 'Isabel Precoce' se cultivó sobre tres porta injertos diferentes ('IAC 572', 'IAC 766' e 'IAC 313') y se evaluaron las características fisicoquímicas de los frutos a los 14, 19, 21 y 28 días después del envero (cuando los frutos empiezan a madurar y la piel a colorear). Los resultados mostraron que los racimos aumentaron de peso y el color de la piel cambió significativamente hasta 19 días después del envero. Además, las uvas acumularon sólidos solubles, azúcares y antocianinas durante 28 días de maduración post-envero. El porta injerto utilizado afectó la longitud del racimo, la firmeza de la pulpa y el contenido de azúcar y antocianinas, pero no influyó en la coloración de la piel. En conclusión, la uva 'Isabel Precoce' alcanzó el peso máximo a los 24 días del envero y la máxima calidad en contenido de sólidos solubles, relación sólidos solubles /acidez titulable, antocianinas y azúcares solubles totales a los 28 días. Los porta injertos 'IAC 313' e 'IAC 766' produjeron uvas con más azúcares solubles totales y antocianinas a los 28 días después del envero que 'IAC 572'.

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