UNIVERSIDADE FEDERAL DE LAVRAS

MARAISA HELLEN TADEU

PHENOTYPIC SELECTION OF PEACH CULTIVARS FOR THE TROPICS

LAVRAS - MG

2017

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Dissertation presented to the Federal University of Lavras in partial fulfillment of the requirements of the Agronomy and Plant Science Graduate Program in Plant Production concentration area for the degree of Doctor.

Advisor

Dr. Rafael Pio

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SELEÇÃO FENOTÍPICA DE CULTIVARES DE PÊSSEGO PARA TRÓPICOS

Dissertation presented to the Federal University of Lavras in partial fulfillment of the requirements of the Agronomy and Plant Science Graduate Program in Plant Production concentration area for the degree of Doctor.

Aproved on December 1, 2017.

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To my family and friends.

I DEDICATE

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RESUMO

O pessegueiro (*Prunus persica*) é uma espécie de clima temperado e quando cultivado nos trópicos modifica o seu comportamento na superação da dormência, fenologia, produção e qualidade de fruto. Dentro deste contexto a seleção de cultivares com baixo requerimento de frio, alta qualidade de fruto e que seja precoce para aproveitar a sazonalidade do mercado é um desafio para o cultivo nos trópicos. Entretanto essas características têm relação direta com a adaptabilidade desta frutífera em locais de temperaturas amenas e sua estabilidade em relação a diversidade dos anos para cultivo nos trópicos. Contudo se torna necessário o conhecimento sobre o comportamento de diferentes cultivares nos trópicos para o sucesso da cadeia produtiva. Neste contexto, o primeiro capítulo teve como objetivo a seleção através de análise multivariada, de cultivares de pessegueiro com maior adaptabilidade e estabilidade de produção para os trópicos. O segundo capítulo, tem objetivo de avaliar a duração dos estádios fenológicos e determinar a adaptabilidade e estabilidade das fases reprodutiva e vegetativa dos pessegueiros nos trópicos com objetivo de otimizar o sistema de produção. O terceiro capítulo teve como objetivo identificar os comprimentos de onda específicos fornecidos através de diodos emissores de luz (LED) que melhoram a qualidade da fruta do pêssego pós-colheita. O quarto capítulo teve como o objetivo caracterizar e avaliar a influência de diferentes cultivares de pessegueiro (‘Aurora-1’, ‘Centenário’, ‘Biuti’, ‘Bonão’, ‘Diamante’, ‘Douradão’ ‘Libra’, ‘Tropical’ e ‘Régis’) cultivadas em regiões tropicais, sobre as características físico-químicas, propriedades reológicas e aceitação sensorial da geleia resultante a fim de identificar as cultivares com o maior potencial para a utilização industrial.

Palavras chave: *Prunus persica*. Produção. Adaptabilidade.

ABSTRACT

The peach tree (*Prunus persica*) is considered a species of temperate climate, and when cultivated in the tropics modifies its behavior in overcoming dormancy, phenology, production and fruit quality. In this context, the selection of cultivars with a low chilling requirement, high fruit quality and being precocious to take advantage of the seasonality of the market is a challenge for the researcher, as regards the growing in the tropics. However, these characteristics are directly related to the adaptability of this fruit in places of mild weather and its stability in relation to the diversity of the years for cultivation in the tropics. However, it is necessary to know the behavior of different cultivars in the tropics for the success of the productive chain. In this context, the first chapter aimed to select, through multivariate analysis, peach cultivars with greater adaptability and production stability for the tropics. The second chapter proposed to evaluate the duration of phenological stages and to determine the adaptability and stability of the reproductive and vegetative phases of the peaches in the tropics with the objective of optimizing the production system. The third chapter aimed to identify the specific wavelengths provided by light emitting diodes (LEDs) that improve the quality of postharvest peach fruit. The fourth chapter aimed at characterizing and evaluating the influence of different peach cultivars ('Aurora-1', 'Biuti', 'Bonão', 'Centenário', 'Diamante', 'Douradão', 'Libra', 'Régis' and 'Tropical') cultivated in 'Tropical' regions on the physical-chemical characteristics, rheological properties and sensory acceptance of the resulting jelly in order to identify the cultivars with the greatest potential for industrial use and to verify which cultivars present a wide range of consumption in the region of Minas Gerais.

Keywords: *Prunus persica*. Production Adaptability.

SUMMARY

1 INTRODUCTION

Native to the region of Northwest China, the peach tree is reported its existence since 20 centuries BC in Chinese literature. The peach was disseminated when China was taken to Persia where its name was originated. And from there, it was distributed by Europe (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA EMBRAPA, 2003).

The peach tree is a temperate species that has been crafted and adapted to the temperate climate conditions of the tropics. This species currently has large commercial production areas, mainly between 30 and 45º north and south latitudes. Peach acquires better quality in areas where summer temperatures are high (RASEIRA; NAKASU, 2002).

Brazil, in 2014, produced 212,509 t of peaches in an area of 18,206 ha, corresponding to a yield of 11.67 t ha^{-1}. In national terms, the South region stands out as the highest producer and the second largest in the Southeast. The State of Minas Gerais is considered the fourth largest national peach producer, with a production of 19,912 t in an area of 904 ha (AGRIANUAL, 2017).

In Brazil, improvement programs for peach trees, mainly at the Instituto Agronômico de Campinas (IAC) and Embrapa Clima Temperado, have released several cultivars with a low chilling requirement, demand less than 100 hours, adapted to the milder regions, typically in the tropics. Thus expanding the production areas in the country (SOUZA et al., 2013).

Southeastern Brazil has the economic potential for the cultivation of peach trees, with the advantage of early harvesting of fruits, when compared not only with the main Brazilian producing regions but also with the producing countries located in the Southern Hemisphere, such as Chile, Argentina, Uruguay and South Africa. Thus, the possibility of a diversity of cultivars better adapted to the tropics, whose adoption by producers could increase the income and seasonality of the product supply (LEONEL; PIEROZZI; TECCHIO, 2011).

The fruit market has a large variety of products and socioeconomic factors that it causes the consumer to demand good quality and define their standards. The interest of the consumers is good quality fruit in relation to the good aspects such as skin color, size, flesh firmness, good phytosanitary status and flavor (GIOVANAZ et al., 2014). The characteristics of fruit quality, phenology and production are influenced by the cultivar and the environment. However, the diversity in the climate in the tropics and the variations of the years become an important influence in the cultivars. As regards genotype x environment interaction, the analyzes of adaptability and stability are necessary because of the possibility to identify cultivars with predictable behavior and that are responsive to environmental variations under specific or broad conditions (CRUZ; REGAZZI; CARNEIRO, 2012).

Thus, selecting cultivars of high production, precocious and high quality is the challenge of the researchers. The techniques of multivariate analysis aim to classify the genotypes using agglomerative methods of homogeneity within groups and heterogeneity between groups (CRUZ; REGAZZI; CARNEIRO, 2012) and may be useful in recommending cultivars for certain regions.

Peach is attractive due to its fruit aroma and nice color, being consumed mainly ‘in natura’, but peaches are not available all year round and their shelf life is limited. The industrialization comes in different product forms, such as peaches in syrup, jams, juices etc. The quantitative profile of the phytochemical present in different jams of various fruit, including peach, generally did not differ from those found in the natural fruit. Another option to preserve quality postharvest physiology of crops is Light emitting diodes (LEDs). LEDs can be an effective application to extend the shelf-life, maintaining or increasing the phytochemical content and in the ripening fruits. However, studies are necessary for these alternatives to maintain postharvest quality and industrialization of jams.

This study aimed to select through phenological and productive behavior, peach cultivars with greater adaptations from the tropics, as well as to study techniques to improve fruit quality in the postharvest and the processing with the production of jellies.

2 LITERATURE REVIEW

2.1 Origin and economic importance

It is believed that peach was originally from eastern and southeastern Asia. Its cultivation may have started approximately 4,000 years ago in China. From China, peach spread along the trade routes through Persia and the Romans distributed peaches throughout Europe and these three groups are recognized as part of the origin of this fruit. The southern group of peaches originated in regions with a similar climate to the southeastern USA, with mild winters and hot wet summers. The northern group, originated in regions with a climate presenting cold winters, and hot dry summers. And the third group originated in the arid northwest regions of China (SCORZA; OKIE, 1991).

The first peaches in the American continent were brought by early Spanish explorers through Florida (USA) and Mexico (SCORZA; OKIE 1991). Native people spread early ripening yellow non-melting flesh peaches across the continent. In the 1800s, white melting flesh peach cultivars were brought into the USA by the French and the English. In this period, the peaches from the new world lacked quality and commercial attributes (SHERMAN; LYRENE; SHARPE, 1996).

In Brazil, the peach tree was introduced in 1532, by Martim Afonso de Souza, through seedlings brought from Madeira Island and planted in São Vicente, São Paulo (MEDEIROS; RASEIRA, 1998).

This peach tree is one of the species from temperate climate regions, which has been worked on and adapted to the conditions of temperate and subtropical climate. This species currently occupies large areas of commercial production, mainly between 30º and 45º, N and S latitudes, bearing in mind that peaches acquire better quality in regions where summer temperatures are high (RASEIRA; NAKASU, 2002).

The southeastern region, in places with mild climate, presents good conditions for the economical exploration of fruit trees from temperate climate, mainly due to the high altitude (RAMOS; LEONEL, 2008), and to the use of cultivars with low chilling requirement. It has been observed that, as a consequence of genetic improvement, the expansion of temperate fruit farming has progressively advanced with economic success (LEONEL et al., 2011). Brazil, in 2014, produced 212,509 t of peaches in an area of 18,206 ha, corresponding to a yield of 11.67 t ha^{-1}. In national terms, the South region stands out as the highest producer and the second largest in the Southeast. The State of Minas Gerais is considered the fourth largest national peach producer, with a production of 19,912 t in an area of 904 ha (AGRIANUAL, 2017).

2.2 Botanical classification and description of the plant

The cultivated peach, *Prunus persica* (L.) var. (Rosales), belongs to the Rosaceae family, in the Prunoideae subfamily, Prunus genus, Amygdalus subgenus, and Euamygdalus section (RASEIRA et al., 2008).

The peach tree is a fast growing plant, starting with expressive production which begins in the third year after planting (SIMÃO, 1998). When it is naturally developed, it can reach heights greater than 6m. The main stems can reach 40cm in diameter, from which vigorous branches, known as scaffolds, originate and will define the architecture of the plant (BARBOSA et al., 1990). The roots are pivotal when propagated by seed, however, in adult plants, due to lateral branching, these roots become numerous, extended and shallow, exploring an area larger than the crown projection area, reaching up to two times this area (RASEIRA; CENTELLAS- QUEZADA, 2003).

According to the distribution of flower buds, the productive branches are classified into mixed, brindilas, darts and thieves. The mixed branches present length ranging from 20 to 100 cm, with floriferous and vegetative buds, usually ending in vegetative bud. Brindilas are thin and flexible branches, between 15 and 30 cm in length, where floriferous buds prevail. Its apex may have both vegetative and flower buds. Darts are short branches with approximately 5 cm, which has vegetative apical bud and various flowering buds, between 4 and 8. The watershoots are vigorous, originating from the base of the plant or stem, they grow vertically and may emit secondary branches, generally useless for production as they mainly present vegetative buds (BARBOSA et al., 1990; RASEIRA; CENTELLAS-QUEZADA, 2003).

The flowers from peach trees are hermaphrodites, solitary or with two or three flowers grouped together, they have five petals, usually pink but occasionally white, five sepals, and three whorls of stamens are borne on the outer rim of the short tube, known as the hypanthium, that forms the base of the flower.

The fruit is a fleshy drupe, with an endocarp with variable size, it is flattened ovoid and has a grooved surface, and one or two seeds can be found inside it (CHALFUN JÚNIOR, 1999).

2.3 Phenology and climatic factors

Phenological stages are specific moments in the plant's cycle. Stages may coincide with phases, when they involve major changes, or simply characterize any condition within a sub-period. They are originated in order to clearly and objectively detail the stages of development of the plants for management (BERGAMASCHI, 2008).

Phenology helps selecting combinations of cultivars that provide higher yields, in order to obtain good fruiting indexes. In selecting cultivars, it is important to carry out phenological studies, which may provide the necessary information to determine which cultivars are mostly adapted to the local conditions and which are the periods of concentration of the production, thus reducing the risks and expanding offer harvest period (OLIVEIRA et al., 2013).

Flowering, sprouting and fruiting of peach trees and temperate fruits generally vary according to location and year, both being strongly influenced by climatic variations, mainly temperature. Thus, knowledge about local microclimatic conditions and their influence on flowering and vegetative buds, overcoming endodormancy as well as the phenological and productive behavior of the peach tree is fundamental for the implantation of certain varieties adapted to the region in order to be successful (NIENOW; FLOSS, 2002).

Basically, the factors that determine the adaptation of temperate fruits to tropical regions are the ability by the cultivar to sprout, bloom, and grow satisfactorily and produce quality fruits at temperatures that are generally above the optimum average. These factors are directly related to the chilling requirement of the species and / or cultivar (CITADIN, 2001). Dormancy is an adaptive trait that is typical of natural selection. The majority of deciduous species must meet a chilling requirement in order to break dormancy and heat requirement in order to bloom (CAMPOY et al., 2012). The chilling requirement may differ according to species, varieties, or growing regions (WANG; ZHU; FANG, 2012).

The dormancy was defined as a physiological phenomenon characterized by absence of visible growth and reduced metabolic activity (SAMISH, 1954). For Lang (1987) this period is divided into para-dormancy, eco-dormancy and endo-dormancy. Para-dormancy is to the correlative inhibition in which the growth of an organ is inhibited by the action of one or more organs. Elimination or suppression of the inhibitory organ allows almost immediate resuming of growth. Eco-dormancy is caused by one or several environmental factors (temperature, water stress, and others) that are unsuitable for the development of the buds.

Endo-dormancy is the inhibition of growth which is intrinsic to the considered structure and has its effect eliminated by the exposure to temperatures close to 7°C.

Chilling requirement is the main factor in determining the bloom date (RUIZ; CAMPOY; EGEA, 2007), which is an important agronomic trait affecting fruit development in temperate fruit trees. Cultivars with low chilling requirement always bloom and ripe precociously, while those with high chilling requirement bloom and ripe later in comparison (SCORZA; OKIE, 1990). Previous studies have indicated that chilling requirement is a quantitative character controlled by at least one major gene (HAUAGGE; CUMMINS, 1991).

Each cultivar requires a certain period of time at low temperatures in order to overcome endo-dormancy (OJIMA et al., 1984). The sum of hours with temperatures lower than 7.2°C is one of the methods used to calculate the chilling requirement of temperate plants. However, according to Erez and Lavee (1971), temperatures above 7.2°C can also be effective in opening buds. Studies have shown that temperatures as high as 12.4°C also influence plant dormancy, especially for low chilling requirement cultivars (PETRI; HERTER, 2004).

Although widely used, the germplasm classification according to chilling requirement under 7.2ºC has been gradually less accepted due to the fact that temperatures below 12ºC are effective in overcoming endo-dormancy in peach cultivars with low chilling requirements (CHAVARRIA et al., 2009). These characteristics allow the spread of farms growing these species in regions with mild winter, and low accumulation of cold hours during the winter.

Difficulties to enter and outcome endo-dormancy and delay in sprouting have also been associated to a lack of adaptation by temperate species when cultivated in subtropical climates (LABUSCHAGNE et al., 2002). Cultivars with greater chilling requirement begin to drop the leaves precociously in the tropics when compared to cultivars with lower chilling requirement. In these plants, the period of endo-dormancy begins earlier and is extended, inducing the budding to form late, and which give rise to weak lateral shoots with staggered formation. However, low-requirement cultivars enter endo-dormancy later, and the period between the end of defoliation and flowering lasts sometime between three to five weeks, under Mexican planting conditions (PÉREZ, 2002).

Low flowering rates, and many times lack of fruiting, are also indications of inadequate cold accumulation during winter for flower development and lack of climatic adaptation by the cultivar and/or species (OUKABLI; MAHHOU, 2007). For peach trees under mild winter conditions and inadequate cold hours accumulation, the number of aborted floral buds is greater than necrotic vegetative buds (MONET; BASTARD, 1971)

Besides being adequate, accumulation of cold and heat to overcome endo-dormancy and eco-dormancy, respectively, several other factors are linked to the good production of temperate fruit, especially peach trees. Among them, factors prior to flowering, such as the formation of good numbers of flower buds and the maintenance of the fruits after flowering (BELLINI; GIANELLI, 1975). In peach trees, the floral bud induction occurs after the period of vegetative growth (MONET; BASTARD, 1970). Okie and Werner (1996) found a great effect by the cultivar on the density of flower buds in peach and nectarine trees.

The effect of the temperature on the formation of the buds varies according to the stage in which the bud is found. During differentiation, temperatures close to or higher than 25°C are harmful. In the period of slow growth, called endo-dormacy period, the buds present high sensitivity to moderate temperatures. At the fast growing stage, the early flower stage has a sensitivity to low temperatures (MONET; BASTARD, 1971).

Temperatures in pre-flowering also affect the fruit-set. In peach trees, high temperatures have a negative influence on some cultivars (COUTO et al., 2010). Floral buds exposed to temperatures around 25°C presented damaged tissues (MONET; BASTARD, 1971). A negative correlation between fruit set and high temperatures in the pre-flowering period was also observed for apple trees (JACKSON; HAMER; WICKENDEN, 1983) and cherry trees (BEPPU et al., 1997). On the other hand, low temperature in pre-flowering have shown a positive effect for pear fruit (BROWNING; MILLER, 1992).

Citadin et al. (2003) studied the heritage of heat requirement for flowering, which tended to delay flowering, however, without delaying the budding stage with the same intensity. The same authors propose that the genes related to chilling and heat requirement exerted a very similar degree of influence over the time peach trees take to blossom, however, in the vegetative buds, the influence of the genes that control the chilling requirement is superior, indicating that in the genetic control for heat requirement is different for floral and vegetative buds. Selection based on heat requirement would be more effective for floral buds, and selection based on chilling requirements would be more effective for vegetative growth. Therefore, the behavior of some cultivars that sprout before flowering is explained by the assumption that they present a greater heat requirement for flowering than for sprouting. Selection of cultivars with a low chilling requirement for budding and flowering, but with a high heat requirement, especially for flowering, may be an interesting strategy to avoid damage caused by late frost in mild climate regions, with great fluctuation in temperature during the endo-dormancy period.

The flowering period of the peach trees vary according to the intensity of the endo-dormancy of the buds and the temperature. In places with a low heat accumulation, the flowering is precocious, and the flowering period is longer than in locations where winter comes later (SZABÓ; NYÉKI; SZALAY, 2000). The beginning of flowering is also affected by temperature. In temperate climates, flowering occurs between the seventh and fourteenth day before sprouting (SHERMAN; LYEEN, 1998), but under subtropical climate conditions, such as those found in the South and Southeast of Brazil, some cultivars with low chilling requirements present sprouting before flowering (NIENOW; FLOSS, 2002; SILVEIRA, 2003).

The physiological and functional processes in the plants occur over thermal limits in their environments. To complete each physiological sub-period, an accumulation of a certain amount of heat is required. Typically, this accumulation of heat is expressed with Growing Degree Days (GDD) and represents the sum above a minimum base temperature (LEITE et al., 2005). The accumulation of heat units (GDD) can provide the measurement of biological development or growth rates, which are linearly related to temperature (CESARACCIO et al., 2001).

The calculation of degree-days, the base temperature for the species is subtracted from the average daily temperature in the study site (BRUNINI et al., 1976) and the result corresponds to the number of accumulated degrees-days during the day, above the base temperature (SHAYKEWICH, 1995). The base temperature is the minimum temperature below which the plant slows its development (SHAYKEWICH, 1995; SOUZA, 1990), being specific for each species. Each degree above the base temperature corresponds to one degree-day. Each plant species has a base temperature for different phenological phases or a single value may be adopted for the entire crop cycle (PEZZOPANE et al., 2008). In the literature there are different values for base temperature in the calculation of degree-days for the culture of the peach tree: Dejong and Grossman(2005) used 7°C in studies carried out in the United States, as well as Citadin et al. (2001) used 4.5°C in Rio Grande do Sul, Brazil; Pérez-Pastor et al. (2004) used 6°C in southeastern Spain; Litschmann, Oukropec and Kirzan (2008) used 7°C in the Czech Republic and Gariglio et al. (2009), 4.5 °C in central-western Argentina.

2.4 Physical-chemical quality of fruit

The fruit from the peach tree is a typical fleshy drupe, with fine pericarp, fleshy mesocarp and woody endocarp. The endocarp (core) may be free from or adherent to the pulp, which may be yellow or white (SACHS; CAMPOS, 1998). The cultivars with white mesocarp are destined to the market ‘in natura’, and in general, are sweeter. The fruits with yellow mesocarp are preferred for industrialization, because they have a firmer texture and better shape conservation after cooking (BARBOSA et al., 1997).

The quality of the fruits corresponds to the set of attributes or properties that make them enjoyable as food and, consequently, these attributes are indispensable in determining consumer acceptance, and plays an important and decisive role in the marketing process. For the consumer, the quality attributes are strongly related to the sensory attributes and, among the main ones, the appearance, the texture, the nutritional value, the flavor and the aroma stand out. The joint evaluation of these properties allows the knowledge of the true value of the fruit, as well as its conservation or deterioration capacity (DAREZZO, 1998). The understanding of the physical, chemical and biochemical processes related to the different attributes is essential to optimize production and avoid losses in quality (FERNANDEZ, 2000).

These characteristics of quality are influenced by cultivar, mineral nutrition, irrigation, plant architecture, pruning, thinning, temperature, relative humidity, solar radiation, orchard location, soil properties and cultural practices (FALLAHI; MOHAN, 2000). In addition, there is a variation in fruit characteristics within the cultivars, due to the location of the fruits along the branches as there is competition between them, differences in flowering time, and the occurrence of pests (ALBUQUERQUE et al., 2004).

The sugar content and its relationship with the titratable acidity are determinant in the composition of flavor (ALMEIDA; DURIGAN, 2006), and the preference of Brazilian consumers is for fruit with low to medium acidity and with high soluble solids content (TREVISAN et al., 2010), that is, a high ratio between the soluble solids content and the titratable acidity. According to Trevisan (2003), peach cultivars with a sweet flavor have a solid soluble/titratable acidity ratio above 35 and, for more acidic fruit, this ratio can vary between 15 and 25.

The ideal harvest point for peaches is indicated by the change in the epidermis color, the aroma is attenuated and the pulp is firmer to resist damages from transportation and storage (PIMENTEL, 1978).

The peaches present an increase in the respiratory rate and the endogenous release of ethylene during its ripening, and, because of these characteristics, they are considered to be climacteric. This behavior allows the fruit, after harvesting, to continue softening the pulp, increasing sugar content and undergoing changes in color and aroma (CANTILLANO, 2003).

Peaches with non-melting texture, for the fresh market, are typically cling stone or semi free stone with firm flesh that does not breakdown as the fruit ripen (VAN DER HEYDEN; HOLFORD; RICHARDS, 1997), whereas melting-texture peaches often deteriorate in the shipping chain if harvested tree-ripe (BROVELLI et al., 1995; LESTER; SHERMAN; ATWELL, 1996). However, consumers can perceive this firmness as unripe fruit. Non-melting texture, in addition to small fruit size, in these early ripening varieties, presents significant marketing challenges to the growth of subtropical peach industry (OLMSTEAD et al., 2015).

Harvesting can be considered a critical factor influencing postharvest, because it determines fruit quality during storage and marketing (KLUGE et al., 2002). When harvested earlier, the unripe fruit does not develop good flavor, predominantly present green coloration and high firmness, it dehydrates more easily, has low sugar content, high content of acids and starch (CRISOSTO, 1994). Generally, unripe fruit are highly resistant to pathogens, becoming more susceptible at later stages of ripening (CHITARRA; CHITARRA, 2005). Opposed to that, over-ripened fruit have a short shelf-life, low firmness, and are more susceptible to infection by pathogens, therefore, they present low quality (CRISOSTO, 1994).

The main drivers in initial peach purchases are appearance and aroma, and subsequent purchases are predominantly based on flavor and textural aspects (DELGADO et al., 2013; DIEHL et al., 2013). A minimum TSS of 10% has been proposed for maximum consumer acceptance (KADER; HEINTZ; CHORDAS, 1982); however, acidity and astringency also are important drivers in peach flavor (PREDIERI; RAGAZZINI; RONDELLI, 2006). The fruit flavor can be affected by production practices (OLIENYK et al., 1997) and supply chain conditions in the postharvest (LURIE; CRISOSTO, 2005). Poor fruit quality as determined by small fruit size, low SS and reduced skin color may be driven by early harvests to minimize fruit damage in the shipping chain (KADER; HEINTZ; CHORDAS, 1982). However, breeders, fruit growers, and market intermediaries are increasingly aware of the consumer demand for better fruit flavor (YUE et al., 2014). Selection for flavor has not been a priority in perennial fruit breeding programs because of the importance of disease resistance, consistent fruit yield, and large fruit size (GALLARDO et al., 2012).

Peach is attractive due to its fruit aroma and nice color, being consumed mainly 'in natura', but peaches are not available all year round and their shelf life is limited. The industrialization in different product forms, such as peaches in syrup, jams, juices etc. Jams are more popular and consumed. The qualitative profile of carotenoids, flavonoids and other phenolics present in different jams of various fruit, including peach, generally did not differ from those found in the natural fruits (TOMÁS-LORENTE et al., 1992). The thermal treatment during jam or canning processing causes a loss of phenols and the magnitude of such a loss depends on the commodity and the processing conditions (CAMPBELL; PADILLA-ZAKOUR, 2013). Surprisingly, information on the changes occurring during peach jam processing is limited.

2.5 Effect of light emitting diodes (LEDs) on postharvest

Currently, there is a growing interest for bio-active compounds of fruits and vegetables due to their putative role in preventing diseases such as diabetes, cancer, stroke, arthritis, and also aging. A clear inverse relationship between the consumption of fruits and vegetables and the incidence of cardiovascular and cerebrovascular, degenerative, and proliferative diseases as well as mortality, has been largely proved by epidemiological studies (SUN et al, 2002). Stone fruits such as peaches contain a range of natural chemicals and pigments (phenolic compounds, ascorbic acid, vitamin E and carotenoids) (BYRNE et al., 2004). Polyphenols are the main sources of antioxidant capacity in peaches, although vitamin C and carotenoids also contribute to it. β-Carotene and β-cryptoxanthin are the main carotenoids present in peach, and they are precursors of vitamin A. They are secondary plant metabolites (GIL et al., 2002). Peaches have lower total antioxidant capacity than other fruits such as strawberry, apple, or orange (RUPASINGHE; CLEGG, 2007), but it is nutritionally important because they are one of the most important commodities consumed worldwide.

According Dalla Valle et al. (2007) the postharvest storage time is strictly correlated with antioxidant contents that are related to some chemical and physical parameters, such as flesh firmness and skin color. In particular, the authors reported that peach antioxidant content may be affected by the ripening stage at harvest, storage techniques and time elapsed between harvest and consumption, underlining that postharvest life of fruit has a deep impact on their antioxidant potential. In peaches, fruit firmness, color, and aroma were important characteristics consumers used to evaluate fruit quality when selecting fruit to be purchased (BRUHN et al., 1991).

Poor fruit quality in postharvest of peaches has been correlated to reduced consumer acceptance (CRISOSTO, 2002; DELGADO et al., 2013; OLMSTEAD et al., 2015). Light is one of the most important environmental factors affecting the phytochemical content in plant tissues (MASSA et al., 2008). Compared to conventional light sources, gallium–aluminum–arsenide light emitting diode (LED) lighting systems have several unique advantages, including the ability to control the spectral composition, small mass and volume, durability, long operating lifetimes, wavelength specificity and narrow bandwidth, relatively cool emitting surfaces, minimum heating, and photon output that is linear with the electrical input current. (BOURGET, 2008; MASSA et al., 2008). Due to the advantages, LEDs are alternative choices for investigations on the effects of specific wavelengths of light on postharvest physiology of crops (NODA; FUJITA, 2009).

Different plants exhibit different responses to different wavelengths of lights. When studying strawberries treated under different lights [UVA (385 nm), blue (470 nm), green (525 nm), red (630 nm)] the results obtained were that blue, red, and green LED improved anthocyanin content in unripe strawberries compared to dark storage; blue and green LED improved vitamin C content. Total phenolics were mostly stimulated by blue LED, total soluble solids improved greatly by green LED (KIM et al., 2011). In tomatoes, the accumulation of lycopene along with an increase in total carotenoid content was also observed in response to red light treatment (ALBA; CORDONNIER-PRATT; PRATT, 2000; LIU et al., 2009; SCHOFIELD; PALIYATH, 2005). In citrus fruit, red LED light was effective in enhancing carotenoid content, especially the content of β-cryptoxanthin, while blue LED light had no significant effect on the carotenoid content in the flavor of Satsuma mandarin (MA et al., 2012a, 2012b). In ripe green tomatoes, when using blue light (440 to 450 nm) Dhakal and Baek (2014a, 2014b) found higher content of glutamic acid and γ-aminobutyric acid measured in comparison to red light. Xu et al. (2014a, 2014b) describe that strawberries treated with blue LED (470 nm) had an increase in ethylene production, respiration, color development, total antioxidant activity, and antioxidant enzyme activity compared to the control group. Ripe green tomatoes pretreated with blue light (440–450 nm) from blue light emitting diodes (LEDs) showed results that indicate that simple single blue wavelength illumination can be an effective application to extend the shelf-life of tomatoes by delaying fruit softening and ripening (DHAKAL; BAEK, 2014a, 2014b).

2.6 Peach breeding: genetic diversity, adaptability and stability

The countries such as Brazil, Australia, Mexico, South Africa, Taiwan, Thailand and the United States have breeding programs aimed at obtaining peach (*Prunus persica* (L.)

Batsch) cultivars adapted to low chilling requirement (TOPP; SHERMAN; RASEIRA, 2008). In Brazil, the Instituto Agronômico de Campinas (IAC) and Embrapa Clima Temperado have released several cultivars with a high yield, which are characterized by a low chilling requirement, requiring less than 100 hours, adapted to the milder, typically subtropical, regions, which allowed the development of the cultivation in other regions (MONTES et al., 2008, SOUZA et al., 2013). Improving fruit quality is a goal for peach breeding programs, as it has a direct relationship with market and consumer preferences. For peach tree, quality refers to obtaining plants with high productivity, large and firm fruit, with excellent flavor, color, shape and rexture (WAGNER JUNIOR et al., 2011). In addition, it is important to note that there are no significant differences between the two varieties.

Regarding the evolution of the species, genetic variability is fundamental for natural selection and it is in the populations with genetic variability that the selection of plants with characteristics of agronomic interest, such as larger and tastier fruits, plants that are resistant to diseases and pests takes place. To achieve the goal of an improvement program, it is essential to have genetic variability in the available germplasm for breeding. Studies have already been carried out, evaluating the genetic diversity for peach (WAGNER JÚNIOR et al., 2011).

The studies on genetic diversity provide parameters for the identification of favorable parents to obtain segregating populations in hybridization programs and to obtain genetically improved populations (COSTA et al., 2006). It may even be useful in the recommendation of cultivars for certain regions when the objective is to increase the genetic base of the cultivars to be suggested to farmers (BERTAN et al., 2007).

The many methods can be used to evaluate genetic diversity, whose choice is based on the accuracy desired by the researcher, the way the data were obtained and the ease of analysis (RODRIGUES et al., 2010). The multivariate analysis techniques have been used routinely, since they simultaneously consider the evaluated characteristics of the genotypes, besides the correlation between them (CONDÉ et al., 2010). Among the multivariate statistical techniques, the main component analyzes and canonical variables and the clusters methods are mentioned (CRUZ; REGAZZI; CARNEIRO, 2012). Both agronomic, morphological and molecular characteristics, among others, can be used to quantify genetic diversity (AMORIM et al., 2007).

Most of these methods require the evaluation of genotypes in all environments. This condition is difficult to fulfill as germplasm evaluation is a dynamic process. Entries could be lost due to climatic factors, pest attack and continuous replacement of genotypes. If data sets are obtained from several locations, some genotypes may not be tested in all sites. Similarly, if yield tests are registered in different years, genotypes might not be tested yearly. Genotypes change from year to year as new genotypes become available and older ones become obsolete. Incomplete datasets require special analysis to consider all the information and minimize the chance of losing valuable genotypes (MAULIÓN et al., 2016).

The phenotypic response by each genotype to environmental variations is generally different and reduces the correlation between phenotypic and genotypic values, is necessary to carry out a large number of assessments of the genotypes, in different growing environments, in order to safely select or recommend different cultivars. However, only quantification studies and the nature of the interaction G x E do not provide detailed information about the behavior of each genotype in relation to environmental variations (CRUZ; REGAZZI; CARNEIRO, 2012). Thus, analyzes of adaptability and stability may aid in the recommendation of cultivars, since they allow the identification of predictable performance genotypes that are responsive to environmental variations (SILVA; DUARTE, 2006).

The term stability is used to characterize a genotype that shows a relatively constant yield, independent from environmental conditions. This concept of stability is named biological or static (BECKER, 1981). A consistent performance genotype in all environments does not necessarily respond to improved growing conditions with increased yield. Plant breeders, therefore, prefer an agronomic or dynamic stability concept by which genotypes are not required to respond equally to environmental fluctuations (BECKER; LEON, 1988).

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ARTICLE 1 - METHODS FOR SELECTION OF PEACH CULTIVARS FOR TROPICAL REGIONS

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Abstract

The objective of the present study was the selection of peach cultivars through multivariate analysis with greater adaptability and production stability for the tropics. Randomized plot design with 17 cultivars (‘Aurora-1’; ‘Biuti’; ‘Centenário’; ‘Delicioso Precoce’; ‘Diamante’; ‘Doçura-2’; ‘Douradão’; ‘Dourado-2’; ‘Flordaprince’; ‘Jóia-3’; ‘Kampai’, ‘Libra’; ‘Maravilha’; ‘Okinawa’; ‘Ouromel-4’; ‘Régis’ and ‘Tropical’) were evaluated during 2013-2016. The following variables were evaluated: during the production cycle of each year, the average date for the beginning of harvest (BH), phenotypic values for the period between pruning and the beginning of harvest (development cycle - DC), the number of fruit per tree (NF), accumulated production (P. Kg/tree) and estimated accumulated productivity (P. t.ha^{-1}), the length of fruit (L) and larger fruit diameter (D) were measured in mm, fruit mass (FM) and stone mass (SM) in grams (g). For the relation between soluble solids and titratable acidity (SS/TA). In order to evaluate the multivariate analysis by the cluster analysis method the cultivars were grouped into three different groups for Tocher and canonical variable, and two groups for UPGMA. The performance among the studied variables were DC and P. t.ha^{-1} according to adaptability and stability, ‘Kampai’, it had general adaptability and highest stability for DC and P. t.ha^{-1}. The analysis of selection index selected cultivars ‘Aurora-1’, ‘Centenário’, ‘Douradão’, ‘Kampai’ and ‘Régis’. The cultivars ‘Centenário’, ‘Douradão’, ‘Kampai’ and ‘Régis’ were the most adaptable and stable in relation to precocious and productivity for crops in the tropics.

Keywords: *Prunus persica*. Precocious. Production.

1 Introduction

The advantage of peach production in tropics condition regions has expanded as the plant adapted well to the areas and extended harvest period which contributes to the diversification and improvement of fruit quality and yield (Souza et al., 2013). Furthermore, this advance is due to breeding programs that develop specific cultivars, the studies on behavior in different localities and the use of special auxiliary techniques for cultivation (Souza et al., 2011). Peach trees established at low latitude regions require climatic adaptation to subtropical temperate conditions of low-chilling. The adoption of low chill peach cultivars tropics regions with mild winters enables the harvest of fruit in times when supply is lower (Barbosa et al., 2010).

Knowledge about the genetic variability of the species can be useful even when recommending cultivars for certain regions as the goal is to increase the genetic base of cultivars that will be recommended to farmers (Bertan et al., 2007). Characterization of accessions is vital to avoid loss of diversity, to preserve potential valuable traits and to identify characteristics that contribute the most to the diversity. Additionally, associations among fruit quality, agronomic and phenological traits are important as these have recognized significance for improving plant response in agricultural management, and thus in producing in uncertain climate scenarios (Barrios-Masias and Jackson, 2014).

As peach cultivars keep on producing fruit for many years, the selection of genotypes with high yield and stability throughout years would be critical for horticulturist, whose main concern is to avoid years with low production and prevent their incomes from falling. Additionally, the production stability is important to avoid disturbing the regular market supply (Maulión et al., 2016). The analysis of main components, canonical variables and agglomerative methods are included among the multivariate statistical techniques. (Cruz et al., 2012).

The interaction between endogenous and environmental factors may be different and may contribute to the adaptability and stability for budding and fructification and may affect the genotype's shoot formation (Scariotto et. al., 2013). The environmental conditions, characteristics of the locations where the genotype is established, and the variation from one year to another, play important roles in the variability regarding the need of chill conditions for each genotype, and this may affect the breaking of the endo-dormancy in buds of fruit-bearing plants in temperate climate. (Viti et. al., 2010). On the other hand, peach cultivars of poor adaptation to conditions in tropics regions can show symptoms of flowering delay, lower percentage of flowering and sprouting and, consequently, reduction in the production, with deformed fruit and with low quality (Citadin et al., 2006).

The objective of the present study was to selection through multivariate analysis, peach cultivars with greater adaptability and production stability for the tropics.

2 Material and Methods

The experiment was conducted at an experimental orchard in the south of Minas Gerais State, in the municipality of Lavras, Brazil, between 2013 and 2016. The city is located at 21°14’ South latitude and 45°00’ West longitude, at an average altitude of 918 meters. The climate is tropical climate of altitude, with dry winter and rainy summer (Alvares et al., 2013). The average precipitation during the experimental period was 1,166 mm yearly, whereas the average normal climatic rainfall was 1,530 mm; the experimental period was 364 mm lower (Figure 1).

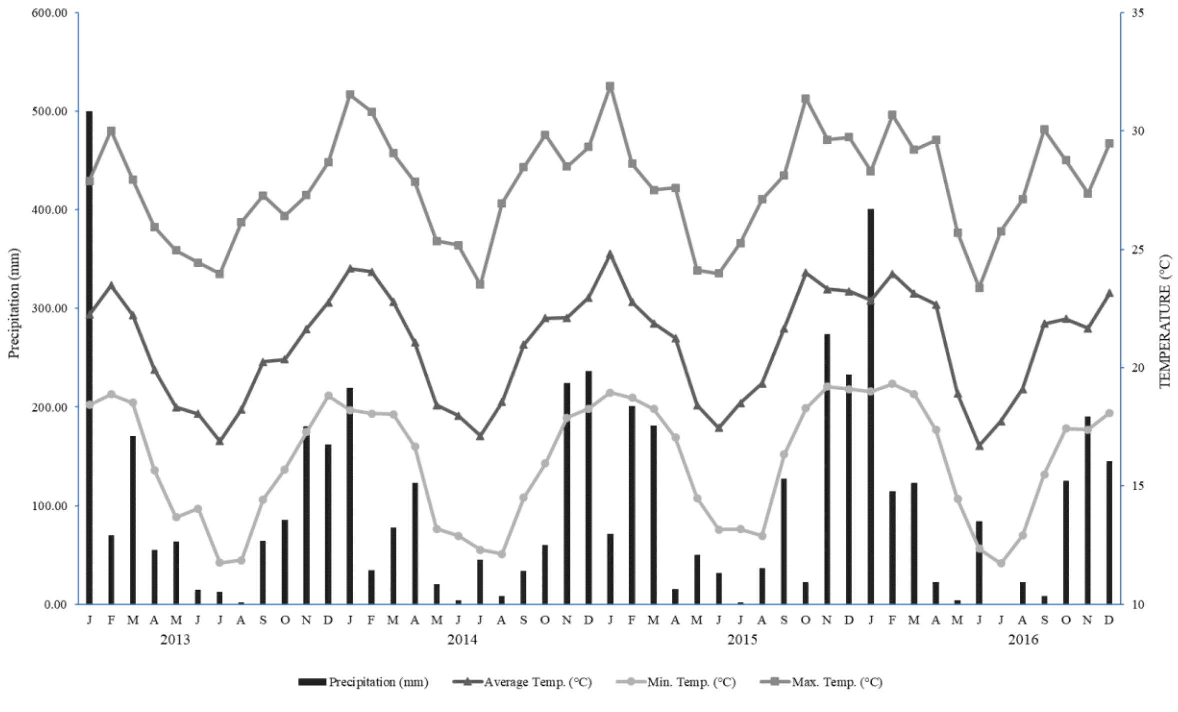

Figure 1. Climate data from January 2013 to December 2016 in Lavras, MG, Brazil.
Source: Lavras Main Climatological Station – UFLA/INMET.

The experiment was set up in a randomized plot design with 17 cultivars (Table 1 and Figure 2), three replicates, and plots consisting of two plants each. The peach cultivars were grafted on ‘Okinawa’ rootstock and were planted into the field in July 2011, spaced by 5.0m between rows and 1.5 m between plants (population density of 1,333 plants per ha), in trained to a “Y’ system. The orchard received standard fungicide and insecticide sprays and fertilization, similar to the treatments used in commercial orchards. On May 13, 2013; June 2, 2014; June 13, 2015 and May 31, 2016, defoliation was performed followed by an application of 0.25% hydrogen cyanamide (a.i.).

Table 1. List of cultivars, genealogy, and origin of cultivars evaluated.

Cultivars	Genealogy	Origin
Aurora-1	F2 of Peach ‘Tutu’ (IAC 1353-1) x nectarine ‘Colombina’ (FLA 19-37)	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Biuti	Halford-2 x Rubi	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Centenário	open-pollinated seedling of ‘Ouromel-2’ (‘Ouromel’ x ‘Sunred’)	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Delicioso Precoce	Supermel x Rubrosol	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Diamante	Convênio x Pelota 77	Embrapa Clima Temperado in Brazil
Doçura-2	‘Cristal’ (IAC 159-1) x ‘Colombina’ (Fia 19-37S)	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Douradão	Open pollination (‘Tutu’ x ‘Maravilha’) F2	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Dourado-2	‘Tutu’(IAC 1353-1) x ‘Maravilha’ (Fia. 13-72)	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Flordaprince	Fla 2-7 x ‘Maravilha’	University of Florida in the USA
Jóia-3	Catita x Rubro-sol	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Kampai	‘Chimarrita’ x ‘Flordaprince’	Embrapa Clima Temperado in Brazil
Libra	Conserva 594 x ‘Pepita’	Embrapa Clima Temperado in Brazil
Maravilha	[‘Sunred’ x 28-48(‘Okinawa’ x ‘Highland’) open-pollinated]	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Okinawa	Seedling imported to USA	Ryuku , Japan
Ouromel-4	‘Ouromel’ x ‘Rubro-sol’,	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Régis	Open pollination of ‘Petisco-2’ (IAC 370-8)	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil
Tropical	IAC P 371-2 (open-pollinated) = (‘Tutu’ x ‘Rubro-sol’) F2	IAC – Instituto Agronômico de Campinas (Campinas Agronomic Institute) in Brazil

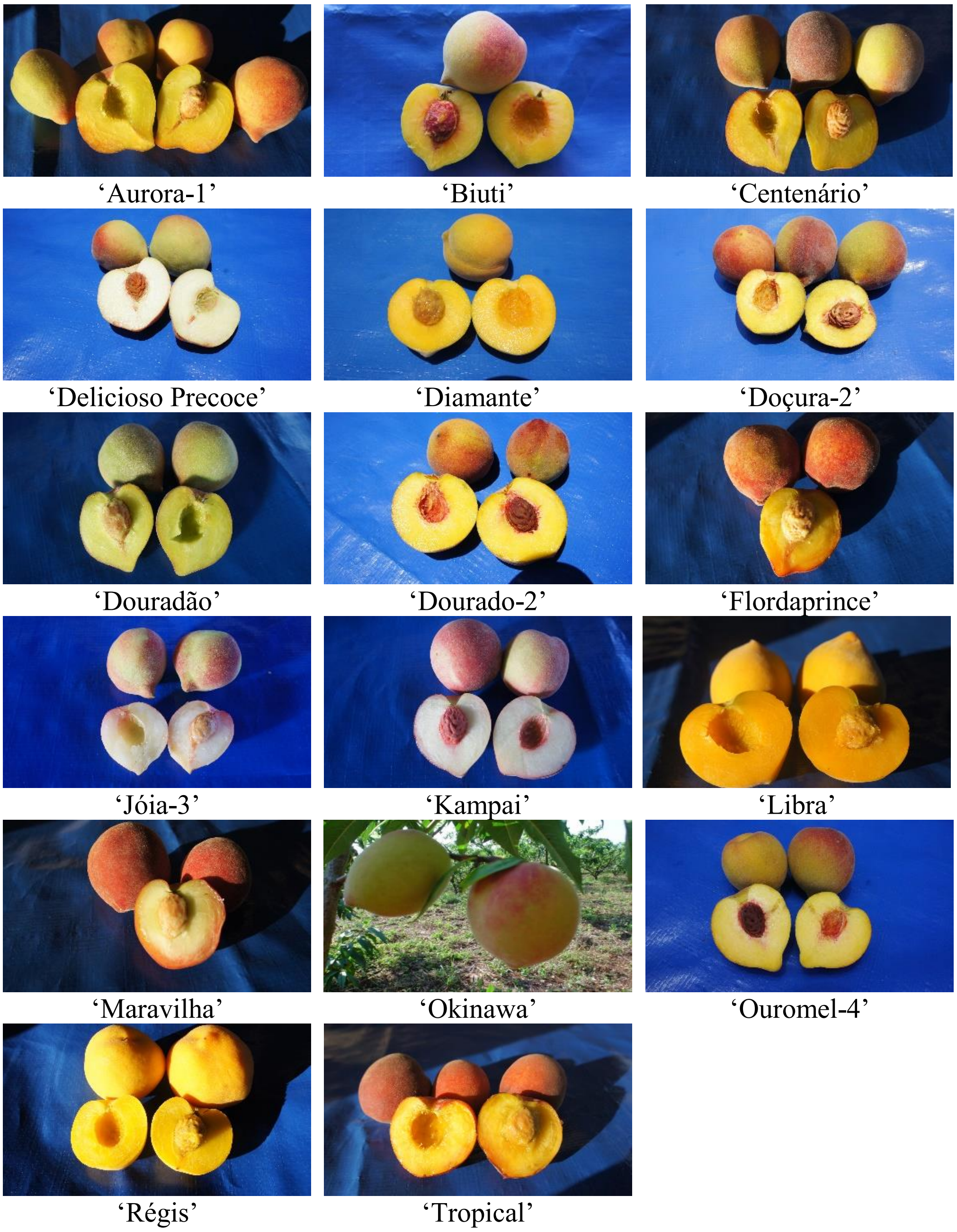

Figure 2. Fruit of 17 cultivars of peach.

Source: From the author, (2017).

During the production cycle of each year, the average date in for the beginning of harvest (BH), phenotypic values for the period between pruning and the beginning of harvest (development cycle - DC) in days were assessed. The fruits were manually harvested, using as criteria the change of background color from green to yellow or creamy white. At the end of the production cycle, all of the values were recorded in order to determine the number of fruit per tree (NF), accumulated production variables (P. Kg/tree) and estimated accumulated productivity (P. t.ha^{-1}), which was calculated by multiplying the yield by the population density (1,333 plants per hectare).

Twenty random fruit from each cultivar per year, for subsequent laboratory analysis, were collected. The assessed characteristics were physical and chemical variables. The length of fruit (L) and larger diameter of fruits (D) were measured in mm, fruit mass (FM) and stone mass (SM) in grams (g). For the relation between soluble solids and titratable acidity (SS/TA). The soluble solids content of fruits (SS) was analyzed in the juice that was manually extracted from the equatorial region from one side of each fruit, through a digital ATAGO refractometer (Palete PR-101), and the values were expressed in °Brix. The titratable acidity (TA) was determined by titrating 10g of the flesh juice with additional 50 ml of distilled water with 0.1N NaOH solution and the result was expressed in percentage of malic acid.

The data for the average of the four years were submitted to analysis of variance, and then they were grouped by using the Scott-Knott test at a 5% of error probability.

The diversity among the cultivars was evaluated by cluster analysis by using multivariate analysis, applying the Tocher optimization method (Cruz et al., 2012), the hierarchical method "Unweighted Pair Group Method with Arithmetic Mean – UPGMA", by canonical variable analysis (Cruz et al., 2004). The standardized mean for the distance by Mahalanobis (Cruz et al., 2012) was used as dissimilarity measure. Canonical Variables were also used, an alternative process to evaluate the degree of genetic similarity between genotypes that takes into account both the residual covariance matrix and the phenotypic covariance matrix as the evaluated characters (Rao, 1952). The relative contribution of features to the dissimilarity was estimated according to the criteria of Singh (1981).

The Mojena (1977) method was used to determine the optimal number of groups in the dendrogram. This method is a procedure based on the relative size of mergers levels (distances) in the dendogram and consists in selecting the number of groups on stage j which first satisfies the following inequality: $\alpha j > \theta k$, where αj is the value for the distances between the merger levels corresponding to the stage j (j = 1, 2, ..., n), and θk is the reference cutoff value expressed by $\theta k = \bar{\alpha} + k\hat{o}_{\alpha}$ where $\bar{\alpha}$ and $k\hat{o}_{\alpha}$ are, respectively, the unbiased estimates of the mean and standard deviation values of α; k is a constant. The value of k=1.25 was set as stopping rule to determine the number of groups, as suggested by Milligan and Cooper (1985).

The interaction between the years and the cultivars was presented through the method proposed by Eberhart and Russell. This method was used for the variables DC and P(t.ha^{-1}). Their model is based on computations of linear regression (βi) for each genotype compared to environmental conditions and deviation from regression (S^2di). By using regression coefficient and deviation from regression, the authors have established a method that provides estimates for stability and adaptability parameters of genotypes grown under various conditions. Genotypes in which $\beta i>1$ respond better to more favorable conditions, whereas genotypes in which $\beta i<1$ respond better to adverse environmental conditions. A stable cultivar is considered to be the one that has regression coefficient approximately at 1 and standard error of regression as low as possible. Genotypes in which $\beta i>1$ respond better to more favorable growing conditions, whereas genotypes in which $\beta i<1$ respond better to adverse environmental conditions (Eberhart and Russell, 1966).

The Mulamba and Mock selection index was used (Resende, Silva and Azevedo, 2014). The five variables adopted to perform the Mulamba and Mock selection index were precocious harvest (DC), number of fruit per tree (NF), estimated production variables (P. Kg/tree), fruit mass (FM) in grams, and the relation between soluble solids and titratable acidity (SS/TA) in peaches cultivars of average four years.

All statistical analysis were performed using GENES software (Cruz, 2013).

3 Results

The beginning of harvest (BH) took place between the end of September and the middle November. The cultivars ‘Libra’ (25/Sep. at 117 days of DC) ‘Régis’ (25/Sep. at 117.17 days of DC) and ‘Flordaprince’ (26/Sep. at 118.92 days of DC) were precocious, whereas ‘Biuti’ (20/Nov. at 173 days of PC) was late. The cultivars with the highest number of fruits per plant at harvest were ‘Aurora-1’ e ‘Biuti’ (223.25 and 195.54 fruit, respectively). While ‘Diamante’ had the lowest, averaging 27.38 fruit per plant. ‘Biuti’ showed the highest production per tree (12.82 kg) and ‘Tropical’ showed the lowest (1.56 kg). Consequently, the cultivars showed parallel results for productivity, as the highest was ‘Biuti’ (17.09 t ha^{-1}) and the lowest was ‘Tropical’ (2.08 t ha^{-1}). For the variables related to physical characteristics of the fruit, ‘Douradão’ presented the longest length (66.73 mm), the largest diameter (62.62 mm), fruit mass (119.18 g) and stone mass (6.20 g). The cultivars that showed the highest SS/TA were ‘Tropical’ (55.05), ‘Douçura-2’ (52.26) and ‘Douradão’ (51.28) (Table 2).

Table 2. Average for the beginning of harvest (BH), phenotypic values for the period between pruning and the beginning of harvest (DC) in days, number of fruit per tree (NF), estimated production variables (P. Kg/tree), accumulated production (P. $t.ha^{-1}$), length of fruit (L) in mm, larger diameter of fruit (D) in mm, fruit mass (FM) in grams, stone mass (SM) in grams and the relation between soluble solids and titratable acidity (SS/TA) in peaches cultivars of average four years in Lavras/Brazil.

Cultivars	**BH**	**DC**	**NF**	**P. kg/tree**	**P. $t.ha^{-1}$**	**L**	**D**	**FM**	**SM**	**SS/TA**
Aurora-1	04/Oct	126 e	223.25 a	8.65 b	12.09 b	53.3 c	48.1 d	62.03 c	3.4 e	28.69 e
Biuti	20/Nov	173 a	195.54 a	12.82 a	17.09 a	54.58 c	52.55 c	71.96 c	4.56 d	17.06 f
Centenário	01/Oct	123.75 e	92.38 c	6.01 c	8.05 c	56.5 c	50.33 c	71.92 c	4 e	46.23 b
Delicioso Precoce	12/Oct	134.42 d	45.13 c	3.28 d	4.47 d	60.8 b	55.45 b	96.33 b	4.53 d	43.98 c
Diamante	27/Oct	149.33 b	27.38 c	2.42 d	3.22 d	53.46 c	51.03 c	102.82 b	5.58 b	17.67 f
Doçura-2	15/Oct	137.17 d	68.79 c	4.6 c	6.22 c	54.43 c	51.23 c	79.45 c	3.71 e	52.26 a
Douradão	11/Oct	133.17 d	53.92 c	4.47 c	5.68 c	65.73 a	62.62 a	119.18 a	6.2 a	51.28 a
Dourado-2	18/Oct	140.17 c	77.63 c	5.59 c	7.46 c	54.56 c	51.57 c	80.28 c	3.85 e	41.07 c
Flordaprince	26/Sep	118.92 f	66.33 c	3.43 d	4.58 d	52.5 c	51.67 c	68.31 c	5.51 b	16.01 f
Jóia-3	07/Oct	129.75 d	151.04 b	6.17 c	8.23 c	50.19 d	44.57 d	53.9 c	3.69 e	37.07 d
Kampai	11/Oct	133.58 d	68.13 c	6.02 c	8.04 c	59.26 b	56.08 b	103.46 b	5.42 b	35.81 d
Libra	25/Sep	117 f	71.88 c	4.69 c	6.25 c	54.37 c	54.43 b	92.45 b	4.85 c	16.29 f
Maravilha	30/Sep	122.5 e	55.71 c	3.33 d	4.5 d	50.7 d	49.51 c	65.61 c	4.55 d	14.88 f
Okinawa	29/Oct	151.08 b	118.08 c	5.81 c	7.79 c	58.58 b	49.42 c	71 c	3.32 e	27.15 e
Ouromel-4	24/Oct	146.33 b	103.67 c	5.1 c	7.36 c	55.84 c	49.2 c	67.17 c	3.56 e	47.58 b
Régis	25/Sep	117.17 f	146.92 b	6.16 c	8.31 c	51.07 d	50.62 c	65.47 c	4.09 e	20.91 f
Tropical	29/Sep	121.17 e	35.79 c	1.56 d	2.08 d	48.37 d	46.47 d	56.79 c	3.94 e	55.05 a
General Average	11/out	133.79	94.21	5.3	7.14	54.96	51.46	78.12	4.4	33.47
CV (%)		2.36	36.89	27.17	27.65	2.95	3.75	10.9	8.5	7.48
Accuracy		99.25	93.32	94.63	94.48	97.60	96.27	96.38	96.79	99.50

Average values followed by the same letter belong to the same group according to the Scott-Knott test ($P \leq 0.05$).

Adopting the criteria used by Eberhart and Russell to assess the adaptability and stability of cultivars in the years it was possible to verify that the environmental indexes varied in different years regarding the establishment of the peach tree (Table 3). The relationship between these and the variables evaluated allowed the classification of the favorable environment (positive indexes) and unfavorable indexes (negative indexes), with averages above the general average for the favorable environments. Considering the productivity in the years 2013 and 2014, they were unfavorable. As for DC length, the classification of favorable and unfavorable environment was also observed, however, the favorable environments were those that presented negative indexes, as cultivars went through shorter cycles in the year 2013, and the environments with positive indexes were those considered as unfavorable, with average DC longer than the general average for the years 2014, 2015 and 2016.

Tabela 3. Averages reached by the 17 peach cultivars, evaluated in four environments (years), and their respective environmental indexes for the classification of favorable and unfavorable environments the beginning of harvest (DC) in days accumulated production (P. $t.ha^{-1}$).

Years	**DC**		**$P.t.ha^{-1}$**	
	Average	**Indexes(Ij)**	**Average**	**Indexes(Ij)**
2013	119.9216	-13.8725	1.9997	-5.1434
2014	135.9804	2.1863	4.5486	-2.5945
2015	135.1765	1.3824	11.1034	3.9603
2016	144.098	10.3039	10.9206	3.7775
Average	133.7941	0	7.143075	0

The cultivars with average below general were considered precocious for DC. In this respect ‘Aurora-1’, ‘Centenário’, ‘Douradão’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Maravilha’, ‘Régis’ and ‘Tropical’ were precocious (Table 4).

Table 4. Estimation of parameters of adaptability and phenotypic stability, Eberhart and Russell (1966), for 17 peach cultivars evaluated in four years for the beginning of harvest (DC) in days accumulated production (P. $t.ha^{-1}$).

Cultivars	DC				$P.t.ha^{-1}$			
	ß0	ß1	S²d	R²(%)	ß0	ß1	S²d	R²(%)
Aurora-1	126.00	0.99 ns	-8.13 ns	97.60	12.09	1.93 **	19.38"	83.44
Biuti	173.00	1.03 ns	9.55 ns	88.35	17.09	3.21 **	46.67"	86.50
Centenário	123.75	0.81 ns	-9.43 ns	97.69	8.05	1.12 ns	1.67 ns	87.57
Delicioso Precoce	134.42	0.69 ns	-11.74 ns	99.89	4.47	0.61 ns	-3.26 ns	94.27
Diamante	149.33	0.95 ns	111.97"	52.65	3.22	0.51 *	0.10 ns	66.61
Doçura-2	137.17	0.73 ns	123.87"	37.26	6.22	0.96 ns	-3.43 ns	98.16
Douradão	133.17	1.37 ns	62.61"	79.42	5.68	0.59 ns	1.71 ns	66.13
Dourado-2	140.17	1.54 **	3.64 ns	95.91	7.46	1.00 ns	-1.48 ns	92.68
Flordaprince	118.92	1.09 ns	27.72’	82.00	4.58	0.68 ns	-2.77 ns	92.27
Jóia-3	129.75	0.83 ns	67.95"	56.92	8.23	0.88 ns	-1.21 ns	89.89
Kampai	133.58	1.40 *	-6.60 ns	98.30	8.04	1.34 ns	-2.49 ns	97.42
Libra	117.00	1.03 ns	-7.24 ns	97.26	6.25	0.65 ns	10.54’	47.76
Maravilha	122.50	0.64 ns	-8.75 ns	95.38	4.50	0.41 *	-2.86 ns	82.69
Okinawa	151.08	1.02 ns	-4.39 ns	95.49	7.79	0.67 ns	-0.76 ns	81.33
Ouromel-4	146.33	0.80 ns	7.17 ns	83.83	7.36	1.15 ns	-3.90 ns	99.80
Régis	117.17	1.03 ns	-11.75 ns	99.96	8.30	1.08 ns	17.10"	63.42
Tropical	121.17	1.04 ns	6.91 ns	89.76	2.08	0.20 *	-3.62 ns	78.11
General Average	133.94				7.14			
V(ß0):	2.95				0.996			
V(ß1):	0.04				0.063			
r(ß0,ß1):	0.07				0.955			

**, *: significantly different of 1, by the t test, at 1 and 5% probability, respectively. ‘,’: significantly different of 0, by the F test, at 1 and 5% probability, respectively

Regarding adaptability and stability by Eberhart and Russell for the period between pruning and beginning of harvest (DC), the cultivars ‘Dourado-2’ e ‘Kampai’, were classified as general adaptability, as they were not different through the years. The cultivars with adaptability to favorable environments were ‘Okinawa’, ‘Libra’, ‘Douradão’, ‘Flordaprince’, ‘Tropical’, ‘Biuti’ and ‘Régis’. The cultivars ‘Aurora-1’, ‘Delicioso Precoce’, ‘Diamante’, ‘Ouromel-4’, ‘Centenário’, ‘Jóia-3’, ‘Doçura-2’ and ‘Maravilha’ showed adaptability to unfavorable environments. All of the cultivars presented low stability or predictability.

The cultivars with average above general for $P.t.ha^{-1}$ had good productivity. They were ‘Aurora-1’, ‘Biuti’, ‘Centenário’, ‘Dourado-2’, ‘Jóia-3’, ‘Kampai’, ‘Okinawa’, ‘Ouromel-4’ and ‘Régis’.

As for adaptability and stability by Eberhart and Russell for variable Productivity ($t.ha^{-1}$), the cultivars which are considered to be of general adaptability were ‘Centenário’, ‘Delicioso Precoce’, ‘Doçura-2’, ‘Douradão’, ‘Dourado-2’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Okinawa’, ‘Ouromel-4’ and ‘Régis’. The cultivars with adaptability to favorable environments were ‘Aurora-1’ and ‘Biuti’. The cultivars with adaptability to favorable environments were ‘Diamante’, ‘Maravilha’ and ‘Tropical’. The highest stability or predictability was submitted by ‘Diamante’. The other cultivars showed low stability or predictability.

The analysis for grouping promoted by the Tocher’s method resulted in three unique groups within the 17 peach cultivars (Table 5). Group I was formed by 14 peach cultivars, subdivided into five groups, comprising 82.35% of genotypes. Group II was represented by the peach cultivars ‘Diamante’ and ‘Biuti’, while Group III was composed only by ‘Tropical’.

Table 5. Genotypes groups sorted by the optimization method of Tocher, for 17 peach cultivars in Lavras, MG, Brazil, in 2013, 2014, 2015 and 2016 production cycles, based on 9 characteristics, using the standardized average to calculate the Mahalanobis distance.

Groups	Sub-Groups	Cultivars
I	I.a	‘Flordaprince’, ‘Maravilha’, ‘Libra’ and ‘Régis’
	I.b	‘Dourado-2’, ‘Ouromel-4’, ‘Doçura-2’, ‘Delicioso Precoce’, ‘Centenário’, ‘Kampai’ and ‘Jóia-3’
	I.c	‘Douradão’
	I.d	‘Aurora-1’
	I.e	‘Okinawa’
II		‘Diamante’ and ‘Biuti’
III		‘Tropical’

As for the clustering performed by the hierarchical method “UPGMA”, there was the individualization of three unique groups for the characteristics. When analyzing Figure 3, it is possible to see that the highest number of cultivars was selected for the group I, with 15 from the total of 17 evaluated cultivars, which indicates a small genetic divergence among them. Group II was composed of ‘Diamante’ and ‘Biuti’.

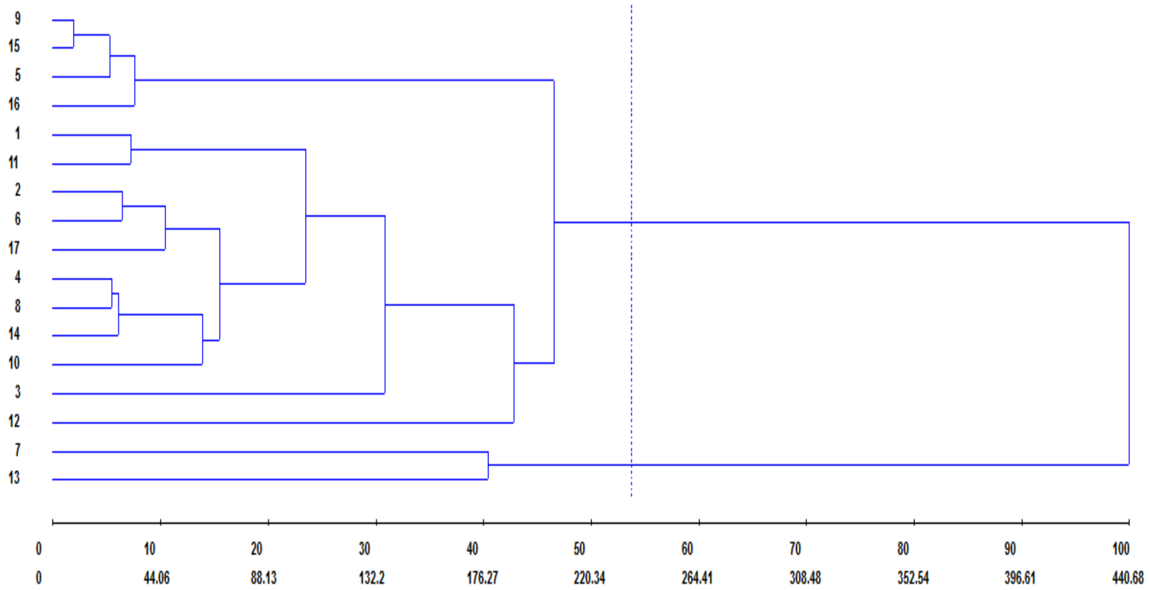

Figure 3. Dendrogram of genetic dissimilarity among the 17 peach cultivars, in 2013, 2014, 2015 and 2016 production cycles, obtained by the "UPGMA" method, based on nine variables, using the standardized averages for the Mahalanobis distance. The percentages of distances between the cultivars were represented in the X axis and the 17 cultivars were: (1) 'Aurora-1'; (2) 'Delicioso Precoce'; (3) 'Okinawa'; (4) 'Dourado-2'; (5) 'Libra'; (6) 'Douradão'; (7) 'Diamante'; (8) 'Ouromel-4'; (9) 'Flordaprince'; (10) 'Centenário'; (11) 'Jóia-3'; (12) 'Tropical'; (13) 'Biuti'; (14) 'Doçura-2'; (15) 'Maravilha'; (16) 'Régis'; and (17) 'Kampai', which were represented in the Y axis.

Both methods have demonstrated similar behavior when groupings the cultivars, however, they were not identical. It is possible to observe that the constituent cultivars in groups I and III defined by the Tocher's method were grouped together in the group I defined by the UPGMA method.

For the analysis of canonical variables, it was necessary two canonical variables to define axes (CV1 and CV2) which would explain 80.67% of the total variability described. Three groups were formed. Group II comprised the cultivars 'Diamante' and 'Biuti', group III had only 'Tropical' and all the other cultivars were sorted into group I (Figure 4). This analysis agreed with the clustering methods.

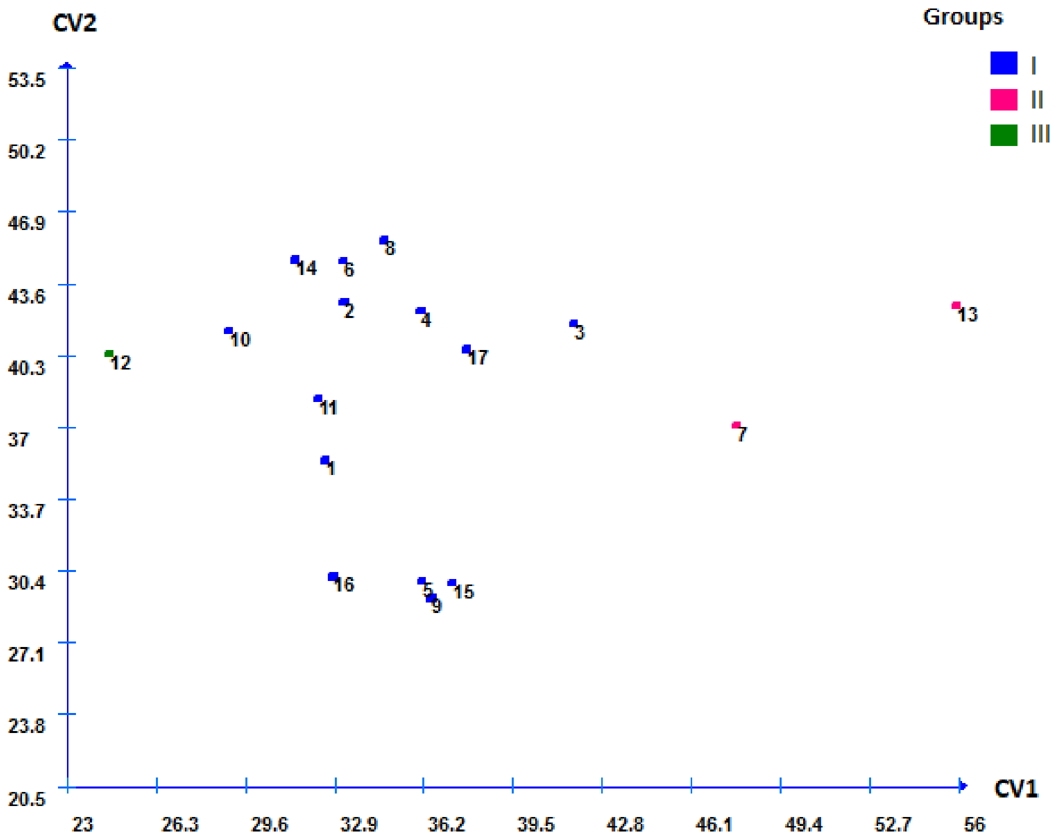

Figure 4 - Scores plotted along the first and second canonical variable axes (CV1 and CV2) for the nine variables study of the 17 cultivars were: (1) ‘Aurora-1’; (2) ‘Delicioso Precoce’; (3) ‘Okinawa’; (4) ‘Dourado-2’; (5) ‘Libra’; (6) ‘Douradão’; (7) ‘Diamante’; (8) ‘Ouromel-4’; (9) ‘Flordaprince’; (10) ‘Centenário’; (11) ‘Jóia-3’; (12) ‘Tropical’; (13) ‘Biuti’; (14) ‘Doçura-2’; (15) ‘Maravilha’; (16) ‘Régis’; and (17) ‘Kampai’,.

The variables evaluated in this study may be considered representative, as they were efficient in the dissimilarity analysis and subsequently in the clustering of cultivars. The relative contribution for the genetic diversity of peach when analyzing the variables through the Singh’s method showed the highest rate observed for DC at 34.60%, followed by SS/TA (33.40%), length of fruits (10.21%), production (10.13%), fruit mass (4.96%), stone mass (4.70%), productivity (1.48%), number of fruit per tree (0.31%), larger diameter of fruits (0.20%) (Figure 5).

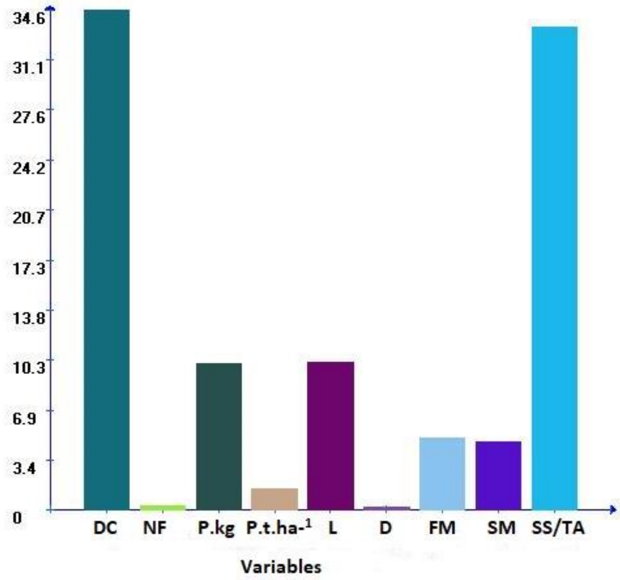

Figure 5. The relative contribution of variables for genetic diversity (Singh, 1981) of 17 peach cultivars in Lavras, MG, Brazil during the 2013, 2014, 2015 and 2016 crop years.

The analysis performed on the Mulamba and Mock selection index (Resende et al., 2014) classified the five analyzed cultivars in higher performance of the precocious harvest (DC), number of fruit per tree (NF), estimated production variables (P. Kg/tree), fruit mass (FM) in grams, and the relation between soluble solids and titratable acidity (SS/TA) in peaches cultivars of average four years. The cultivars were ‘Aurora-1’, ‘Centenário’, ‘Douradão’, ‘Kampai’ and ‘Régis’ (Table 6).

Table 6 - Estimates of predicted genetic gains using the rank summation index of Mulamba and Mock for the selection of peach cultivars based on the precocious harvest (DC), number of fruit per tree (NF), estimated production variables (P. Kg/tree), fruit mass (FM) in grams, and the relation between soluble solids and titratable acidity (SS/TA) in Lavras, MG, Brazil during the 2013, 2014, 2015 and 2016 crop years.

Variables	**H^2 (%)**	**Gain (%)**	**Selection Cultivars**
DC	98.50	-5.20	
NF	87.08	20.99	
P. kg/tree	89.56	16.25	Aurora-1, Centenário, Douradão, Kampai and Régis
FM	92.89	7.47	
SS/TA	99.01	9.21	
Total Gain		48.72	

H^2: heritability

4 Discussion

According to the data, the latest cultivars to yield in this experiment was ‘Biuti’, which agrees with Barbosa et al. (2000) who stated that ‘Biuti’ was late and the beginning of harvest was on 21/Nov. ‘Régis’, ‘Libra’ and ‘Flordaprince’ were precocious cultivars and had the beginning of harvest taking place at the end of September. Simonetto et al., (2004) observed that the beginning of harvest for ‘Flordaprince’ took place in October, which was considered precocious. Pereira and Mayer (2008) considered ‘Régis’ as an ultra precocious cultivar, with its beginning of harvest on 22/Oct. Raseira et al., (2015) stated that ‘BRS ‘Libra’ is a cultivar with early ripening, as its beginning of harvest happens in early October.

‘Biuti’ was the cultivar that showed the highest average for production characteristics presented in the latest harvest. According to Citadin et al. (2002) when studying the heritability of heat requirement for blooming and budburst evaluated if the selection of cultivars with a higher heat requirement for blooming tended to delay the flowering phase without delaying the budburst period. Therefore, the ending of endo-dormancy is not discrete, but a gradual and quantitative process, represented by a continuous increase in the speed of blooming and leafing as heat accumulated increases. This behavior varies according to both genotype and environment.

The cultivar ‘Aurora-1’ produced the highest number of fruit per plant, per harvest, however, its yield and productivity were the second best, behind ‘Biuti’. Barbosa et al. (2010) had a harvest with 112 fruit per tree, which is less than what has been found for this experiment, although it provided a production of 9.2 kg per tree, which is higher than in this experiment. Alves et al. (2012) found an average production of 23.93 kg per tree.

Regarding physical and chemical characteristic of fruit, ‘Douradão’ stands out as the best cultivar. Matias et al. (2013) found the highest SS/TA (26.82), however, for the mass of fruit (75.67g), it was lower than in this experiment. According to Barbosa et al. (2010), ‘Douradão’y produced fruit weighting above 120g for high density and 160g in standard spacing.

As Trevisan (2003), sweet peach cultivars presented a ratio of SS/TA above 35, for sour fruits this ratio was 15 - 25. In contrast ‘Douçura-2’ and ‘Tropical’ with highest SS/TA do not statistically differ from ‘Douradão’. For Silva et al. (2016) the cultivar ‘Tropical’ stood out in relation to quality attributes, showing the highest balance between acidity and soluble solids. Ojima et al. (1986) said ‘Douçura-2’presented highest organoleptic qualities.

By analyzing Table 1, it is possible to verify that the cultivars that presented the highest production of peaches and still fruit with higher masses and ratio were ‘Douçura-2’, ‘Douradão’ and ‘Ouromel-4’. These variables are the most important deciding about the selection of cultivars.

The production of fruits per plant is directly proportional to the amount of fruit produced and the mass of the fruit, in the same way that the estimated productivity is related to the production per plant and a function of population density. For this reason, production is the main parameter to choose the most productive cultivars. Regarding the quality of fruit, according to the classification adopted by the market, the size of the fruit, represented by the average fruit mass and the SS/TA are the main parameters for quality in the selection of cultivars adapted to a certain region.

The ‘Kampai’, demonstrated the greatest adaptability and stability of production (kg per tree) (Citadin et al., 2014), agreeing with this study when evaluating productivity. Scariotto et al. (2013) stated that ‘Kampai’ and ‘Libra’ were the peach tree genotypes with the greatest adaptability and stability for the budburst trait. This agrees with results for ‘Kampai’.

Souza et al. (2017) evaluated the fruit set (represented by the number of fruit that formed flowers). It was found that the cultivars that were classified as medium general adaptability were ‘Aurora-1’, ‘Dourado-2’, ‘Libra’, ‘Maciel’, ‘Joia-3’, ‘Tropical’, ‘Bonão’, ‘Biuti’, ‘Premier’ and ‘Régis’. ’Diamante’ and ‘Charme’ were classified as minimum adaptability. These cultivars were classified as such because they were the most sensitive during the years when the study was carried out. ‘Ouromel-4’ was classified as maximum general adaptability, along with ‘Delicioso Precoce’ and ‘Okinawa’.

According to Vieira et al. (2007), the establishment of genotypes groups by homogeneity within them and heterogeneity among groups is crucial when establishing effective breeding strategies. As reported by Carpentieri-Pípolo et al. (2000), the best hybrid combinations to be tested in breeding programs should involve both parents that are divergent and present high average performance.

As the evolution of species occurs, genetic variability becomes essential for natural selection. Within these populations which present genetic variability, with desirable agronomic characteristics, such as larger and tastier fruit and it produces plants that resist diseases and insects (Wagner Júnior et al. 2011), therefore, allowing farmers to have more cultivar options which allow production in adverse environmental conditions.

Matias et al. (2016) evaluating the physical and the chemical quality of peach fruit in the subTropical region, considered the cultivars ‘Biuti’, ‘Diamante’, ‘Flordaprince’, ‘Delicioso Precoce’ and ‘Tropical’ to belong to only one group by the Tocher’s method. In the results of this present study with the cultivars, ‘Diamante’ and ‘Biuti’ that formed group II, ‘Flordaprince’ and ‘Delicioso Precoce’ belong to group I, but in different subgroups and the cultivar ‘Tropical’ belongs to a single group III. This difference was because this study approaches productive characteristics of the cultivars beyond the physical and chemical properties of the fruits.

In the first two canonical variables explained 80.6728% of all variation. According to Cruz et al., (2004) above 80%, it is viable to study the genetic divergence by means of the geometric distances in dispersion graphics.

The results observed by the Singh (1981) methodology showed that the most important variables for genetic diversity of this experiment were the DC and SS/TA of the fruits. This proves that in selecting cultivars we must give importance to these characteristics beyond the productive characteristics.

When interpreting productive and qualitative data for the selection of cultivars of any fruit tree for a given region and tests results for comparison of means, hardly, a cultivar stands out in all assessed variables. This implies a subjective interpretation of the data, since normally the cultivars that produce larger quantities of fruits have smaller fruit and, consequently, lower mass averages. In the same way, most vigorous cultivars produce more acidic and less colorful fruit, due to the high shading. For this reason, the test for comparison of means is fragile and, in this case, the use of multivariate analyzes is an essential tool, considering that the grouping of all assessed variables for the composition of divergent groups may occur, even with a similar composition. However, its applicability has not been performed in the selection of peach cultivars for cultivation in ‘Tropical’ regions yet.

It is difficult to the researcher select superior cultivars that have simultaneously high performance for all desirable variables. The selection based on a single variable is not indicated because it can result in a higher product for this characteristic but may lead to not so favorable performances for the other variables of agronomic importance. Thus, in order to practice selection based on more characteristics besides production, the selection index theory represents a good alternative since in this methodology the gain is balanced among all the variables considered in the construction of the index (Cruz; Regazzi and Carneiro, 2014). Studies using selection indexes, in particular, Mulamba and Mock index, in peach culture are scarce, however, the simultaneous selection of peach variables using the Mulamba and Mock index allowed the selection of genotypes that accumulate genetic gains in the variables evaluated in this study, even if those gains were balanced.

5 Conclusion

The cultivars ‘Centenário’, ‘Douradão’, ‘Kampai’ and ‘Régis’ were the most adaptable and stable in relation to precocious and productivity for crops in the tropics.

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ARTICLE 2 - DURATION OF THE PHENOLOGICAL STAGES OF PEACH TREES AT TROPICS

Article formatted according to the journal Scientia Horticulturae

Abstract

This study aims to evaluate the duration of the phenological stages and determine the adaptability and stability of reproductive and vegetative phases of peach trees under tropics with the purpose of optimizing the production system. The experiment was set up in a randomized plot design with 23 cultivars (‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Centenário’, ‘Charme’, ‘Delicioso Precoce’, ‘Diamante’, ‘Douçura-2’, ‘Douradão’, ‘Dourado-2’, ‘Eldorado’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Maciel’, ‘Maravilha’, ‘Marli’, ‘Okinawa’, ‘Ouromel-4’, ‘Premier’, ‘Régis’, and ‘Tropical’) in 2014-2016. The average duration (in days) for the three years, between pruning day and each phenological stage (OS - sprouted buds had opened, onset of flowering – OF, full bloom – FB, end of flowering – EF, beginning of fruit harvest - BH, and end of harvest - EH). in each plot, was evaluated through visual observations as which the ones that follows, the chill requirement (CR) of each cultivar for accumulated number of hours with temperatures (≤7.2°C), (≤12°C) and (≥25℃), the thermal demand, expressed in degree-days of development (GDD) and the adaptability and stability of OS and EH. The ‘Eldorado’ was the latest cultivar and the precocious cultivars ‘Aurora-1’, ‘Centenário’, ‘Flordaprince’, ‘Kampai’ when considering OS, OF, FB and EF. The cultivar ‘Eldorado’ was sooner considering BH and EH, but it has a high standard deviation, that is, high variation among the years. The latest, when considering BH and EH, was the cultivar ‘Biuti’. Overall, the year 2016 was the year with the highest CR (≤7.2 ℃ and ≤12 ℃) and with more hours under warm temperatures (≥25 ℃) for OS, OF and FB. Regarding GDD until OS, OF and FB the cultivar with the highest GDD was ‘Eldorado’ and the lowest were ‘Aurora-1’, ‘Centenário’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Okinawa’, ‘Régis’ and ‘Tropical’. ‘Biuti’ was the cultivar that presented highest GDD for BH and the lowest was ‘Eldorado’. ‘Douçura-2’ had general adaptability for OS and EH. The most precocious cultivars, with the greatest adaptability for sprouting and flowering in the tropics, were ‘Aurora-1’, ‘Joía-3’, ‘Kampai’, and ‘Tropical’.

Keywords: *Prunus persica*. Chill Requirement. Precocious.

1 Introduction

The spread of commercial farming of temperate fruit crops in subtropical and tropical regions has increased rapidly in recent years. This increase is especially noticeable regarding peaches in Brazil, where the climatic conditions are highly variable. Subtropical humid zones, located in Southern Brazil, have hot, humid, rainy summers, which favor disease development (Scariotto et al., 2013)

The study of phenology may be considered as an approach to observe the effects of climate change (Schwartz, 1999) and to assess the impact of possible changes in winter chilling accumulation or increased frost risks for trees in temperate climates under the different climate change scenarios (Rea and Eccel, 2006). Knowledge and awareness of flower bud phenological stages and fruit growth development are important requirements for many facets of crop management. Phenological models can informing farmers of crop growth and developmental stages during the growing season, may be useful tools for improving the efficacy and management of fruit production (Chmielewski, 2003). The precocious maturation of fruit should be considered the main factor of economic success for the farmer, due to the low supply in the market (Araujo et al., 2008).

The peach trees must meet a chilling requirement in order to break dormancy and a heat requirement in order to bloom (Campoy et al. 2012). The chilling requirement may be different for different species, varieties, or growing regions (Wang et al. 2012). Chilling requirements is the major factor that determines the bloom date and the overcoming of dormancy (Alburquerque et al. 2008) These parameters are considered to be cultivar-specific and are useful for predicting the probability of the successful adaptation of a cultivar to a pre-determined environment. The determination of chilling requirements and heat requirements are also important within a breeding program, in order to choose the correct parents to obtain early or late blooming cultivars (Campoy et al., 2011)

Mild winter conditions are highly variable for peach tree production and are primarily related to temperatures during the dormancy period of the plants. The cultivars that are best adapted to the tropics have reduced chilling requirements (between 70 and 200 hours at temperatures below 7.2ºC) during their bud endodormancy period (Barbosa et al., 2010). It is believed that temperatures as high as 12ºC are effective in overcoming endodormancy in these cultivars, as verified by Citadin et al. (2014).

The variability in chilling requirements, associated with the year-to-year variation and a diverse cultivar response conditioned by the contrasting dormancy intensity for different cultivars (Saure, 1985). The lack of adaptation of peach tree cultivars to mild winter conditions can cause both blooming and flowering to be insufficient and sporadic, thus limiting subsequent fruit yields (Scariotto et al., 2013). The cultivars with low chilling requirement and with good production stability are important for success in tropics. The precocious cultivars need lower chilling requirement to begin flowering and usually present a lower heat requirement (Citadin et al., 2003).

Given these considerations, the objective was to evaluate the duration of the phenological stages and determine the adaptability and stability of reproductive and vegetative phases of peach trees under tropics with the goal of optimizing the production system.

2 Material and Methods

The experiment was conducted at an experimental orchard in Southern Minas Gerais State, municipality of Lavras, Brazil, between 2014 and 2016. The city is located at 21°14’ South latitude and 45°00’ West longitude, at an average altitude of 918 meters. The climate is ‘Tropical’ climate of altitude, with dry winter and rainy summer (Alvares et al., 2013). The average precipitation during the experimental period was 1,166 mm yearly, whereas the average normal climatic rainfall was 1,530 mm; the experimental period was 364 mm lower (Figure 1).

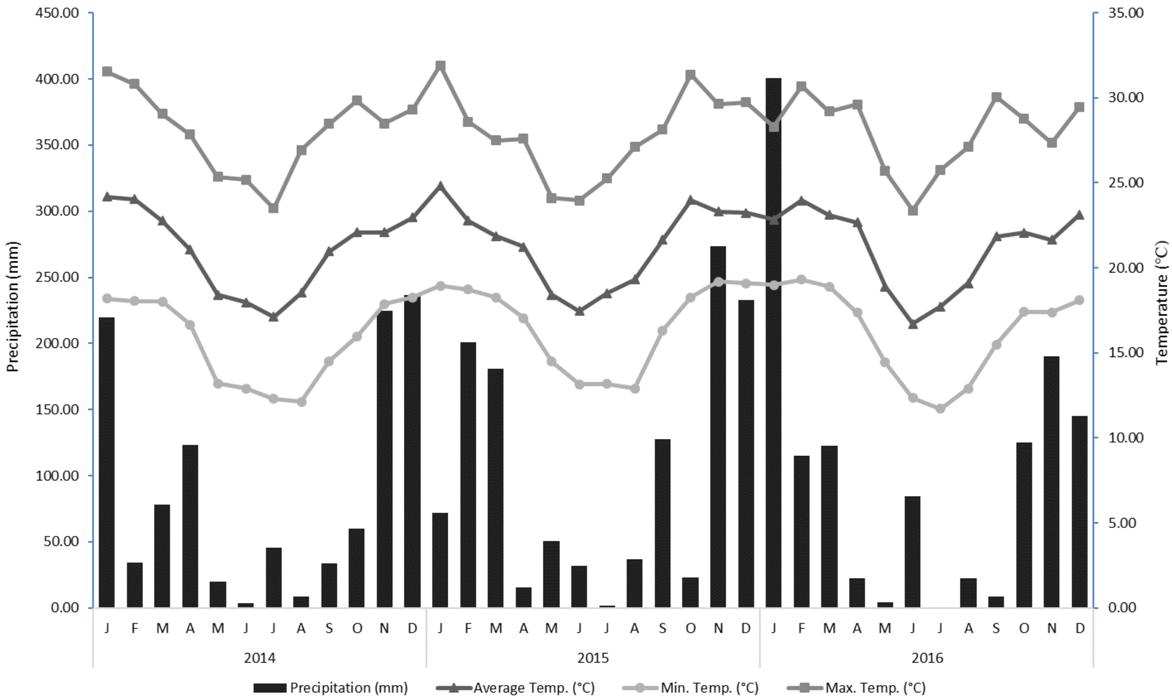

Figure 1. Climate data from January 2014 to December 2016 in Lavras, MG, Brazil. Source: Lavras Main Climatological Station – UFLA/INMET.

The experiment was set up in a randomized plot design with 23 cultivars (‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Centenário’, ‘Charme’, ‘Delicioso Precoce’, ‘Diamante’, ‘Douçura-2’, ‘Douradão’, ‘Dourado-2’, ‘Eldorado’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Maciel’, ‘Maravilha’, ‘Marli’, ‘Okinawa’, ‘Ouromel-4’, ‘Premier’, ‘Régis’, and ‘Tropical’), three replicates, and plots consisting of two plants each. The peach cultivars were grafted on ‘Okinawa’ rootstock and were planted in the field in July 2011, spaced by 5.0 m between rows and 1.5 m between plants (population density of 1,333 plants per ha), in trained to a “Y” system. The orchard received standard fungicide and insecticide sprays and fertilization, similar to the treatments used in commercial orchards. On June 2nd, 2014; June 13th, 2015 and May 31st, 2016 pruning was performed followed by an application of 0.25% hydrogen cyanamide (a.i.).

The average duration (in days) for the three years, between pruning day and each phenological stage in each plot, was evaluated through visual observations as which the ones that follows: onset of bud sprouting (OS - when more than 5% of sprouted buds had opened) , onset of flowering (OF - when more than 5% of flowers had opened), full bloom (FB - when more than 50% of flowers had opened), end of flowering (EF - when 90% of flowers had opened), beginning of fruit harvest (BH), and end of harvest (EH) (Figure 2).

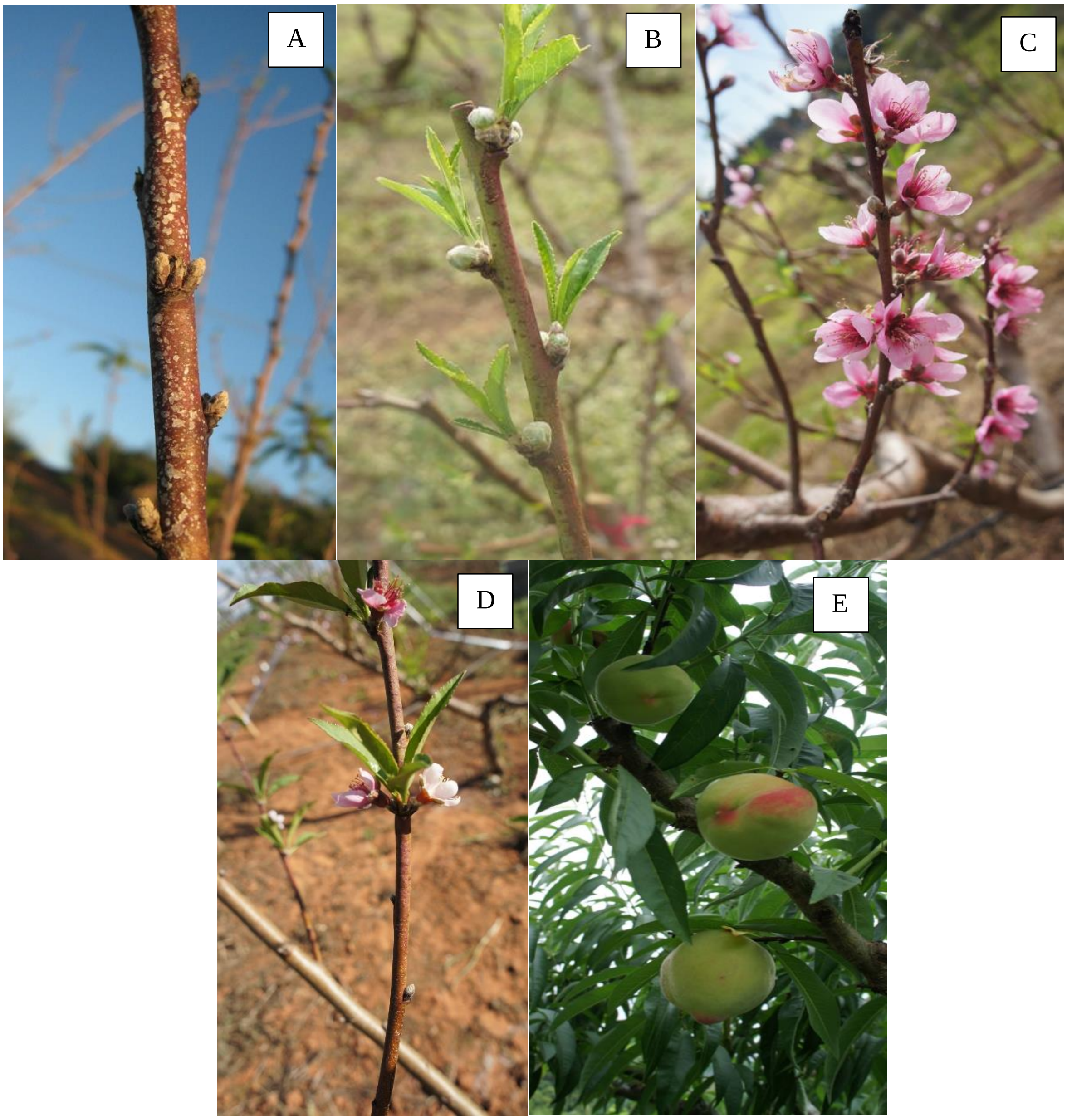

Figure 2 - Phases of flowering and fruiting of peach trees: (A) button dormant, (B) onset of bud sprouting, (C) flowering, (D) onset of bud sprouting and onset of flowering, (E) fruiting of peach trees.
Source: From the author, (2017).

Air temperature data was collected at a frequency of one hour by Lavras Main Weather Station (UFLA/INMET) at UFLA (University of Lavras), 1 km from the experimental area to calculated the number of hours when temperatures were (≤7.2°C), (≤12°C) and (≥25°C) from April to September in 2014, 2015 and 2016. The chill requirement (CR) of each cultivar for accumulated number of hours with temperatures (≤7.2°C), (≤12°C) and (≥25°C) from April 1 until the onset of budding, onset of flowering and full bloom for each cultivar in 2014, 2015 and 2016.

The thermal demand, expressed in degree-days of development (GDD), was calculated by using the sum of DD accumulated from the day of pruning to the phenological stages of onset of bud sprouting, onset of flowering, full bloom and beginning of fruit harvest: $\sum DD = \sum (Ta - Tb)$, where Ta = daily average temperature, and Tb = base temperature (7°C). The Tb adopted for the peach tree was 7°C, according to Dejong (2005). The GDD average was calculated in the years 2014, 2015 and 2016.

The interaction between the years and the cultivars was presented through the method proposed by Eberhart and Russell. This method was used for the variables OS and EH. Their model is based on computations of linear regression (βi) for each genotype compared to environmental conditions and deviation from regression (S2di). By using regression coefficient and deviation from regression, the authors have established a method that provides estimates for stability and adaptability parameters of genotypes grown under various conditions. Genotypes in which βi>1 respond better to more favorable conditions, whereas genotypes in which βi<1 respond better to adverse environmental conditions. A stable cultivar is considered to be the one that has regression coefficient approximately at 1 and standard error of regression as low as possible. Genotypes in which βi>1 respond better to more favorable growing conditions, whereas genotypes in which βi<1 respond better to adverse environmental conditions (Eberhart and Russell, 1966).

All statistical analysis were performed using GENES software (Cruz, 2013).

3 Results

In the year 2015 there weren’t hours with average minimum temperature below 7.2ºC ‘Régis’, but in the year 2014, 11 hours of cold temperature, below 7.2ºC, were recorded, and concentrated in the month of August, and in 2016, 23 hours of cold temperature, below 7.2 ºC were ‘Régis’, and these were concentrated in the months between June and August. Regarding cold hours with a temperature below 12 ºC, which may also be considered important, as 382, 103 and 303 hours under these conditions, were ‘Régis’, for 2014, 2015 and 2016, respectively (Figure 1 and 2).

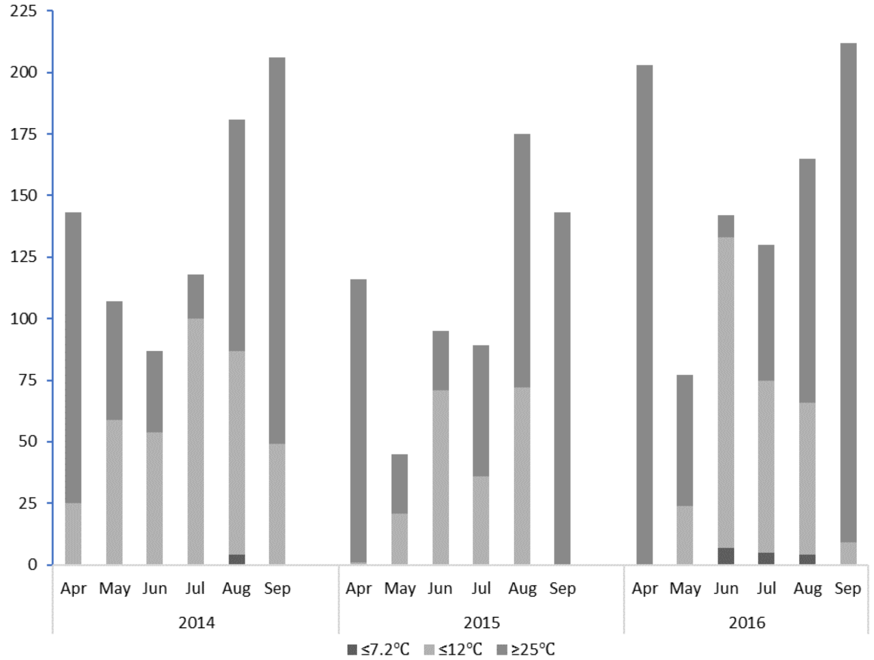

Figure 3. Number of accumulated hours: (≤7.2ºC), (≤12ºC), and (≥25ºC) between the months of April and September for 2014 and 2016 in Lavras, Minas Gerais State, Brazil.

‘Eldorado’ was the latest cultivar when considering OS, OF, FB and EF. The precocious cultivars when considering OS were ‘Aurora-1’, ‘Centenário’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Okinawa’, ‘Régis’ and ‘Tropical’. Considering OF, the precocious ones were ‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Centenário’, ‘Delicioso Precoce’, ‘Douçura-2’, ‘Dourado-2’, Flordaprince, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Maravilha’, ‘Okinawa’, ‘Ouromel-4’, ‘Régis’ and ‘Tropical’. The precocious cultivars considering OF and BF, with the exception of the ‘Premier’, which was precocious only when considering FB, were ‘Eldorado’ and ‘Marli’, which presented a full bloom later and it was the last considering EF. The first cultivars when considering EF were ‘Aurora-1’, ‘Bonão’, ‘Centenário’, ‘Flordaprince’, ‘Kampai’, ‘Libra’, ‘Régis’. The cultivar ‘Eldorado’ was sooner considering BH and EH, but it has high standard deviation, that is, a high variation between the years. The latest, when considering BH and EH, was the cultivar ‘Biuti’ (Table 1).

Table 1. The duration (in days) between pruning day and each phenological stage in each plot, was evaluated through visual observations as which the ones that follows: onset of bud sprouting (OS - when more than 5% of sprouted buds had opened), onset of flowering (OF - when more than 5% of flowers had opened), full bloom (FB - when more than 50% of flowers had opened), end of flowering (EF - when 90% of flowers had opened), beginning of fruit harvest (BH), and end of harvest (EH) for average of 2014, 2015 and 2016 at the experimental orchard in Lavras, Minas Gerais State, Brazil.

Cultivars	OS			OF			FB			EF			BH			EH		
Aurora-1	23.17	±4.13*	d	25.33	±2.64*	d	38.83	±2.87*	c	78.50	±11.99*	e	126.00	±3.33*	c	151.92	±5.50	c
Biuti	27.33	±4.68	c	31.67	±3.52	d	43.17	±3.34	c	96.75	±17.94	c	173.00	±3.28	a	198.75	±6.08	a
Bonão	30.25	±7.26	c	29.75	±6.19	d	48.58	±9.47	c	79.67	±13.51	e	117.92	±12.37	c	135.83	±14.05	c
Centenário	25.25	±4.88	d	26.17	±3.71	d	42.17	±4.23	c	79.08	±11.45	e	123.75	±2.40	c	153.67	±4.45	c
Charme	35.33	±6.50	b	35.00	±5.18	c	63.67	±7.14	b	105.83	±12.05	b	118.42	±18.52	c	137.00	±21.38	c
Delicioso Precoce	30	±4.92	c	30.17	±3.76	d	47.33	±3.36	c	84.58	±11.93	d	134.42	±2.83	b	158.08	±4.75	c
Diamante	34.58	±6.85	b	37.67	±5.30	c	64.92	±9.99	b	103.42	±12.53	b	149.33	±4.60	b	174.50	±6.46	b
Douçura-2	27.25	±5.58	c	29.75	±3.55	d	45.17	±4.87	c	91.33	±12.30	d	137.17	±4.31	b	166.25	±4.10	b
Douradão	29.75	±8.29	c	35.08	±7.39	c	55.67	±9.27	b	90.08	±13.40	d	133.17	±4.66	b	167.42	±8.32	b
Dourado-2	29.17	±6.20	c	30.42	±5.05	d	47.50	±6.37	c	87.25	±13.88	d	140.17	±5.13	b	169.08	±5.21	b
Eldorado	53.92	±9.52	a	48.83	±6.61	a	76.25	±7.86	a	119.50	±15.69	a	75.83	±29.95	d	81.00	±32.08	d
Flordaprince	21.5	±4.47	d	27.67	±3.34	d	44.08	±3.74	c	80.33	±10.78	e	118.92	±3.55	c	144.75	±6.92	c
Jóia-3	25.75	±5.38	d	26.00	±4.00	d	40.33	±4.04	c	84.75	±10.94	d	129.75	±3.36	c	159.67	±4.26	b
Kampai	23.25	±5.34	d	26.58	±4.64	d	43.33	±7.66	c	81.92	±12.73	e	133.58	±5.05	b	163.83	±7.86	b
Libra	26.58	±6.03	c	29.50	±4.72	d	48.00	±7.53	c	76.83	±11.07	e	117.00	±3.12	c	141.83	±6.40	c
Maciel	38.75	±7.58	b	38.00	±7.45	c	62.17	±9.11	b	97.33	±18.45	c	138.42	±21.51	b	156.42	±24.24	c
Maravilha	29.5	±5.97	c	27.83	±4.33	d	39.67	±2.97	c	86.33	±10.02	d	122.50	±1.92	c	143.33	±3.80	c
Marli	36.75	±7.02	b	42.17	±5.29	b	69.92	±6.41	a	118.33	±13.23	a	120.42	±23.30	c	145.42	±28.99	c
Okinawa	23.5	±3.70	d	30.92	±3.45	d	42.25	±3.06	c	90.92	±14.42	d	151.08	±3.66	b	172.75	±3.62	b
Ouromel-4	31.08	±5.38	c	29.00	±3.26	d	45.42	±2.58	c	89.67	±13.17	d	146.33	±2.66	b	175.00	±4.15	b
Premier	27.83	±4.38	c	33.67	±3.20	c	39.50	±6.75	c	90.00	±16.26	d	128.17	±19.26	c	143.00	±21.68	c
Régis	22.5	±4.32	d	22.58	±2.63	d	35.50	±2.95	c	73.50	±11.59	e	117.17	±3.15	c	145.33	±5.59	c
Tropical	24.67	±4.92	d	26.17	±4.09	d	50.17	±5.65	c	83.42	±10.10	e	121.17	±3.46	c	140.33	±3.82	c
General Average	29.46			31.3			49.29			89.97			129.29			153.27		
CV (%)	7.79			10.85			10.46			4.37			10.9			8.99		
Accuracy(%)	98.23			94.57			96.2			98.26			89.22			93.25		

Average values followed by the same letter belong to the same group according to the Scott-Knott test (P≤0.05).* Represent the average ± standard error.

The year 2016 was the latest considering OS. In 2014 there was no difference for OS of the cultivars. In 2015 and 2016 the cultivar ‘Eldorado’ had the latest OS. In 2015 the cultivars that presented a precocious development of OS were ‘Bonão’, ‘Eldorado’, ‘Flordaprince’, ‘Kampai’, ‘Libra’, ‘Okinawa’, ‘Régis’ and ‘Tropical’. In 2016 the cultivars ‘Aurora-1’, ‘Flordaprince’, ‘Jóia-3’, ‘Marli’, ‘Okinawa’, ‘Premier’ and ‘Régis’ were precocious considering OS (Table 2).

Table 2. The duration (in days) between pruning day and onset of bud sprouting (OS - when more than 5% of sprouted buds had opened), for each cultivar in 2014, 2015 and 2016 at the experimental orchard in Lavras, Minas Gerais State, Brazil.

Cultivars	**OS**		
	2014	**2015**	**2016**
Aurora-1	15.00 C a	26.67 B c	41.00 A d
Biuti	15.00 C a	27.67 B c	50.00 A c
Bonão	19.67 B a	18.00 B d	67.33 A b
Centenário	15.00 C a	26.00 B c	48.33 A d
Charme	18.67 C a	40.00 B b	64.00 A b
Delicioso Precoce	16.33 C a	34.33 B b	51.67 A c
Diamante	18.33 C a	35.33 B b	67.33 A b
Douçura-2	15.00 C a	26.33 B c	53.33 A c
Douradão	16.00 C a	25.00 B c	70.33 A b
Dourado-2	20.00 B a	26.00 B c	58.67 A c
Eldorado	26.33 B a	83.67 A a	80.33 A a
Flordaprince	15.00 B a	17.67 B d	43.33 A d
Jóia-3	16.00 C a	27.33 B c	47.00 A d
Kampai	15.00 B a	19.33 B d	50.00 A C
Libra	16.00 B a	21.00 B d	57.00 A C
Maciel	22.00 C a	44.33 B b	72.33 A B
Maravilha	16.00 C a	29.00 B c	58.67 A C
Marli	20.33 C a	36.00 B b	70.00 A b
Okinawa	16.00 B a	17.00 B d	42.33 A d
Ouromel-4	19.00 C a	39.00 B b	52.33 A c
Premier	17.67 C a	31.67 B b	47.00 A d
Régis	15.00 B a	19.00 B d	44.00 A d
Tropical	15.00 B a	17.00 B d	50.00 A c
General Average	17.32	29.88	55.93
CV1		15.57	
CV2		33.98	

Average values followed by the same capital letter in the row and small letter in the column belong to the same group according to the Scott-Knott test ($P \leq 0.05$).

In 2014 and 2015, there was no difference between cultivars considering CR (≤7.2 °C) for OS. In 2016 the cultivars that showed higher CR (≤7.2°C) for OS were ‘Douradão’, ‘Eldorado’ and ‘Maciel’, and the lowest ones were ‘Aurora-1’, ‘Delicioso Precoce’, ‘Douçura-2’, ‘Flordaprince’, ‘Maravilha’, ‘Okinawa’ and ‘Régis’ (Table 3).

Table 3. The chill requirement (CR) of each cultivar for accumulated number of hours with temperatures (≤7.2°C), (≤12°C) and (≥25°C) from April 1 until the onset of budding for each cultivar in 2014, 2015 and 2016 at the experimental orchard in Lavras, Minas Gerais State, Brazil.

CULTIVARS	CR (≤7.2°C) of OS			CR (≤12°C) of OS			Temp. (≥25°C) of OS		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Aurora-1	0	0	7 d	110 B a	105.33 B b	171 A d	190 B a	169.33 C c	286.33 A c
Biuti	0	0	12 b	110 B a	106.33 B b	205 A c	190 B a	172.33 B c	304 A c
Bonão	0	0	12 b	119.33 B a	90.67 C c	224.67 A b	192.33 B a	163 C c	337.33 A b
Centenário	0	0	10.33 c	110 B a	105.33 B b	197 A c	190 B a	170.67 C c	301.67 A c
Charme	0	0	13.33 b	117 B a	121 B b	227.67 A b	190 B a	196 B b	325.33 A b
Delicioso Precoce	0	0	8.67 d	110 B a	115.33 B b	191 A c	190 B a	191.67 B b	299.33 A c
Diamante	0	0	13.33 b	110.67 B a	117 B b	231.33 A b	190 B a	193.33 B b	335.67 A b
Douçura-2	0	0	8.67 d	110 B a	104 B b	192.67 A c	190 B a	174 B c	298 A c
Douradão	0	0	14.67 a	110 B a	103 B b	238.33 A a	190 B a	170.67 C c	345.33 A b
Dourado-2	0	0	12 b	118.33 B a	103 B b	217 A b	190 B a	172.67 B c	320.67 A c
Eldorado	0	0	16 a	128.67 C a	201 B a	256 A a	198.67 C a	331 B a	372 A a
Flordaprince	0	0	8.67 d	110 B a	88.33 C c	181 A d	190 B a	163 C c	288.67 A c
Jóia-3	0	0	10.33 c	110 B a	96 B c	195.67 A c	190 B a	183.33 B b	295 A c
Kampai	0	0	12 b	110 B a	94 B c	205 A c	190 B a	163 C c	304 A c
Libra	0	0	12 b	110 B a	96.33 B c	216.33 A b	190 B a	163 C c	314.67 A c
Maciel	0	0	14.67 a	126.33 B a	126.33 B b	238.67 A a	191.33 B a	206.67 B b	350 A b
Maravilha	0	0	8.67 d	110 B a	107.67 B b	194 A c	190 B a	178.33 B c	304.67 A c
Marli	0	0	13.33 b	121.67 B a	118 B b	231.33 A b	191.33 B a	187.33 B b	350.33 A b
Okinawa	0	0	7 d	110 B a	81 C c	178.33 A d	190 B a	163 C c	283.67 A c
Ouromel-4	0	0	10.33 c	118.33 B a	124.33 B b	197 A c	190 B a	195 B b	301.67 A c
Premier	0	0	10.33 c	117 B a	111 B b	195.67 A c	190 B a	186.67 B b	295 A c
Régis	0	0	8.67 d	110 B a	94 B c	186.33 A d	190 B a	163 C c	286 A c
Tropical	0	0	12 b	110 B a	81 C c	205 A c	190 B a	163 C c	304 A c
General Average	0	0	11.13	113.8	108.26	207.65	190.59	183.48	313.19
CV1		32.72			8.01			4.53	
CV2					18.34			8.97	

Average values followed by the same capital letter in the row and small letter in the column belong to the same group according to the Scott-Knott test (P≤0.05).

In 2014, there was no difference between cultivars considering CR (≤12 °C) for OS. In 2015 'Eldorado' showed higher CR (≤12 °C), and the lower values were found for the cultivars 'Bonão', 'Flordaprince', 'Jóia-3', 'Kampai', 'Libra', 'Okinawa', 'Régis' and 'Tropical'. In 2016 'Eldorado' and 'Maciel' had higher CR (≤12°C) for OS and the lower were 'Biuti', 'Centenário', 'Douçura-2', 'Jóia-3', 'Kampai', 'Maravilha', 'Ouromel-4', 'Premier' and 'Tropical'. In 2016, all cultivars showed higher CR (≤7.2 °C and ≤12 °C).

Regarding the accumulation of hours at warm temperatures (≥25 °C) in OS, in 2014, there was no difference between cultivars. In 2015 and 2016, the cultivar that accumulated the most hours under this condition was 'Eldorado'. In 2015 the lowest accumulation was presented by the cultivars 'Aurora-1', 'Biuti', 'Bonão', 'Centenário', 'Douçura-2', 'Douradão', 'Dourado-2', 'Flordarince', 'Kampai', 'Libra', 'Maravilha', 'Okinawa' and 'Régis'. In 2016, the same results were found, except for 'Bonão' and 'Douradão', and the 'Delicioso Precoce' in this group, only in 2016.

The year 2016 presented the latest OF (Table 4). The cultivar with the latest OF in 2014 was 'Eldorado'. In 2015, the cultivars showed the latest OF were 'Biuti', 'Charme', 'Delicioso Precoce', 'Diamante', 'Eldorado', 'Maciel', 'Marli' and 'Premier'. In 2016, the latest ones were 'Bonão', 'Diamante', 'Douradão', 'Eldorado', 'Maciel' and 'Marli'.

Table 4. The duration (in days) between pruning day and the onset of flowering (OF - when more than 5% of flowers had opened), for each cultivar in 2014, 2015 and 2016 at the experimental orchard in Lavras, Minas Gerais State, Brazil.

CULTIVARS	OF								
	2014			2015			2016		
Aurora-1	19.00	B	b	27.00	B	b	37.00	A	b
Biuti	22.00	B	b	38.00	A	a	44.00	A	b
Bonão	19.67	B	b	21.00	B	b	59.33	A	a
Centenário	17.00	B	b	25.00	B	b	44.00	A	b
Charme	18.67	B	b	45.00	A	a	50.67	A	b
Delicioso Precoce	21.33	B	b	31.67	B	a	47.00	A	b
Diamante	29.67	B	b	30.67	B	a	63.67	A	a
Douçura-2	22.33	B	b	27.33	B	b	47.00	A	b
Douradão	22.00	B	b	26.33	B	b	70.00	A	a
Dourado-2	25.33	B	b	25.33	B	b	54.33	A	b
Eldorado	64.33	A	a	37.67	B	a	64.33	A	a
Flordaprince	23.00	B	b	25.33	B	b	44.00	A	b
Jóia-3	16.00	B	b	24.00	B	b	44.00	A	b
Kampai	15.00	B	b	24.00	B	b	50.00	A	b
Libra	23.67	B	b	24.33	B	b	52.00	A	b
Maciel	20.67	B	b	31.33	B	a	70.67	A	a
Maravilha	18.33	B	b	23.67	B	b	50.00	A	b
Marli	35.00	B	b	32.00	B	a	66.33	A	a
Okinawa	26.00	B	b	27.33	B	b	48.33	A	b
Ouromel-4	21.67	B	b	29.33	B	b	44.00	A	b
Premier	23.00	B	b	32.33	A	a	44.00	A	b
Régis	15.00	B	b	22.67	B	b	35.00	A	b
Tropical	16.00	B	b	22.00	B	b	45.00	A	b
General Average	23.25			28.41			51.07		
CV1				21.70					
CV2				34.64					

Average values followed by the same capital letter in the row and small letter in the column belong to the same group according to the Scott-Knott test (P≤0.05).

In 2016 the cultivars that presented higher CR (≤7.2°C) for OF were ‘Bonão’, ‘Diamante’, ‘Douradão’, ‘Eldorado’, ‘Kampai’, ‘Maciel’, ‘Maravilha’ and ‘Marli’. There was no difference between cultivars in 2014 and 2015 considering CR (≤7.2°C) for OF (Table 5).

Table 5. The chill requirement (CR) of each cultivar for accumulated number of hours with temperatures (≤7.2°C), (≤12°C) and (≥25°C) from April 1 until the onset of flowering for each cultivar in 2014, 2015 and 2016 at the experimental orchard in Lavras, Minas Gerais State, Brazil.

Cultivars	**CR (≤7.2°C) of OF**			**CR (≤12°C) of OF**			**Temp. (≥25°C) of OF**		
	2014	**2015**	**2016**	**2014**	**2015**	**2016**	**2014**	**2015**	**2016**
Aurora-1	0	0	7 c	117 B b	105.33 B a	163.67 A b	190 B b	169.33 B b	269 A b
Biuti	0	0	8.67 c	124.67 B b	120 B a	183.33 A b	190 B b	195.33 B a	288 A b
Bonão	0	0	13.33 a	117.67 B b	97.33 B a	219.33 A a	190 B b	163 B b	325.33 A a
Centenário	0	0	8.67 c	112.33 B b	100.67 B a	186.33 A b	190 B b	166 B b	286 A b
Charme	0	0	10.33 b	117 B b	130.67 B a	197.33 A b	190 B b	213.67 B a	298 A b
Delicioso Precoce	0	0	10.33 b	127.67 B b	113 B a	195.67 A b	191.33 B b	182.33 B a	295 A b
Diamante	0	0	13.33 a	140.67 B b	110 C a	224 A a	203.33 B b	184.67 B a	327.67 A a
Douçura-2	0	0	10.33 b	126.33 B b	106.33 B a	195.67 A b	190 B b	173.33 B b	295 A b
Douradão	0	0	13.33 a	124 B b	104 B a	237 A a	192.33 B b	166 B b	352 A a
Dourado-2	0	0	10.33 b	135.67 B b	104 C a	204.33 A b	194.33 B b	164.33 C b	311.33 A b
Eldorado	2	0	12 a	243.67 A a	119.33 B a	221.67 A a	253.67 B a	194.33 C a	332 A a
Flordaprince	0	0	8.67 c	131 B b	103 B a	186.33 A b	190 B b	163 B b	286 A b
Jóia-3	0	0	8.67 c	110 B b	91 B a	184.67 A b	190 B b	173.33 B b	283 A b
Kampai	0	0	12 a	110 B b	103 B a	205 A b	190 B b	163 B b	304 A b
Libra	0	0	10.33 b	131 B b	101.67 B a	204 A b	192.67 B b	167.33 B b	300.33 A b
Maciel	0	0	13 a	119.33 B b	110 B a	235.67 A a	190 B b	187.33 B a	356.33 A a
Maravilha	0	0	12 a	110 B b	103 B a	205 A b	190 B b	163 B b	304 A b
Marli	0	0	13 a	144 B b	111 C a	225.67 A a	215.33 B b	188 B a	342.33 A a
Okinawa	0	0	10.33 b	138 B b	106 C a	197 A b	197 B b	168.67 B b	301.67 A b
Ouromel-4	0	0	8.67 c	124 B b	107.67 B a	186.33 A b	190 B b	178.33 B b	286 A b
Premier	0	0	8.67 c	126.33 B b	114.33 B a	186.33 A b	193 B b	185.67 B a	286 A b
Régis	0	0	7 c	110 B b	100.67 B a	157 A b	190 B b	164.33 B b	265 A b
Tropical	0	0	10.33 b	110 B b	88.67 B a	189 A b	190 B b	164.33 B b	291 A b
General Average	0.09	0	10.45	128.28	106.55	199.58	195.35	175.59	303.7
CV1		46.29			12.61			7.93	
CV2					22.88			11.35	

Average values followed by the same capital letter in the row and small letter in the column belong to the same group according to the Scott-Knott test (P≤0.05).

‘Eldorado’ was the cultivar which had higher CR (≤12℃) for OF. In 2015, there was no difference among the cultivars considering CR (≤12℃). In 2016, the cultivars that needed the highest CR (≤12℃) for OF were ‘Biuti’, ‘Diamante’, ‘Douradão’, ‘Eldorado’, ‘Maciel’ and ‘Marli’. The year 2016 presented higher CR (≤7.2℃) and CR (≤12℃) for OF.

For the accumulation of hours at warm temperatures (≥25℃) in the OF, the cultivar ‘Eldorado’ was the one that accumulated the most hours during the 3 year period, not differing from the ones that had a higher accumulation only in 2015, which were ‘Biuti’, ‘Charme’, ‘Delicioso Precoce’ and ‘Premier’, and only in 2016, which were ‘Bonão’ and ‘Douradão’. The cultivars that did not differ amongst themselves, with the highest accumulation in 2015 and 2016 were ‘Diamante’, ‘Maciel’ and ‘Marli’.

The cultivars vs. years in FB (Table 6). In 2014 and 2015 ‘Eldorado’ was the latest cultivar considering FB. The precocious cultivars, in 2014, were ‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Jóia-3’, ‘Kampai’, ‘Maravilha’, ‘Okinawa’, ‘Régis’. In 2015, the precocious cultivars were ‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Centenário’, ‘Delicioso Precoce’, ‘Diamante’, ‘Douçura-2’, ‘Douradão’, ‘Dourado-2’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Maciel’, ‘Maravilha’, ‘Okinawa’, ‘Ouromel-4’, ‘Premier’, ‘Régis’ e ‘Tropical’. The latest cultivars considering FB in 2016 were ‘Bonão’, ‘Diamante’, ‘Douradão’, ‘Maciel’ and ‘Marli’. As for the most precocious, they were ‘Aurora-1’, ‘Biuti’, ‘Centenário’, ‘Delicioso Precoce’, ‘Douçura-2’, ‘Dourado-2’, ‘Flordaprince’, ‘Jóia-3’, ‘Maravilha’, ‘Okinawa’, ‘Ouromel-4’, ‘Premier’, ‘Régis’ and ‘Tropical’

Table 6. The duration (in days) between pruning day and full bloom (FB - when more than 50% of flowers had opened), for each cultivar in 2014, 2015 and 2016 at the experimental orchard in Lavras, Minas Gerais State, Brazil.

Cultivars	**FB**								
	2014			**2015**			**2016**		
Aurora-1	32.33	A	d	38.67	A	c	50.67	A	c
Biuti	39.00	B	d	45.33	B	c	57.33	A	c
Bonão	36.33	B	d	32.00	B	c	93.67	A	a
Centenário	49.33	A	c	32.33	B	c	57.33	A	c
Charme	80.33	A	b	60.67	B	b	75.67	A	b
Delicioso Precoce	55.67	A	c	41.67	B	c	56.67	A	c
Diamante	84.33	A	b	42.67	B	c	98.00	A	a
Douçura-2	50.33	A	c	34.00	B	c	63.67	A	c
Douradão	50.67	B	c	36.00	B	c	100.67	A	a
Dourado-2	56.67	A	c	30.33	B	c	71.00	A	c
Eldorado	105.00	A	a	77.00	B	a	80.67	B	b
Flordaprince	52.00	A	c	32.33	B	c	54.67	A	c
Jóia-3	37.33	B	d	34.33	B	c	58.00	A	c
Kampai	24.00	B	d	34.33	B	c	79.00	A	b
Libra	45.67	B	c	31.67	B	c	80.00	A	b
Maciel	72.00	B	b	37.33	C	c	102.00	A	a
Maravilha	37.33	B	d	35.33	B	c	53.33	A	c
Marli	84.67	A	b	52.33	B	b	91.67	A	a
Okinawa	39.67	B	d	37.67	B	c	56.33	A	c
Ouromel-4	52.33	A	c	41.67	A	c	51.33	A	c
Premier	52.33	A	c	40.00	A	c	52.67	A	c
Régis	33.00	B	d	28.00	B	c	50.00	A	c
Tropical	45.00	B	c	34.00	B	c	65.00	A	c
General Average	52.84			39.55			69.54		
CV1				20.93					
CV2				34.86					

Average followed by the same capital letter in the row and the small letter in the column do not differ from one another by the Scott Knott test at 5% of probability.

In 2014, the cultivars that needed higher CR (≤7.2°C) for FB were ‘Charme’, ‘Diamante’, ‘Eldorado’, ‘Maciel’ and ‘Marli’. In 2015 there was no difference between the cultivars for CR(≤7.2 °C). In 2016 ‘Bonão’, ‘Charme’, ‘Diamante’, ‘Douradão’, ‘Eldorado’, ‘Libra’, ‘Maciel’ and ‘Marli’ needed a higher CR(≤7.2°C) to reach full bloom. The cultivars that needed the lowest CR (≤7.2 °C) were ‘Biuti’, ‘Okinawa’ and ‘Premier’. ‘Eldorado’ had the highest CR (≤12°C) for FB in 2014 and the cultivars that needed the lowest were ‘Aurora-1’, ‘Biuti’, ‘Bonão’, Joía-3, ‘Kampai’, ‘Libra’, ‘Maravilha’, ‘Okinawa’, ‘Régis’ and ‘Tropical’. In 2015 ‘Charme’ and ‘Eldorado’ needed the highest CR (≤12°C) to reach FB. The cultivars ‘Bonão’, ‘Diamante’, ‘Douradão’, ‘Eldorado’, ‘Libra’, ‘Maciel’ and ‘Marli’ presented the highest CR (≤12°C) to reach FB in 2016. ‘Eldorado’ accumulated more hours at warm temperatures (≥25°C) in the 3 years, although without significant difference between ‘Charme’ in 2015 and the cultivars ‘Bonão’, ‘Diamante’, ‘Douradão’, ‘Libra’, ‘Maciel’ and ‘Marli’ in 2016 (Table 7).

Table 7. The chill requirement (CR) of each cultivar for accumulated number of hours with temperatures (≤7.2°C), (≤12°C) and (≥25°C) from April 1 until the full bloom for each cultivar in 2014, 2015 and 2016 at the experimental orchard in Lavras, Minas Gerais State, Brazil.

CULTIVARS	**CR (≤7.2°C) of FB**			**CR (≤12°C) of FB**			**Temp. (≥25°C) of FB**		
	2014	**2015**	**2016**	**2014**	**2015**	**2016**	**2014**	**2015**	**2016**
Aurora-1	0.00 B b	0.00 B a	12.00 A b	143.67 B d	120.67 B b	207.00 A b	208.00 B c	199.67 B b	304.00 A b
Biuti	0.00 B b	0.00 B a	10.33 A c	153.33 B d	125.00 B b	206.33 A b	216.00 B c	204.00 B b	309.67 A b
Bonão	0.00 B b	0.00 B a	14.67 A a	156.33 B d	110.00 C b	264.67 A a	215.33 B c	190.00 B b	436.67 A a
Centenário	0.00 B b	0.00 B a	12.00 A b	205.00 A c	111.00 B b	213.00 A b	216.67 B c	189.33 B b	318.00 A b
Charme	2.67 B a	0.00 C a	14.67 A a	291.33 A b	171.33 C a	241.00 B b	297.33 B b	251.67 B a	360.67 A b
Delicioso Precoce	0.67 B b	0.00 B a	12.00 A b	229.67 A c	125.00 B b	215.33 A b	222.67 B c	200.00 B b	310.67 A b
Diamante	4.00 B a	0.00 C a	14.67 A a	318.67 A b	126.33 C b	264.33 B a	286.33 B b	202.67 C b	490.33 A a
Douçura-2	0.00 B b	0.00 B a	13.33 A b	208.67 A c	115.00 B b	224.33 A b	217.00 B c	188.00 B b	333.00 A b
Douradão	1.33 B b	0.00 B a	16.00 A a	213.67 B c	117.00 C b	282.00 A a	223.67 B c	192.67 B b	450.67 A a
Dourado-2	0.00 B b	0.00 B a	13.33 A b	229.00 A c	109.67 B b	239.00 A b	217.00 B c	180.33 B b	352.00 A b
Eldorado	4.00 B a	0.00 C a	14.67 A a	358.00 A a	197.67 C a	261.67 B a	374.00 A a	309.67 B a	375.33 A b
Flordaprince	0.67 B b	0.00 B a	12.00 A b	215.33 A c	111.67 B b	212.00 A b	222.33 B c	187.00 B b	309.33 A b
Jóia-3	0.00 B b	0.00 B a	13.33 A b	152.00 B d	116.00 B b	219.33 A b	216.00 B c	190.00 B b	318.67 A b
Kampai	0.00 B b	0.00 B a	13.00 A b	134.67 B d	115.33 B b	237.00 A b	191.33 B c	191.67 B b	358.00 A b
Libra	0.00 B b	0.00 B a	14.67 A a	181.67 B d	109.67 C b	256.33 A a	216.33 B c	186.33 B b	391.67 A a
Maciel	3.33 B a	0.00 C a	16.00 A a	292.67 A b	123.67 B b	282.00 A a	247.00 B c	194.00 B b	431.00 A a
Maravilha	0.00 B b	0.00 B a	12.00 A b	152.33 B d	116.00 B b	210.00 A b	214.00 B c	192.67 B b	309.33 A b
Marli	4.00 B a	0.00 C a	16.00 A a	319.00 A b	137.67 B b	282.00 A a	288.67 B b	222.67 C b	416.67 A a
Okinawa	0.00 B b	0.00 B a	10.33 A c	155.00 B d	117.33 B b	205.00 A b	216.00 B c	199.33 B b	307.00 A b
Ouromel-4	0.00 B b	0.00 B a	12.00 A b	218.00 A c	124.33 B b	207.33 A b	217.00 B c	199.00 B b	304.00 A b
Premier	1.33 B b	0.00 B a	10.33 A c	215.00 A c	125.00 B b	197.33 A b	228.00 B c	196.00 B b	301.67 A b
Régis	0.00 B b	0.00 B a	12.00 A b	143.33 B d	107.33 B b	205.00 A b	208.67 B c	172.00 B b	304.00 A b
Tropical	0.00 B b	0.00 B a	13.33 A b	183.67 B d	113.00 C b	231.00 A b	216.33 B c	192.00 B b	345.67 A b
General Average	0.96	0.00	13.16	211.74	123.72	233.17	233.72	201.33	353.83
CV1		28.18			14.35			12.81	
CV2		43.67			19.34			24.20	

Average values followed by the same capital letter in the row and a small letter in the column belong to the same group according to the Scott-Knott test (P≤0.05).

Overall, 2016 was the year with the highest CR (≤7.2 °C and ≤12 °C) and with more hours under warm temperatures (≥25 °C) for OS, OF and FB.

Regarding GDD until OS, the cultivar with the highest GDD was ‘Eldorado’ and the lowest ones were ‘Aurora-1’, ‘Centenário’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Okinawa’, ‘Régis’ and ‘Tropical’ (Table 5). Regarding OF and FB, ‘Eldorado’ was the cultivar with the highest GDD, but ‘Marli’ showed only the highest GDD for FB. The cultivars that had the lowest GDD for OF and for FB were ‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Centenário’, ‘Delicioso Precoce’, ‘Douçura-2’, ‘Dourado-2’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Maravilha’, ‘Okinawa’, ‘Ouromel-4’, ‘Premier’, ‘Régis’ and ‘Tropical’, and ‘Premier’ presented the lowest GDD only for FB. ‘Biuti’ was the cultivar that presented the highest GDD for BH and the lowest one was ‘Eldorado’ (Table 8).

Table 8. The necessary number of growing degree-days [GDD (base 7 °C)] to reach the specific phenological stages of the average duration (in days) for the three years, between pruning day and each phenological stage in each plot, was evaluated through visual observations as which the ones that follows: onset of bud sprouting (OS - when more than 5% of sprouted buds had opened) , onset of flowering (OF - when more than 5% of flowers had opened), full bloom (FB - when more than 50% of flowers had opened) and beginning of fruit harvest (BH).

Cultivar	GDD of OS			GDD of OF			GDD of FB			GDD of BH		
Aurora-1	278.42	±44.19*	d	301.94	±26.62*	d	465.60	±29.36*	c	1627.50	±68.75	c
Biuti	324.55	±49.77	c	378.45	±37.90	d	500.91	±30.60	c	2378.02	±84.78	a
Bonão	362.28	±82.46	c	355.15	±70.15	d	581.18	±111.69	c	1518.51	±167.36	c
Centenário	302.00	±52.27	d	311.34	±38.71	d	500.73	±47.12	c	1585.33	±50.61	c
Charme	422.56	±72.87	b	419.55	±58.22	c	766.24	±84.19	b	1563.87	±253.63	c
Delicioso Precoce	347.34	±47.46	c	358.63	±39.49	d	560.88	±35.55	c	1763.83	±64.15	c
Diamante	410.72	±77.83	b	450.52	±58.77	c	790.44	±126.71	b	2002.98	±79.11	b
Douçura-2	313.41	±55.68	c	353.35	±37.10	d	536.51	±55.45	c	1814.07	±88.96	b
Douradão	357.27	±94.77	c	420.01	±86.31	c	662.61	±107.10	b	1743.94	±89.33	c
Dourado-2	348.25	±69.06	c	361.74	±55.78	d	563.00	±74.66	c	1865.97	±100.30	b
Eldorado	662.18	±115.70	a	581.64	±75.95	a	927.13	±95.62	a	1083.84	±428.34	d
Flordaprince	258.75	±47.91	d	327.73	±34.82	d	521.70	±40.93	c	1657.30	±106.88	c
Jóia-3	309.14	±59.26	d	310.93	±42.31	d	482.74	±44.33	c	1691.13	±80.07	c
Kampai	278.35	±57.26	d	315.53	±49.35	d	498.92	±78.03	c	1708.49	±87.02	c
Libra	317.60	±66.14	c	350.12	±51.51	d	578.45	±90.58	c	1629.43	±108.81	c
Maciel	466.99	±86.52	b	459.09	±87.64	c	719.63	±98.53	b	1865.71	±300.63	b
Maravilha	328.94	±55.46	c	330.53	±45.83	d	474.90	±30.43	c	1566.69	±45.46	c
Marli	441.49	±80.67	b	508.24	±60.23	b	833.22	±76.90	a	1635.55	±321.02	c
Okinawa	281.89	±39.12	d	366.92	±36.07	d	494.61	±28.21	c	2036.87	±81.93	b
Ouromel-4	360.95	±53.51	c	345.14	±33.73	d	538.19	±26.60	c	1961.56	±61.79	b
Premier	331.78	±46.71	c	402.21	±34.90	c	454.40	±75.77	c	1760.83	±270.82	c
Régis	268.75	±45.88	d	270.01	±26.42	d	422.66	±30.69	c	1491.93	±58.16	c
Tropical	294.28	±52.71	d	309.26	±43.99	d	599.96	±68.01	c	1555.85	±68.10	c
General Average	350.78			373.39			585.85			1717.79		
CV (%)	7.91			11.12			11.34			11.62		
Accuracy(%)	98.32			94.46			95.85			88.48		

Average values followed by the same capital letter in the row and the small letter in the column belong to the same group according to the Scott-Knott test (P≤0.05).
* Represent the average ± standard error.

Regarding adaptability and stability standards by Eberhart and Russell for the period between pruning and onset of bud sprouting (OS), the cultivars ‘Biuti’, ‘Centenário’, ‘Charme’, ‘Delicioso Precoce’, ‘Douçura-2’, ‘Dourado-2’, ‘Kampai’, ‘Libra’, ‘Maravilha’, ‘Ouromel-4’ and ‘Tropical’ were considered as generally adaptable. They did not show differences between the climate during the period (Table 9). The cultivars with adaptability to favorable environments were ‘Bonão’, ‘Diamante’, ‘Eldorado’, ‘Douradão’, ‘Maciel’ and

'Marli'. The cultivars 'Aurora-1', 'Flordaprince', 'Jóia-3', 'Okinawa', 'Premier' and 'Régis' showed adaptability to unfavorable environments. The highest stability or predictability was presented by 'Aurora-1' and 'Premier'. The other cultivars showed low stability or predictability.

Table 9. Estimates parameters of adaptability and phenotypic stability, Eberhart and Russell (1966), for 22 peach cultivars evaluated for the onset of bud sprouting (OS - when more than 5% of sprouted buds had opened) and the end of harvest (EH) in days for average of three years (2014, 2015 and 2016) at the experimental orchard in Lavras, Minas Gerais State, Brazil.

Cultivars	Onset of bud sprouting				End of harvest			
	Average (ß0)	**ß1**	**S²d**	**R^2(%)**	**Average (ß0)**	**ß1**	**S²d**	**R^2(%)**
Aurora-1	23.17	0.72**	0.65 ns	96.74	151.92	0.79 ns	-64.20 ns	71.94
Biuti	27.33	0.85ns	-4.87 ns	99.03	198.75	0.91 ns	-45.89 ns	75.42
Bonão	30.25	1.23**	100.13''	88.18	135.83	0.72 ns	760.02'	24.45
Centenário	25.25	0.88 ns	-8.26ns	99.91	153.67	0.63 ns	-127.02 ns	74.43
Charme	35.33	1.13 ns	5.23 ns	98.02	137.00	1.24 ns	1238.87''	38.86
Delicioso Precoce	30.00	0.87 ns	5.07 ns	96.68	158.08	0.63 ns	-149.20 ns	79.72
Diamante	34.58	1.24*	-7.37 ns	99.85	174.50	0.89 ns	-45.89 ns	74.63
Douçura-2	27.25	0.97 ns	-6.62 ns	99.60	166.25	0.61 ns	-185.04 ns	90.26
Douradão	29.75	1.47*	15.69 ns	97.93	167.42	1.32 ns	-50.54 ns	86.84
Dourado-2	29.17	1.07 ns	6.90 ns	97.53	169.08	0.72 ns	-98.30 ns	73.87
Eldorado	53.92	1.38**	560.39''	63.99	81.00	3.83**	5918.93''	58.99
Flordaprince	21.50	0.77*	5.13 ns	95.86	144.75	0.61 ns	294.87 ns	31.04
Jóia-3	25.75	0.82*	-7.25 ns	99.61	159.67	0.54 ns	-115.95 ns	65.10
Kampai	23.25	0.96 ns	7.50 ns	96.81	163.83	1.24 ns	-44.65 ns	84.86
Libra	26.58	1.07 ns	15.83 ns	96.15	141.83	0.91 ns	-55.69 ns	76.46
Maciel	38.75	1.34**	9.39 ns	98.14	156.42	1.86*	4669.68''	29.90
Maravilha	29.50	1.09 ns	-7.69 ns	99.85	143.33	0.39 ns	-109.40 ns	47.80
Marli	36.75	1.23**	-4.42 ns	99.48	145.42	0.98 ns	14304.10''	3.86
Okinawa	23.50	0.62**	26.42'	85.29	172.75	0.51 ns	-170.53 ns	80.09
Ouromel-4	31.08	0.90 ns	31.01'	91.67	175.00	0.54 ns	-97.46 ns	60.81
Premier	27.83	0.77 ns	-0.31 ns	97.44	143.00	2.28**	2749.42''	51.42
Régis	22.50	0.76**	1.36 ns	96.88	145.33	0.61 ns	-74.98 ns	62.33
Tropical	24.67	0.85 ns	38.05''	89.12	140.33	0.24 ns	-19.03 ns	15.33
General Average	29.46				153.27			
V(ß0):	2.16				52.36			
V(ß1):	0.01				0.17			
r(ß0,ß1):	0.73				-0.59			

**, *: significantly different from 1, by the t test, at 1 and 5% probability, respectively. ',': significantly different from 0, by the F test, at 1 and 5% probability, respectively

As for the adaptability and stability standards by Eberhart and Russell for the period between pruning and the end of harvest (EH), the cultivars considered to have general adaptability were ‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Charme’, ‘Centenário’, ‘Delicioso Precoce’, ‘Diamante’, ‘Douçura-2’, ‘Dourado-2’, ‘Douradão’, ‘Flordaprince’, ‘Jóia-3’, ‘Kampai’, ‘Libra’, ‘Maravilha’, ‘Marli’, ‘Okinawa’, ‘Ouromel-4’, ‘Tropical’ and ‘Régis’. The cultivars with adaptability to favorable environments were ‘Eldorado’, ‘Maciel’ and ‘Premier’. All of the cultivars showed low stability or predictability.

4 Discussion

The occurrence of thermal fluctuation during winter and temperatures above 20ºC are undesirable in overcoming the endodormancy of the species (Erez; Couvillon; Hendershott, 1979).

The cultivars ‘Bonão’, ‘Eldorado’, ‘Maravilha’ and ‘Ouromel-4’ presented OS before OF, as for ‘Charme’, ‘Delicioso Precoce’ and ‘Maciel’ had almost the same day for OS and OF. According to Citadin et al. (2003) when studying the heritage of the heat requirement for anthesis and budding, observed that individuals tended to delay flowering with a high heat requirement for flowering, but did not delay the budding with the same intensity. The authors state that the genetic control for heat requirement is different from floral and vegetative buds. Therefore, there is a possibility that the genes related to the chilling and heat requirement exert a very similar degree of influence in the peach trees dormancy. However, in the vegetative buds, the influence of the genes that control the chilling requirement is higher.

The photosynthetic capacity of the plant is an important number for vegetative buds, therefore for the production of leaves and shoots (Pereira and Mayer, 2008). According to Raseira and Nakasu (1998), leaves are needed to produce fruit according to commercial standards, between 30 and 35.

‘Biuti’ showed the latest BH (173 days). This cultivar, when evaluated for the tropics, concluded the average between BF and BH at 151-180 days and BH in Dec.- Jan. (Barbosa et al., 2010). ‘Eldorado’ showed later OF, FB and EF, but early BH and EH, this may be possible due to the high variation between the plots and years without harvest. These results disagree to the ones by Alves et al., (2012) in which the ‘Eldorado’ cultivar presented the latest maturation and highest productivity.

The year 2016 showed the highest CR, which implied in the delay of OB and OF. The CR varies according to the cultivar and the nutritional state, besides the type of bud and its location in the plant (Wagner Júnior et al., 2009). Herter et al. (2001) reported that cold has effect on the base of dormancy as in the sprouting season, decreasing and increasing rapidly, with the increase in the accumulation of cold, respectively. The cultivars that showed the most precocious OS were the ones with the highest CR and were under warm temperatures, above 25 °C. According to Putti, Petri and Mendes (2003), a variation for the sprouting time among cultivars may be related not only to the CR but also to heat requirement, as meeting, because this requirement is necessary for the occurrence of budding.

There was a variation for OF and FB among the years for the cultivars ‘Charme’, ‘Diamante’, ‘Eldorado’, ‘Maciel’, ‘Marli’ and ‘Premier’, this may be due to a variation of temperatures. According to Scariotto et al. (2013), the flowering may be staggered due to a lack of adequate accumulation of cold hours during the endodormancy period or to some problem during the leaf fall period. Alves et al. (2012) observed that the ‘Marli’ cultivar increased the cycle between years, possibly due to the increase in temperature and the decrease in the number of cold hours recorded in August. The results in this study showed that the variation in the phenology was observed in all the cultivars with increase CR when warm temperatures increase (≥25 °C.).

According to Junior et al. (2007), when evaluating the CR below 7.2 and 13°C for FB, ‘Régis’ presented a CR (7.2°C) lower than 40 hours, as for (13°C), it was less than 500 hours, and FB took place before July/10th. ‘Centenário’, ‘Aurora-1’; ‘Doçura-2’, ‘Flordaprince’, and ‘Douradão’ had CR (7.2°C) from 41 to 50 hours, and for CR (13°C), it was between 501 to 560 hours and FB from July, 11th until the 20th. ‘Premier’ and ‘Biuti’ had CR (7.2 °C) for 51 to 70 hours, as for CR (13°C), it was less than 561 to 650 hours and FB took place from July 21st to 31st. The cultivars ‘Eldorado’, ‘Diamante’ and ‘Marli’ had CR (7.2°C) and (13 °C) for 70 and 650 hours, respectively and FB after the beginning August. The results showed that the CR observed in this study was lower than those ones observed in the literature. The cultivars with the highest CR (≤7.2°C) in all the assessed years were ‘Douradão’, ‘Maciel’ and ‘Marli’, all ‘Régis’ 16 hours. For CR (≤12°C) the highest values were found for ‘Eldorado’ (358 hours), and the lowest was ‘Régis’ (107.33 hours).

The most precocious cultivars, with lower CR and warm temperature for OS, OF and FB were ‘Aurora-1’, ‘Biuti’, ‘Jóia-3’, ‘Kampai’, ‘Maravilha’, ‘Okinawa’, ‘Régis’ and ‘Tropical’.

The effect of temperature, however, is ambiguous. The cultivar CR is determined genetically, and it must be met as the temperature is decisive for flowering. Variations in flowering time may be due to the combination of bud dormancy intensity and air heating rate (Szabó and Nyéki, 2000). The CR and warm temperatures (≥25°C) observed in this study, show that the increase of both cause delay in the phenological cycle, this is in agreement with Nava (2007), who stated that peach trees that showed full flowering under diurnal temperatures above 25°C (under greenhouse) anticipated in 10 days in comparison to the outdoor plants, under diurnal temperatures below 25°C. The cultivars observed in this study that had the most precocious with lower CR and warm temperature for OS, OF and FB were 'Aurora-1', 'Biuti', 'Jóia-3', 'Kampai', 'Maravilha', 'Okinawa', 'Régis' and 'Tropical'.

The interaction between the cultivar and the chilling requirement was significant in the GDD, accumulation necessary to reach 10% of bud break, after 800 hours of chilling. 'Eldorado' had the highest GDD (10434) among all cultivars (Citadin et al., 2001). The result agrees with the ones observed for 'Eldorado', which presented high GDD for OS, OF and FB, however the authors observed higher GDD than the ones observed in this study.

According to Citadin et al., (2003), the selected cultivars with higher GDD for flowering tend to delay flowering, however, they slow, with the same intensity, the budding time. As it was observed in this study, the cultivar with the lowest GDD for OS, OF and FB behave as precocious, and these cultivars were 'Aurora-1', 'Centenário', 'Flordaprince', 'Jóia-3', 'Régis' and 'Tropical'.

Mounzer et al., (2008) observed different phenological growth stages for the 'Flordastar' peach trees, in Murcia, Spain, and the requirements were also presented by accumulated GDD since dormancy breaking until leafing and the formation of buds, as 225 chilling units were needed to break dormancy and start swelling (fully expanded leaves and 30% of final shoot length, and perceptible calyx). Afterwards, as the temperature increased, the following phenological stages (flower bud swelling, perceptible flower petals, and flowers forming a hollow ball) were reached as more than 50% of opened flowers were 'Régis' for FB and after accumulating an average of 329 GDD. BH required 1,246 GDD. This result agrees with the ones observed for FB that varies between the lower GDD of 'Régis' (422.67) and the greater for 'Eldorado' (927.13). In BH, GDD ranged among the ones found for 'Eldorado' (1083.84) and the ones found for 'Biuti' (2378.02).

The period from FB to fruit maturity for cultivars of peach is influenced by daily temperatures between the start of FB and 30 days after FB. Typically, warm temperature and GDD accelerate fruit development. The temperatures in the first 90 days after FB are the primary factor in influencing the maturity time of peach cultivars in California (Tombesi et al., 2010). However, as it was observed for the cultivars ‘Aurora-1’, ‘Bonão’, ‘Centenário’, ‘Charme’, ‘Flordaprince’, ‘Jóia-3’, ‘Libra’, ‘Maravilha’, ‘Marli’, ‘Premier’, ‘Regís’ and ‘Tropical’, they were precocious and showed lower GDD.

According to Souza et al., (2017) the cultivars ‘Biuti’, ‘Centenário’, Douçura and ‘Maravilha’ were considered to have general adaptability and good predictability for the time between pruning and OS, as these cultivars didn’t behave differently under different climate for OS. The cultivars ‘Douçura-2’, ‘Douradão’, ‘Kampai’ and ‘Okinawa’ were considered to have general adaptability and good predictability for the time between pruning and EH, as these cultivars didn’t present different time of production. The results found in this study were different. The cultivars ‘Biuti’, ‘Centenário’, ‘Douçura-2’, ‘Maravilha’ showed general adaptability for OS, for the entire production cycle, that is, days between pruning and EH, the cultivars with general adaptability were ‘Douçura-2’, ‘Douradão’, ‘Kampai’, and ‘Okinawa’.

5 Conclusion

The most precocious cultivars, with the greatest adaptability for sprouting and flowering in the tropics, were ‘Aurora-1’, ‘Joía-3’, ‘Kampai’, and ‘Tropical’.

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ARTICLE 3 - LIGHT-EMITTING DIODES TO ENHANCE POSTHARVEST PEACH FRUIT QUALITY

Article formatted according to the journal Scientia Horticulturae

Abstract

The objective of this study was to identify specific light wavelengths delivered through light-emitting diodes (LED)which may enhance peach fruit quality in postharvest. The peach cultivar 'Tropic Beauty' from three different nitrogen treatments (45 kg N.ha^{-1}, 90 kg N.ha^{-1}, and 179 kg N.ha^{-1}), subjected to four different light treatments (white, blue, red, and green) at an intensity of 1000 µmol m^{-2} s^{-1} and a dark control; and periods of exposure being zero, one, and six hours. Fruit samples were assessed for soluble sugars, pH, titratable acidity (TA), firmness, color (before and after exposure) and volatile compound analysis. The experiment was conducted with a completely randomized plot design in a triple factorial scheme (light * time * nitrogen treatment). Firmness was not affected by the interaction of light color, time exposure, and nitrogen rate, but was affected by time exposure and nitrogen rate, fruit from the 45 kg.ha^{-1} N and 90 kg.ha^{-1} N treatments had the best firmness for time 0 and rate of nitrogen (179 kg.ha^{-1}) had the greatest firmness as influenced by blue light. The soluble sugars were not affected by either light or time exposure treatment, fruit from the lowest rate (45 kg.ha^{-1}) had higher soluble solids. Light (color) treatments also did not affect Brix, pH, TA. The fruit from 45kg.ha^{-1} has the highest Brix. The highest pH was measured in peaches from the 90 kg.ha^{-1} N with a six-hours light exposure and 179 kg.ha^{-1} N with one-hour exposure. The fruit from 90 kg.ha^{-1} N and zero hour has the highest TA. The factor time had a significant difference only in different colors before and after treatment (ΔE) and 6 hours showed a bigger change in fruit color. No differences were detected between factor nitrogen and lights. The treatments with the highest accumulation of volatile compounds were one (45 kg.ha^{-1} of N, time zero and not light); 19 (45 kg.ha^{-1} of N, six hours and dark) and eight (45 kg.ha^{-1} of N, one hour in white light-emitting diode LED). The time exposure, light colors did not affect postharvest fruit quality. However, fruit from trees treatments of 45 kg.ha^{-1} of nitrogen was the highest in the quality of fruits. The higher amount of volatile compounds were treatments 45 kg.ha^{-1} of nitrogen, no exposure to light and one-hour exposure to the white light-emitting diode (LED).

Keywords: Nitrogen. *Prunus persica*. Volatile compound.

1 Introduction

The Florida peach industry is based upon the production of a tree-ripe fresh fruit market with excellent fruit quality at the stores. As growers seek markets outside of Florida and throughout the Midwestern U.S., fruit are being harvested before they are tree-ripe in order to reach these locations. Consumers use multiple senses to purchase peaches, as sight, smell, and touch are used to identify ideal fruit. Return purchases are made as a result of excellent flavor which is at its optimum when fruit are harvested physiologically or when they are tree-ripe. Poor postharvest fruit quality for peaches has been correlated with reduced acceptance by the consumer and an overall decline in U.S. consumption (Crisosto, 2002; Delgado et al., 2013; Olmstead et al., 2015.)

There is an ongoing interest for bio-active compounds in fruits and vegetables due to their putative role in preventing diseases such as diabetes, cancer, stroke, arthritis, as well as aging. Regarding peach, an initial survey with 300 U.S. consumers indicated that fruit with "high Vitamin C content" was a top attribute desired when determining peach purchases (Olmstead et al., 2015). A clear inverse relationship between the consumption of fruits and vegetables and the incidence of cardiovascular and cerebral vascular, degenerative, and proliferative diseases and mortality has been largely supported by epidemiological studies (Sun et al, 2002).

Stone fruits such as peaches contain a range of natural chemicals and pigments (phenolic compounds, ascorbic acid, vitamin E and carotenoids; Byrne et al., 2004). Secondary metabolites such as vitamin C (ascorbic acid) and carotenoids contribute to the pool of beneficial health and aroma compounds in peaches. β-carotene and β-cryptoxanthin, the precursors of vitamin A are the main carotenoids present in peaches (Gil et al., 2002). In tomatoes and watermelons, carotenoid content affects norisoprene and monoterpene aroma compounds; however, it is unknown how carotenoid content affects key peach volatiles, particularly norisoprenoid compounds, which are important in the overall peach aroma (Lewishohn et al., 2005).

Over 100 compounds have been identified in peach fruit, which contribute to the overall aroma profile, with lactones (predomantly γ- and δ-decalactone), C13 norisoprenoides (β-damascenone and β-ionone) and C6 aldehydes contributing greatly to peach aromas. Postharvest storage conditions such as increasing length of storage at 1°C can reduce the evolution of some of these compounds, particularly lactones, of which γ-decalactone is a major contributor to the characteristic peach flavor (Raffo et al., 2008).

Plants exhibit various responses to different light wavelengths. Light emitting diodes (LED) that apply different wavelength treatments offer numerous advantages over conventional light sources. These include the ability to control spectral composition over small mass and volume, durability, long operating lifetimes, wavelength specificity and narrow bandwidth, relatively cool emitting surfaces, minimum heating, and photon output that is linear with the electrical input current (Bourget, 2008; Massa et al., 2008). LED treatments can be applied to enhance fruit quality and perhaps increase volatile emission to improve consumer acceptance.

Strawberries treated with different light treatments, UVA (385 nm), blue (470 nm), green (525 nm), and red (630 nm) resulted in improved anthocyanin content in immature strawberries with blue, red, and green lights compared to storing them in the dark, while blue and green LED improved vitamin C content. Total phenolics were mostly stimulated by blue LED, while total soluble solids increased with the use of green light (Kim et al., 2011). In tomatoes, lycopene accumulation and carotenoid content increased in response to red light treatment (Alba et al., 2000; Schofield and Paliyath, 2005). In citrus fruit, red LED light was effective in enhancing carotenoid content, especially the content of β-cryptoxanthin, while blue LED light had no significant effect on the carotenoid content (Ma et al., 2012). Thus, it appears that red light treatments may increase carotenoid concentration in peaches and perhaps increase volatile emission from unripe and ripe peach fruit.

While blue light (470 nm) in strawberries increased ethylene production, respiration, color development, total antioxidant activity, and antioxidant enzyme activity compared to the control (Xu et al., 2014 a, b), blue light in mature green tomatoes extended the shelf-life by delaying fruit softening and ripening (Dhakal and Baek, 2014). However, it is unknown what different LED wavelengths will do to extend or shorten peach postharvest shelf life.

The objective of this study was to identify specific light wavelengths delivered through light-emitting diodes (LED) which may enhance peach fruit quality in postharvest.

2 Material and Methods

The experiments were conducted at Fifield Hall laboratories located at Horticultural Sciences Department, University of Florida, Gainesville, FL, USA. ‘TropicBeauty ripe fruit were harvested from UF Plant Science Research and Education Unit, Citra, FL USA from the peach cultivar ‘TropicBeauty’ from of an existing experiment where trees are being subjected to three different nitrogen treatments (45 kg $N.ha^{-1}$, 90 kg $N.ha^{-1}$, and 179 kg $N.ha^{-1}$). Fruit of uniform ripeness from each of these nitrogen treatments were sorted and placed on a tray which will be subjected to four different light treatments during storage at 20°C, focusing on white, blue, red, and green at an intensity of 1000 µmol m^{-2} s^{-1} and a dark control; and periods of exposure being zero, one, and six hours. Each treatment will have a minimum of two fruit per replicate with four replicates per treatment. A subset of the fruit was sampled prior to initiation of light/time combination treatments to establish a baseline for all fruit quality parameters. Fruit samples were assessed for soluble sugars, pH, titratable acidity (TA), firmness, color (before and after exposure) and volatile compound analysis. The experiment was conducted with a completely randomized plot design in a triple factorial scheme (light * time * nitrogen treatment).

Fruit Quality Analysis: The skin and flesh color were evaluated by three readings obtained on opposite sides of the skin, in the equatorial region of the fruit, and an internal reading in the central region of the flesh. Readings were performed using a Minolta. Values for different colors were calculated in order to study color changes. ΔE* (total color difference) was defined as: $\Delta E^* = [(L^*i - L^*o)^2 + (a^*i - a^*o)^2 + (b^*i - b^*o)^2]^{0.5}$, where L* o, a* o, and b* o are the values of the samples at zero time and L*i, a* i, and b* i the measured values for each sample with time. Fruit firmness was measured with a penetrometer in Kg (Wagner Instruments, Greenwich, CT) and juice content was measured on a subset of fruit. Soluble solids content (SSC), pH and titratable acidity (TA) for malic acid will be measured for a subset of chopped fruit from each treatment and from the control group. Approximately 100 gm of chopped fruit will be homogenized and centrifuged, and the supernatant of homogenate will be used for measuring SSC, pH and TA. The remaining samples will be frozen and stored at -20°C for additional analysis.

The soluble solids content of fruits (SS) was analyzed in the juice that was manually extracted from the equatorial region of one side of each fruit and the values were expressed in °Brix. The titratable acidity (TA) and pH were determined by Methorohm Automatic Titrator with 6g of the flesh juice with additional 50 ml of distilled water with a 0.1N NaOH solution and the result was expressed in percentage of malic acid.

Volatile Compound Analysis: After the LED treatment, the samples were assessed for volatile compound analysis. Peach fruit volatiles were collected from chopped fruit with nonyl acetate as an internal standard as described by Schmelz et al. (2003). The chopped fruit was enclosed in glass tubes, with its air filtered through a hydrocarbon trap (Agilent, Palo Alto, CA), which flowed through the tubes for 1h with collection of the volatile compounds on a Super Q column. Volatiles collected on the Super Q column were eluted with methylene chloride after the addition of nonyl acetate as an internal standard. Volatiles were separated on an Agilent (Palo Alto, CA) DB-5 column and analyzed on an Agilent 6890N gas chromatograph with retention times compared to known standards (Sigma Aldrich, St Louis, MO). Volatile levels were calculated as ng g^{-1} FW h^{-1} collectied. Identities of volatile peachs were confirmed by GCMS as described by Schmelz et al. (2001). The diversity among the treatment for Volatile Compound Analysis was also estimated by multivariate analysis, applying the graphic dispersion analysis (Cruz et al., 2012).

The data was subjected to the R statistical program (R core team, 2016) version 3.2.1 and the GENES software (Cruz, 2013).

3 Results

Firmness was not affected by the interaction between light color, time exposure, and nitrogen rate. The firmness had dual affected interaction (Table 1). For the interaction between time and nitrogen rate, fruit from the 45 kg.ha^{-1} N and 90 kg.ha^{-1} N treatments had the best firmness for time zero. The 90 kg.ha^{-1} N treatment had the best firmness among the nitrogen rates. Fruit from the highest rate of nitrogen (179 kg.ha^{-1}) had the greatest firmness as influenced by the blue light, but the time exposure had no effect. The highest firmness was in the control (not light and time zero) for 90 kg.ha^{-1} N.

Table 1. Light and time exposure influence on the fruit firmness (kg) in 'Tropic Beauty' peach harvested from peach three nitrogen rates (45, 90, and 179 kg.ha^{-1}).

	Firmness (Kg)								
Hours	**45 kg.ha^{-1} N**			**90 kg.ha^{-1} N**			**179 kg.ha^{-1} N**		
0	3.44	B	a	4.71	A	a	1.23	C	a
1	1.44	B	b	2.16	A	b	1.88	AB	a
6	1.96	A	b	2.10	A	b	1.40	B	a
Light	45 kg.ha^{-1} N			90 kg.ha^{-1} N			179 kg.ha^{-1} N		
Blue	1.35	B	b	1.95	AB	bc	2.55	A	a
Dark	1.82	A	b	1.62	A	c	1.25	A	b
Green	1.96	A	b	1.84	A	c	1.70	A	ab
Red	1.53	B	b	2.32	A	bc	1.10	B	b
White	1.84	B	b	2.92	A	b	1.62	B	ab
Not	3.44	B	a	4.71	A	a	1.23	C	b

Average followed by the same capital letter in the row, the small letter in the column do not differ from one to another and ns: no significance by the Tukey test at 5% of probability.

The Brix was not affected by light and time exposure treatments. However, fruit from the lowest rate (45 kg.ha^{-1}) had higher solids than fruit from either 90 kg.ha^{-1} or 179 kg.ha^{-1} (Figure 1).

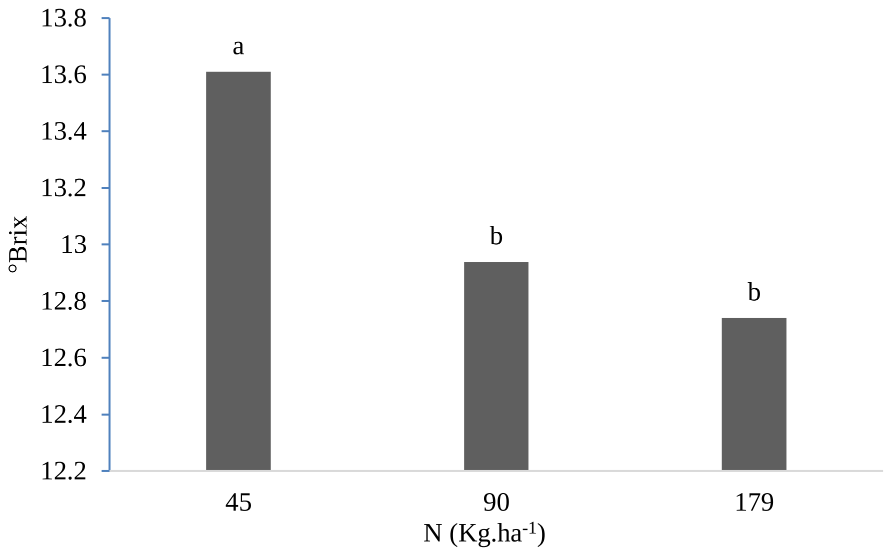

Figure 1. Nitrogen influences °Brix on fruit in 'Tropic Beauty' harvested from peach three nitrogen rates (45, 90, and 179 kg.ha^{-1}).

Light (color) treatments also did not affect pH and TA but had dual interaction between time and nitrogen rate (Table 2). The highest pH was measured in peaches from 90 kg.ha^{-1} N treatment with a six-hours light exposure, and 179 kg.ha^{-1} N treatment with one-hour exposure. The highest in one hour was for 179 kg.ha^{-1} and six hours for 90 kg.ha^{-1}. For TA was the highest in the treatment with zero hour exposure and 90 kg.ha^{-1} N. For time 45 kg.ha^{-1} N was six hours.

Table 2. Light exposure influences on fruit pH and TA in 'Tropic Beauty' harvested from peach three nitrogen rates (45, 90, and 179 kg.ha^{-1}).

	pH			**TA**		
Hours	**45 kg.ha^{-1}**	**90 kg.ha^{-1}**	**179 kg.ha^{-1}**	**45 kg.ha^{-1}**	**90 kg.ha^{-1}**	**179 kg.ha^{-1}**
0	4.00 A a	3.80 A b	3.91 A a	0.47 B b	0.82 A a	0.63 B a
1	3.95 AB a	3.88 B ab	4.01 A a	0.59 A a	0.63 A b	0.55 A a
6	3.88 B a	3.99 A a	3.95 AB a	0.64 A a	0.60 A b	0.61 A a

Average followed by the same capital letter in the row, the small letter in the column do not differ from one to another and ns: no significance by the Tukey test at 5% of probability.

Factor time had a significant difference only in different colors before and after treatment (ΔE) and 6 hours exposure showed a bigger change in fruit color. No differences were detected between the factors nitrogen and lights (Figure 2).

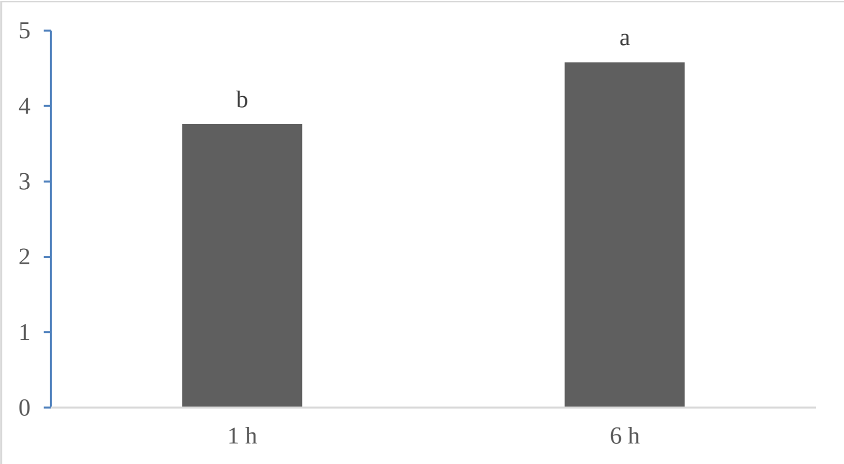

Figure 2. Time exposure influences on fruit different colors before and after treatment (ΔE) in 'Tropic Beauty' harvested from peach three nitrogen rates (45, 90, and 179 $kg.ha^{-1}$).

The patterns of volatile emissions for peach of a set of 30 volatiles were measured after treatments (Table 3). The diversity between the treatment for analysis of volatile compounds by graphical dispersion analysis resulted in treatments: one (45 $kg.ha^{-1}$ of N, time zero and not light); 19 (45 $kg.ha^{-1}$ of N, six hours and dark) and eight (45 $kg.ha^{-1}$ of N, one hour in light white LED) being those with the highest accumulation of volatile compounds quantify by GC-MS (Figure 3).

Table 3. Emissions of volatiles from fruit of peach after treatment with light. Emitted volatiles were collected as described in the Materials and methods and quantified by GC-MS. Values are ng g^{-1} FW h^{-1}.Id. (treatment identification).

Treatment				propyl acetate	3-methyl-1-butanol	2-methyl-1-butanol	isobutyl acetate	cis-3-hexanal	hexanal	butyl acetate	ethyl isovalerate	cis-3-hexen-1-ol	trans-2-hexen-1-ol
Id.	N (kg.ha^{-1})	Time (hour)	Light										
1	45	0	Not	22.68	0.00	0.00	1.34	0.19	2.92	0.18	3.06	0.00	2.25
2	90	0	Not	2.02	0.00	0.00	0.66	6.71	8.67	0.47	1.62	0.27	1.14
3	179	0	Not	1.19	0.00	0.00	0.74	0.60	5.97	0.58	7.72	0.37	7.66
4	45	1	Dark	1.31	0.00	0.00	0.62	1.87	4.25	0.26	4.15	0.21	6.44
5	45	1	Blue	0.43	0.00	0.00	0.51	1.20	3.77	0.58	6.44	0.11	6.47
6	45	1	Green	0.47	0.00	0.00	0.41	0.14	1.78	0.43	2.24	0.15	1.62
7	45	1	Red	0.61	0.00	0.00	0.46	1.70	3.78	0.57	2.46	0.47	6.70
8	45	1	White	6.44	0.00	0.00	2.60	4.38	15.73	1.20	11.53	0.00	11.12
9	90	1	Dark	1.53	0.00	0.00	0.18	0.49	1.18	0.30	1.97	0.00	1.97
10	90	1	Blue	1.33	0.07	0.00	0.60	0.25	1.95	0.55	3.29	0.26	6.78
11	90	1	Green	0.99	0.00	0.00	0.98	3.20	0.54	0.75	0.18	0.00	0.15
12	90	1	Red	0.06	0.00	0.00	1.00	1.08	3.62	0.73	2.96	0.00	2.13
13	90	1	White	1.72	0.00	0.00	0.72	1.55	4.07	0.86	3.00	0.08	3.49
14	179	1	Dark	1.28	0.00	0.00	0.69	0.17	3.66	0.34	1.43	0.12	1.77
15	179	1	Blue	0.66	0.00	0.00	0.91	1.45	4.64	0.40	11.49	0.56	5.73
16	179	1	Green	0.74	0.00	0.00	0.71	1.65	9.10	0.57	9.32	0.47	7.88
17	179	1	Red	1.20	0.00	0.00	0.46	0.70	0.59	0.43	1.38	0.08	1.80
18	179	1	White	1.43	0.00	0.00	0.86	0.92	4.35	1.19	5.48	0.00	4.54
19	45	6	Dark	6.33	0.00	0.00	17.63	0.73	2.32	0.94	3.90	0.00	3.21
20	45	6	Blue	3.12	0.00	0.00	0.58	0.50	0.40	1.06	0.04	0.00	2.02
21	45	6	Green	0.03	0.00	0.00	1.52	0.59	1.11	0.26	1.70	0.00	1.96
22	45	6	Red	0.67	0.00	0.00	1.69	1.01	0.06	0.94	2.90	0.00	1.82
23	45	6	White	0.03	0.33	0.00	2.83	1.50	0.46	0.98	4.17	0.00	0.43
24	90	6	Dark	0.00	0.00	0.00	2.16	0.54	0.01	1.11	1.10	0.15	0.37
25	90	6	Blue	0.48	0.00	0.00	1.07	0.44	1.80	0.44	4.18	0.00	4.40
26	90	6	Green	0.05	0.00	0.00	1.43	0.99	0.70	0.49	0.68	0.07	0.63
27	90	6	Red	2.17	0.00	0.00	6.71	1.02	1.25	1.16	6.75	0.00	2.58

28	90	6	White	3.78	0.00	0.00	4.20	1.74	4.42	0.68	4.47	0.00	1.06
29	179	6	Dark	1.52	0.00	0.00	0.88	0.35	2.57	0.14	4.45	0.00	5.18
30	179	6	Blue	0.66	0.00	0.00	0.71	0.50	0.92	0.15	4.25	0.26	5.48
31	179	6	Green	0.58	0.00	0.00	0.74	0.44	0.26	0.12	1.57	0.00	1.84
32	179	6	Red	0.61	0.00	0.00	1.02	0.50	1.02	0.17	3.46	0.00	3.37
33	179	6	White	4.83	0.00	0.00	2.81	0.61	4.12	0.34	7.13	0.10	6.19

Table 3. Continued

Treatment													
Id.	**N (kg.ha^{-1})**	**Time (hour)**	**Light**	**1-hexanol**	**isopentyl acetate**	**amyl acetate**	**pentyl acetate**	**prenyl acetate**	**hexanoic acid**	**benzyl aldehyde**	**ethyl caproate**	**cis-3-hexenyl acetate**	**hexyl acetate**
1	45	0	Not	0.00	1.61	0.21	0.07	0.00	0.00	0.00	0.45	19.72	49.58
2	90	0	Not	0.00	1.10	0.00	0.45	0.00	0.00	0.43	0.27	6.61	19.90
3	179	0	Not	3.50	0.93	0.00	0.82	0.00	0.00	0.00	0.14	20.82	124.41
4	45	1	Dark	2.13	0.45	0.16	0.00	0.05	0.00	0.00	0.15	28.36	92.82
5	45	1	Blue	1.28	0.40	0.00	0.00	0.00	0.00	0.00	0.08	27.19	66.58
6	45	1	Green	0.88	0.41	0.00	1.20	0.00	0.00	0.00	0.00	33.75	105.34
7	45	1	Red	0.00	0.62	0.09	0.00	0.00	0.00	0.00	0.11	40.57	137.95
8	45	1	White	3.09	2.09	0.36	0.00	0.00	0.00	0.00	0.61	75.73	256.36
9	90	1	Dark	0.00	0.22	0.28	0.04	0.16	0.00	0.00	0.47	31.08	74.27
10	90	1	Blue	0.00	0.64	0.25	0.00	0.24	0.00	0.00	0.51	28.77	74.70
11	90	1	Green	0.00	1.01	0.47	0.00	0.11	0.00	0.00	0.25	30.35	12.76
12	90	1	Red	0.00	0.85	0.19	0.72	0.00	0.00	23.95	0.21	12.76	23.95
13	90	1	White	0.88	0.74	0.31	0.72	0.07	0.00	0.30	0.32	21.33	62.74
14	179	1	Dark	0.00	0.47	0.12	0.00	0.00	0.00	0.00	0.16	26.09	82.13
15	179	1	Blue	2.37	0.84	0.06	1.31	0.00	0.00	0.00	0.12	39.45	206.52
16	179	1	Green	1.94	0.79	0.00	0.00	0.10	0.00	0.00	0.27	52.79	240.34
17	179	1	Red	1.50	0.35	0.00	0.80	0.05	0.00	0.00	0.12	17.53	65.81
18	179	1	White	1.45	1.19	0.20	1.88	0.13	0.00	0.00	0.33	42.36	190.11
19	45	6	Dark	0.00	1.93	1.25	0.00	0.13	0.00	0.23	0.46	26.82	34.95
20	45	6	Blue	0.00	1.99	0.46	0.00	0.42	0.00	0.59	0.65	42.82	68.94

21	45	6	Green	0.00	0.70	0.15	0.00	0.09	0.00	0.36	0.15	23.58	17.62
22	45	6	Red	0.00	1.06	0.19	0.00	0.11	0.00	1.02	0.32	29.53	34.96
23	45	6	White	0.00	3.63	0.65	0.00	0.16	0.00	0.66	0.31	37.52	56.53
24	90	6	Dark	1.99	2.04	0.20	0.00	0.44	0.00	1.04	0.66	43.69	116.97
25	90	6	Blue	0.00	0.77	0.00	0.00	0.10	0.00	1.36	0.18	18.00	27.16
26	90	6	Green	0.00	0.68	0.08	0.00	0.18	0.00	0.84	0.16	27.92	40.88
27	90	6	Red	0.00	0.34	0.81	0.00	0.48	0.00	0.44	0.48	43.50	50.32
28	90	6	White	0.00	1.12	0.31	0.00	0.09	0.00	0.22	0.32	26.33	55.06
29	179	6	Dark	0.00	0.66	0.00	0.00	0.09	0.00	0.58	0.20	26.89	60.71
30	179	6	Blue	0.53	0.30	0.00	0.00	0.07	0.00	0.00	0.19	18.97	57.62
31	179	6	Green	1.19	0.37	0.00	0.00	0.00	0.00	0.25	0.13	19.39	69.79
32	179	6	Red	0.22	0.62	0.13	0.00	0.07	0.00	0.62	0.20	25.37	75.74
33	179	6	White	2.01	1.46	0.15	0.00	0.30	0.00	0.24	0.22	29.21	80.89

Table 3. Continued

Treatment				**trans-2 hexenyl acetate**	**phenylacetal-dehyde**	**gamma hexalactone**	**ethyl heptanoate**	**nonyl aldehyde**	**ethyl caprylate**	**gamma-octalactone**	**nonyl acetate**	**gamma-decalactone**	**delta-decalactone**
Id.	**N ($kg.ha^{-1}$)**	**Time (hour)**	**Light**										
1	45	0	Not	81.18	0.11	3.00	0.18	0.09	5.37	0.26	6.93	2.00	0.52
2	90	0	Not	22.47	0.00	2.76	0.14	0.00	3.29	0.37	6.94	3.93	0.82
3	179	0	Not	94.92	0.00	2.12	0.00	0.25	1.00	0.21	6.95	1.97	0.65
4	45	1	Dark	80.55	0.04	2.69	0.00	0.09	1.03	0.33	6.94	4.51	1.59
5	45	1	Blue	83.96	0.08	4.01	0.00	0.00	0.63	0.37	6.95	6.92	2.41
6	45	1	Green	100.39	0.00	3.01	0.00	0.00	0.57	0.25	6.92	5.30	1.87
7	45	1	Red	136.09	0.00	3.10	0.00	0.24	0.89	0.25	6.95	5.67	1.77
8	45	1	White	259.58	0.14	9.58	0.13	0.46	4.76	0.98	6.95	5.55	4.68
9	90	1	Dark	100.10	0.09	4.17	0.09	0.26	3.06	0.53	6.93	8.12	2.59
10	90	1	Blue	92.02	0.07	4.53	0.08	0.34	2.22	0.67	6.94	8.50	3.20
11	90	1	Green	90.81	0.10	4.18	0.00	0.00	1.01	0.44	6.92	6.54	2.29
12	90	1	Red	43.61	0.00	3.43	0.07	0.00	2.07	0.33	6.94	3.46	0.99
13	90	1	White	70.42	0.13	2.98	0.05	0.17	2.28	0.28	6.94	6.05	2.32

14	179	1	Dark	91.05	0.00	2.50	0.00	0.09	1.26	0.31	6.92	6.16	1.70
15	179	1	Blue	152.32	0.00	3.54	0.00	0.41	1.04	0.36	6.94	6.37	1.90
16	179	1	Green	196.36	0.00	2.29	0.00	0.48	1.59	0.15	6.94	3.46	1.04
17	179	1	Red	72.15	0.00	2.03	0.00	0.00	0.82	0.20	6.94	3.04	0.96
18	179	1	White	166.94	0.00	2.88	0.06	0.35	2.18	0.23	6.93	4.52	1.23
19	45	6	Dark	50.71	0.11	6.18	0.14	0.18	4.18	0.82	6.95	6.56	1.89
20	45	6	Blue	95.31	0.15	5.42	0.18	0.32	5.35	0.53	6.93	6.35	1.70
21	45	6	Green	41.25	0.06	4.58	0.00	0.05	1.96	0.78	6.95	7.53	2.22
22	45	6	Red	60.28	0.11	3.88	0.08	0.09	3.30	0.55	6.94	6.05	1.70
23	45	6	White	74.86	0.16	4.02	0.08	0.17	2.48	0.49	6.94	6.06	1.83
24	90	6	Dark	118.95	0.04	4.21	0.13	0.31	3.79	0.59	6.93	11.25	4.08
25	90	6	Blue	42.69	0.00	4.03	0.08	0.00	1.70	0.41	6.93	4.60	1.48
26	90	6	Green	61.10	0.00	4.35	0.04	0.15	1.39	0.59	6.94	8.17	2.77
27	90	6	Red	77.18	0.00	3.88	0.09	0.21	3.16	0.68	6.94	8.30	2.27
28	90	6	White	68.64	0.00	3.14	0.07	0.11	2.49	0.47	6.94	7.58	2.39
29	179	6	Dark	92.39	0.00	3.24	0.06	0.08	2.16	0.38	6.94	6.05	1.49
30	179	6	Blue	75.77	0.00	2.19	0.06	0.18	1.64	0.28	6.94	4.89	1.35
31	179	6	Green	75.00	0.00	3.03	0.00	0.00	1.50	0.26	6.94	4.80	1.46
32	179	6	Red	88.01	0.00	3.16	0.00	0.19	2.14	0.38	6.94	5.62	1.54
33	179	6	White	95.19	0.00	3.45	0.06	0.15	1.80	0.42	6.93	4.74	1.09

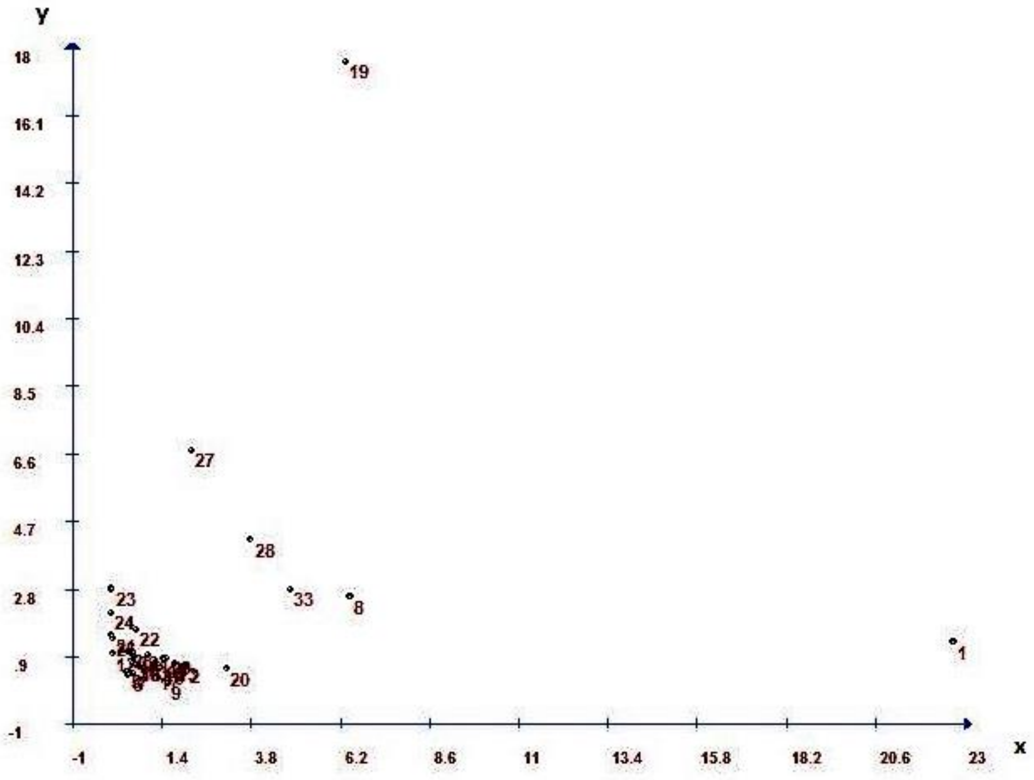

Figure 3. Graphic dispersion analysis showing the genetic differences among 33 treatments in peaches (indicated in numbers) according to the X and Y axes represent the measures relative to the distances expressed obtained by contents of 30 volatile.

4 Discussion

The results observed as nitrogen rate affect fruit quality, 90 kg.ha^{-1} N treatment presented the highest firmness and TA for the fruit. The 45 kg.ha^{-1} N treatment had highest Brix. This suggests that no treatment is needed for fruit when applying these nitrogen rates. Its not in accordance with the observations by Dolinski et al., (2005) who stated that the qualitative parameters of total soluble solids, titratable total acidity and firmness were not affected by the N dosages of 40, 80 and 160 kg.ha^{-1}. The high doses of nitrogen fertilization influence peach fruit quality, causing excessive canopy growth and shading (Weinbaum et al., 1992).

The fruits treated with blue light and 179 kg.ha^{-1} presented the highest firmness. The tomatoes treated with lights had a gradual decrease in the firmness of all tomatoes as the storage time increased. Tomatoes pretreated with blue light maintained significantly higher levels of firmness than those pretreated with dark (Dhakal and Baek, 2014)

The strawberries treated with blue light maintained higher TA content in comparison with the control fruit during storage. Total sugar content exhibited a decreasing trend in all strawberries, regardless of treatment, during storage. There was no significant difference in total sugar content between blue-treated and control fruits in the initial 6 days of storage, however, blue light treatment improved the total sugar content afterward (Xu et al., 2014). There was no significant difference observed between lights for Brix, pH, and TA.

The irradiation of each light showed a little difference, but the soluble solid content increased the most under the green light treatment. There was no great difference in acidity increase or decrease but after harvest, between the control group and the test group (LED UVA, blue, green and red), LED irradiation treatment does not show much effect in acidity change of strawberry (Kim et al., 2011).

The color difference (ΔE) also had differences between exposure time. For value expressed for fruit color, under blue light, samples tended to increase gradually, which exhibited a higher level than for the control after 4 days of storage (Xu et al., 2014). The ripe green tomatoes treated with blue light presented a slower rate of color change from green to red when compared to red light treatment (Dhakal and Baek, 2014).

The light intensity should be based on the physiological requirements of the plant and controlled in a reasonable range. The hydroponic lettuce demonstrated that concentrations of soluble sugars in lettuce increased and the concentration of nitrate substantially decreased with a light intensity increase from 50 μmol m^{-2} s^{-1} to approximately 200 μmol m^{-2} s^{-1}. Therefore, the suitable light intensity for vegetable growth and development varies among species and cultivars. However, the suitable light intensity for certain leaf vegetables cultivated in controlled environments is in the range between 200 and 300 $\mu molm^{-2}$ s^{-1}(Zhou et al., 2011). In this study, the intensity of 1000 $\mu molm^{-2}$ s^{-1} was for postharvest. This high intensity should have caused the low difference between treatments.

Kim et al. (2012) analyzed volatile compounds from different types of vegetable oils under LED irradiation for 12 weeks. Yellow, red, blue, and fluorescent lights were used as treatment through LED equipment. Samples stored under dark conditions were also observed at the same time. An MS-based electronic nose and discriminant function analysis were used to determine the amount of volatiles from various oils under LED irradiation. As the exposure time of LED treatment increased, volatile compounds in sesame oil and perilla oil increased considerably under blue light. Under fluorescent, red, and yellow light, the volatile compounds from extra virgin olive oil increased significantly.

According to (Bian et al., 2015), the use of supplemental light could enhance light conditions and effectively increases beneficial phytochemical levels while reducing levels of harmful substances in vegetables. However, light quality combination strategies and modulation methods on plant species and plant development stages should be carefully evaluated when selecting a supplemental light source for vegetables as the effect of light quality on phytochemical accumulation varies among species and cultivars, even under the same cultivation conditions and light modulation strategies.

5 Conclusion

The time exposure, light colors did not affect postharvest fruit quality. However, fruit from trees treatment of 45 $kg.ha^{-1}$ of nitrogen was the highest for quality of fruits. The higher amount of volatile compounds were from treatments 45 $kg.ha^{-1}$ of nitrogen, no exposure to light and one hour exposure to light white LED. This experiment served as a pilot study to determine that different colors and intensity of LED has little influence on peach fruit quality in the postharvest.

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ARTICLE 4 - PEACH CULTIVARS FROM 'TROPICAL' REGIONS: CHARACTERIZATION AND PROCESSING POTENTIAL

CULTIVARES DE PÊSSEGO DE REGIÕES TROPICAIS: CARACTERIZAÇÃO E POTENCIAL DE PROCESSAMENTO

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Abstract

In order to increase the availability to consumers and add even more value to peaches (*Prunus persica* (L.) Batsch) and to identify which cultivars grown in 'Tropical' regions are more suitable for jelly processing, the objective in this study was to characterize and evaluate the influence of different peach cultivars ('Centenário', 'Bonão', 'Biuti', 'Libra', 'Tropical', 'Aurora-1', 'Diamante', 'Régis' and 'Douradão') cultivated in 'Tropical' regions on the physical-chemical characteristics, rheological properties and sensory acceptance of the resulting jelly. It was verified that the evaluated cultivars presented great variability among themselves in relation to the physical and physical-chemical characteristics and in relation to the bioactive compounds and antioxidant activity. The jellies elaborated from these cultivars, although presenting great variability in relation to the physical-chemical and rheological parameters, presented similar, high acceptance. It is concluded that all cultivars studied are suitable for processing and can be used for industrialization.

Keywords: *Prunus persica* (L.) Batsch, sensory quality, processing.

Resumo

Com o objetivo de aumentar a disponibilidade para os consumidores, agregar ainda mais valor aos pêssegos (*Prunus persica* (L.) Batsch) e identificar quais cultivares cultivadas em regiões tropicais são mais adequadas para o processamento de geleia, o objetivo neste estudo foi caracterizar e avaliar a influência de diferentes cultivares de pessegueiro ('Centenário', 'Bonão', 'Biuti', 'Libra', 'Tropical', 'Aurora-1', 'Diamante', 'Régis' e 'Douradão') cultivadas em regiões tropicais nas características físico-químicas, reológicas e sensoriais da geleia resultante. Verificou-se que as cultivares avaliadas apresentaram grande variabilidade entre si em relação às características físicas e físico-químicas e em relação aos compostos bioativos e atividade antioxidante. As geleias elaboradas a partir destas cultivares, embora apresentam grande variabilidade em relação aos parâmetros físico-químicos e reológicos, apresentaram alta aceitação. Conclui-se, que todas as cultivares estudadas são indicadas para processamento e podem ser destinadas à industrialização.

Palavras-chave: *Prunus persica* (L.) Batsch, qualidade sensorial, processamento.

1 Introduction

The peach tree produces fruits with very pleasant aroma and color that are part of the economic importance fruits list, not only for their exotic appearance, but also for being a source rich in carotenoids and minerals (CANTÍN et al., 2009). Due to its excellent organoleptic quality, the peach is very appreciated in Brazil, as evidenced by the continuous increase in the consumption of the fruit in fresh or processed in the form of several products, usually available in the market, which has provided increasing interest in its commercial cultivation. In 2015, Brazil imported about 3,980 tons of peach for fresh consumption and 7,031 tons of processed peaches (IBGE, 2016). This shows a great market potential in Brazil and since domestic production has not yet reached enough volume to meet domestic demand, efforts have been made, especially towards the production of peaches in subtropical' and 'Tropical' regions (SOUZA et al., 2013).

The peach tree (*Prunus persica*) is a temperate climate species, but some cultivars have been developed for growth in sub'Tropical' and 'Tropical' regions. The adoption of peach cultivars that require fewer cold units in mild winter regions makes it possible to harvest the fruits in times of lower supply (BARBOSA et al.,2010). This is due to the early harvest of early peaches in southeastern Brazil occurring in anticipated times in relation to the traditional producing regions of Rio Grande do Sul and Santa Catarina (ARAÚJO et al., 2008). In addition to the exploitation of the peach tree in subtropical and tropical regions, the fruits are harvested at a time when there is a peach shortage in the Brazilian market, obtaining better prices when marketed as fresh fruit, it still allows the production of high-quality processed products. This is because during the peach harvest season in Minas Gerais State there are few precipitation providing better quality fruits, both intrinsic and extrinsic (SOUZA et al., 2013).

Due to the availability of several peach cultivars, it is necessary to survey the cultivars that are most suitable and indicated for processing. One way to raise consumption and add even more value to the final product is through processing or industrialization through the manufacture of juices, jams and jellies (KAPPOR and RANOTE, 2016). In this context, the objective of this study was to characterize and evaluate the influence of different peach cultivars (‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Centenário’, ‘Diamante’, ‘Douradão’, ‘Libra’, ‘Régis’ and ‘Tropical’) cultivated in ‘Tropical’ regions on the physical-chemical characteristics, rheological properties and sensory acceptance of the resulting jelly in order to identify the cultivars with the greatest potential for industrial use and to verify which cultivars present a wide range of consumption in the region of Minas Gerais.

2 Materials and Methods

The peaches were collected in the orchard of the fruit sector of the Federal University of Lavras, Lavras-MG (Brazil) when they presented their physiological maturity. After the harvest, the peaches were selected for size, uniformity and maturation and were then cold stored in the Postharvest Laboratory. The peach cultivars used in this research were: ‘Aurora-1’, ‘Biuti’, ‘Bonão’, ‘Centenário’, ‘Diamante’, ‘Douradão’, ‘Libra’, ‘Régis’ and ‘Tropical’. The city is located at 21°14’ South latitude and 45°00’ West longitude, at an average altitude of 918 meters. The climate is ‘Tropical’ climate of altitude, with dry winter and rainy summer (Alvares et al., 2013).

Nine jelly formulations were elaborated, with the only modification among them being the peach cultivar. For pulp acquisition, the selected and sanitized fruits were homogeneized with 50% water for about 5 minutes in a Poly industrial model mixer. LS-4 with 4.0 L capacity at a speed of 3500 rpm. Subsequently, to obtain the clarified juice the pulp obtained was passed through a fine mesh sieve. For the preparation of the jellies 65% of the clarified peach juice, 35% sugar, 1% high methoxylation pectin (Danisco, São Paulo, Brazil) and 0.5% citric acid were used. Initially, the sugar and pulp were combined and heated in an open pan with gas flame (Macanuda, SC, Brazil). When the soluble solids reached 65°Brix, heating was stopped. For the Brix degree, the total soluble solids were measured by a RT-82 portable refractometer. After finishing the jellies, they were placed in 250 ml sterile glass jars, cooled to room temperature and stored at a temperature of 7°C until the moment of analysis.

To characterize the different cultivars, analyzes of length, diameter, pulp/pit ratio, total soluble solids, total titratable acidity, total soluble solids/total acidity (ratio), pH and color were performed on fresh fruits in three replicates. The cultivars were also evaluated for phenolic compounds content, antioxidant activity (ABTS) and vitamin C concentration. The total soluble solids, pH, total titratable acidity, color (L*, Chroma and °Hue), texture profile analysis and sensorial analysis were analyzed in the jellies.

The length and diameter of the fruits were measured using a 150 mm digital pachymeter (Kingtools, São Paulo, SP) and a pulp/pit ratio (P/P) was performed using a semi analytical balance AUX220 (Shimadzu of Brazil, São Paulo, SP). The total acidity, soluble solids and pH values were determined according to the Adolfo Lutz Institute (IAL, 2005). The color was determined according to the method described by GENNADIOS et al.(1996).

The total phenolic analysis was performed according to the Folin–Ciocalteu method with some modifications. The antioxidant activity was determined according to the ABTS assay (RE et al., 1999). The ascorbic acid analysis was performed though the colorimetric method with 2,4-dinitrophenylhydrazine (2,4-DNPH).

The texture profile analyses (TPA) of the jellies were made in penetration mode under the conditions described by SOUZA et al. (2014). The jelly samples were compressed by 30%. The parameters analyzed were hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness. An acceptance test was performed with 90 consumers, where the evaluated characteristics were color, taste, consistency and overall liking, through a 9-point hedonic scale (1 = extreme disliked and 9 = extremely liked). The sensorial test was conducted over two days. On the first day the evaluation of five formulations was done and on the second, the four remaining formulations. Sensory analysis was obtained according to the local Ethics Committee, approval number 1.091.594.

In order to compare the different cultivars in relation to the physical, physico-chemical, bioactive compounds and antioxidant activity and the different peach jelly obtained in relation to physical-chemical, rheological and sensorial characteristics, a univariate statistical analysis (ANOVA) and Tukey test was performed to verify if there was a significant difference among the samples at a 5% significance level ($p \leq 0.05$).The jelly data was also evaluated using principal component analysis (PCA) in order to correlate physical-chemical and rheological with the different types of peach cultivars. The SensoMaker software 1.6 was used for data analysis.

3 Results and Discussion

The average values and the average test of the physical and physicochemical properties evaluated for the different cultivars are shown in Table 1. It can be verified that there was significant difference ($p \leq 0.05$) for all evaluated attributes.

Table 1. Average lenght (AL), average diameter (AD), pulp/pit ratio (P/P), total soluble solids (SS), total acidity (TA), pH, soluble solids/total acidity ratio (ratio), color (L*, Croma and Hue) in different peach cultivars.

Cultivars	**AL (mm)**	**AD (cm)**	**P/P**	**SS (ºBrix)**	**TA (%)**	**pH**	**Ratio**	**L***	**Croma**	**° Hue**
Aurora-1	63.63^{bc}	4.16 ^{bc}	15.67^{ab}	15.20^{a}	0.80^{c}	6.06a	19.00^{c}	66.18^{ab}	38.82^{c}	88.54^{a}
Biuti	49.16^{c}	4.63^{bc}	10.64^{bc}	9.86 ^{b}	0.77^{c}	3.34 c	12.80^{cd}	60.40^{cd}	37.50^{c}	84.74^{ab}
Bonão	88.93^{a}	5.26^{bc}	16.95^{a}	11.70^{b}	1.04^{b}	3.59c	11.25^{d}	65.50 ^{ab}	47.51^{bc}	77.75^{bc}
Diamante	69.40^{b}	7.43^{a}	9.53^{c}	14.03^{a}	1.15^{a}	3.62d	12.2^{cd}	61.62^{abc}	38.31^{c}	77.64^{c}
Douradão	63.67^{bc}	6.10^{ab}	10.42^{bc}	14.26^{a}	0.28 ^{e}	4.21 b	50.92^{a}	65.33 ^{ab}	47.97^{abc}	77.09^{c}
Libra	70.56^{b}	5.13^{bc}	13.83^{abc}	10.83^{b}	1.14^{a}	3.49c	9.5^{d}	61.45^{abc}	60.66^{a}	72.39cd
Régis	50.30^{c}	4.33 ^{bc}	11.66^{abc}	10.00^{b}	0.54^{d}	4.06 b	18.51^{c}	56.58 ^{d}	58.38^{ab}	66.35^{d}
Tropical	46.83^{c}	3.90^{c}	12.05^{abc}	10.83^{b}	0.31^{e}	4.56b	34.93^{b}	67.40^{a}	52.03^{ab}	85.13^{a}
CV(%)	9.80	13.94	15.62	5.44	4.25	5.21	10.33	3.65	9.70	3.03

*Mean values with common letters in the same column indicate that there is no significant difference among samples ($P < 0.05$) by Tukey's mean test.
**Total acidity: g citric acid/100 g f.w.

As regards the size parameters of the different peach cultivars, through Table 1, it is possible to verify that the cultivars ‘Bonão’ and ‘Diamante’ stood out presenting the longest length (88.93 mm) and the largest diameter (7.43 cm), respectively. Regarding the pulp/pit ratio, the ‘Bonão’ cultivar showed the highest proportion of pulp (16.95). For fresh fruit consumption, is important to note that the larger the fruit and the higher the pulp/pit ratio, the greater the consumer acceptability. Thus, among the cultivars studied, the ‘Bonão’ is that which stands out the most because it is a larger fruit with a higher pulp/pit ratio.

The soluble solids content varied from 9.86 to 15.20 °Brix, the acidity ranged from 0.28 to 1.15 g of citric acid/100 g, the pH ranged from 3.34 to 6.06 and the ratio ranged from 9.5 to 50.92. These are the main parameters that indicate if the fruits are more indicated for consumption in fresh form or if processing is more appropriate. In general the soluble solids contents and acidity are within the ranges found in the literature (SOUZA et al., 2013).

In general, all peach cultivars, especially ‘Centenário’, ‘Aurora-1’, ‘Diamante’ and ‘Douradão’, presented high soluble solids levels. The Brix is widely related to the presence of sugars and organic acids, thus reflecting the amount of these nutrients.

In relation to acidity, the less acidic were ‘Centenário’ and ‘Douradão’, that also stood out because they presented the highest soluble solids levels and the ‘Aurora-1’ cultivar stood out because of the higher pH. All evaluated cultivars probably sensorially well-accepted.

For the fruit flavor estimation, one of the most used ways is through the SST/ATT ratio. This relationship (SS/AT), influenced by climatic conditions, especially by luminosity and temperature, is considered appropriate for determining fruit quality (ANTUNES et al., 2010). The higher contents of this variable is due to the high level of soluble solids and/or the low level of acidity, and the higher the ratio, the greater the sweetness of the fruit in relation to its acidity. The ‘Douradão’ cultivar stood out for having a higher ratio (50.92). This characteristic demonstrate that this cultivar has high sweetness and low acidity which reflects in an optimal sweet-acid balance which is desirable for fresh fruit consumption.

As for the coloration of the different peach cultivar fruits, the color parameter L* varied from 56.58 (‘Régis’) to 67.40 (‘Tropical’), Chroma from 36.65 (‘Centenário’) to 60.66 (‘Libra’) and Hue from 66.35 (‘Régis’) to 85.58 ‘Centenário’). From these results it can be verified that all the peaches have a red/yellowish coloration, and the cultivars ‘Régis’ and ‘Diamante’ differ from the others, showing a more reddish coloration. In addition, the cultivar ‘Tropical’ stands out for having a lighter color and ‘Libra’ because it has a higher color intensity/purity.

Table 2 shows the phenolic compounds content, antioxidant activity and vitamin C content of the different peach cultivars. It can be verified that there was a significant difference among the peach cultivars for all the evaluated parameters ($p \leq 0.05$).

The average table for bioactive compounds and antioxidant activity (Table 2) shows that the ‘Biuti’ cultivar had the highest phenolic content (91.14 mg GAE/100 g). On the other hand, the cultivar ‘Bonão’ presented higher values of antioxidant activity (3.26 µM trolox/gram of fruit - ABTS method) and still had a higher content of vitamin C (40.75 mg/100 g). According to this classification all cultivars can be classified as having a low concentration of phenols. The fruit can also be classified into three categories according to the ascorbic acid content: low (<30 mg.100 g^{-1}), medium (30-50 mg.100 g^{-1}) and high (> 50 mg.100 g^{-1}) of vitamin C (RAMFUL et al., 2011). According to this classification, the cultivars ‘Centenário’, ‘Bonão’, ‘Libra’ and ‘Tropical’ have medium content, while the others are classified as low.

Table 2. The total phenolics, antioxidant capacity (ABTS) and ascorbic acid in different peach cultivars.

Cultivars	Total phenolics	Antioxidant capacity – ABTS	Ascorbic acid
Aurora-1	19.49[e]	1.06[c]	15.52[f]
Biuti	91.14[a]	2.37[ab]	28.17[bc]
Bonão	28.03[cd]	3.26[a]	40.75[a]
Centenário	35.69[b]	2.08[b]	30.20[bc]
Diamante	22.08[de]	1.80[bc]	22.26[de]
Douradão	10.05[f]	0.93[c]	16.74[ef]
Libra	17.87[e]	2.33[ab]	32.07[b]
Régis	33.52[bc]	2.40[ab]	26.11[cd]
Tropical	33.81[bc]	2.20[b]	37.96[a]
CV(%)	6.68	16.27	7.21

* Mean values with common letters in the same column indicate that there is no significant difference between samples ($p \leq 0.05$) by Tukey's mean test.
** Abbreviations: GAE: gallic acid equivalent.
*** Total phenolics (mg GAEs/100 g f.w.); Antioxidant capacity – ABTS (µM trolox/gram of fruit); Ascorbic acid (mg/100 g f.w.)

The average values and the average test of the physicochemical and rheological properties evaluated for the different peach jelly formulations are shown in Table 3 and Table 4, respectively. All analyzed parameters were significant ($p \leq 0.05$) for the jelly made with different peach cultivars. In order to facilitate the visualization, a PCA was elaborated to correlate the physicochemical properties data with peach jellies (Figure 1).

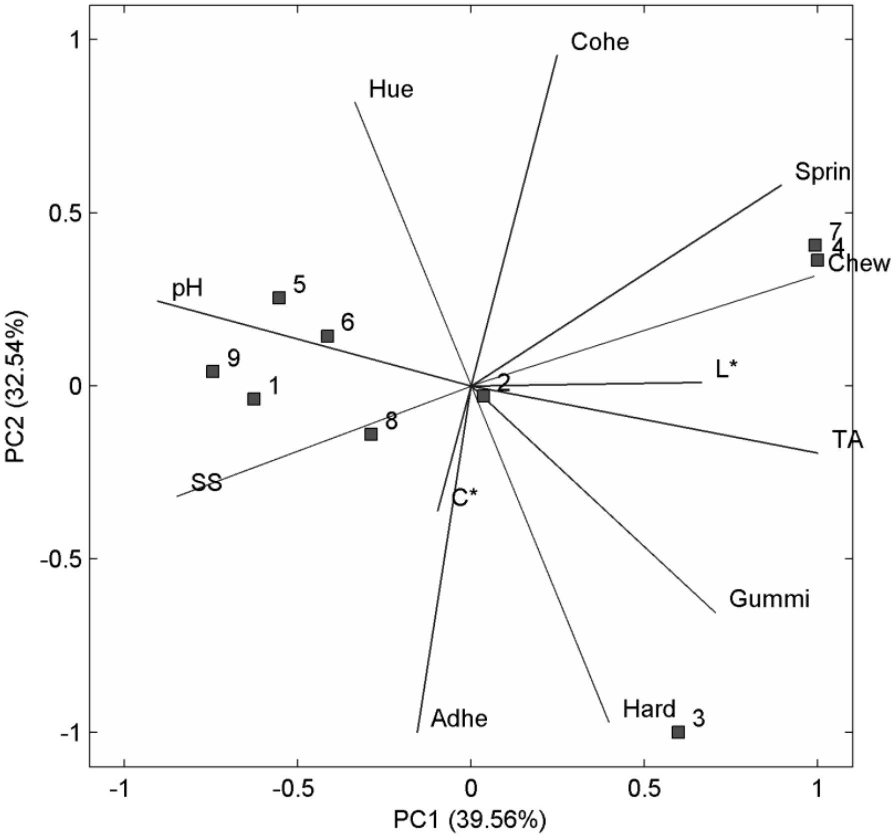

Figure 1. Principal Component Analysis (PCA) for the different peach cultivar jellies. ‘Centenário’ (1); ‘Bonão’ (2); ‘Biuti’ (3); ‘Libra’ (4); ‘Tropical’ (5); ‘Aurora-1’ (6); ‘Diamante’ (7); ‘Régis’ (8) and ‘Douradão’ (9). SS, Soluble Solids; TA, Total acidity; Hard., Hardness; Adhe., Adhesiveness; Sprin, Springiness; Cohe, Cohesiveness; Gummi, Gumminess; Chew, Chewiness.

Through the averages table (Table 3) and the PCA (Figure 1) it can be verified that, with the exception of the cultivars ‘Biuti’, ‘Libra’ and ‘Diamante’, the jellies presented similar solids content (61 - 67.6ºBrix). The jellies obtained from the cultivars ‘Centenário’, ‘Tropical’, ‘Aurora-1’ and ‘Douradão’ were characterized by higher pH values and the cultivars ‘Biuti’, ‘Libra’ and ‘Diamante’ characterized by higher acidity values.

Table 3. Soluble Solids (SS), pH, total acidity (TA), color (L*, Croma and Hue) in peach jelly.

Cultivars	SS	pH	TA	L*	Croma	°Hue
Aurora-1	65.6^{abc}	4.08^{b}	0.26^{bc}	29.93^{cd}	30.09^{bcd}	79.16^{b}
Biuti	62.3^{cd}	3.66^{d}	0.46^{ab}	32.97^{c}	34.20^{bc}	68.69^{e}
Bonão	67.0^{ab}	3.85^{c}	0.42^{abc}	41.14^{a}	43.95^{a}	74.83^{cd}
Centenário	67.6^{ab}	4.59^{a}	0.24b^{c}	25.64^{e}	29.72^{cd}	72.14^{d}
Diamante	53.3^{d}	3.81^{cd}	0.41^{abc}	32.81^{cd}	26.22^{d}	76.44^{cd}
Douradão	69.6^{a}	4.56^{a}	0.21^{c}	28.88^{d}	33.15^{bc}	81.2^{a}
Libra	59.0^{c}	3.64^{d}	0.52^{ab}	37.43^{b}	32.48^{bc}	79.12^{b}
Régis	63.3^{bcd}	3.82^{cd}	0.28^{abc}	31.83^{cd}	34.41^{b}	77.20^{c}
Tropical	61.0^{c}	4.45^{a}	0.19^{c}	29.08^{d}	31.23^{bc}	82.29^{a}
CV(%)	2.5	1.6	24.41	3.17	4.77	0.83

*Mean values with common letters in the same column indicate that there is no significant difference between samples ($p \leq 0.05$) by Tukey's mean test.
** Total acidity: g citric acid/100 g f.w.

In relation to color, it can be seen from Table 3 and Figure 1 that the 'Bonão' cultivar resulted in a lighter jelly and with greater color intesity/purity than the others. The 'Biuti' cultivar resulted in a darker jelly compared with the others. In general when compared to the fruit in fresh form, the jelly presented became redder and darker, possibly due to the concentration and the reactions that occur during the heating, such as the Maillard reaction.

Table 4. Hardness (Hard), adhesiveness (Adhe N/s), springiness (Sprin), cohesiveness (Cohe), gumminess (Gummi N) and chewiness (Chew) in peach jelly.

Cultivars	Hard	Adhe	Sprin	Cohe	Gummi	Chew
Aurora-1	0.06^{b}	0.22^{de}	0.99^{b}	0.82^{ab}	0.05^{b}	0.05^{b}
Biuti	0.47^{a}	1.23^{a}	0.98^{b}	0.37^{c}	0.17^{a}	0.17^{ab}
Bonão	0.05^{b}	0.09^{ef}	1.28^{b}	0.77^{b}	0.04^{b}	0.06^{b}
Centenário	0.07^{b}	0.46b^{c}	0.99^{b}	0.83^{ab}	0.06^{b}	0.06^{b}
Diamante	0.10^{b}	0.02^{f}	4.01^{a}	1.05^{a}	0.10^{b}	0.40^{a}
Douradão	0.08^{b}	0.61^{b}	0.99^{b}	0.81^{ab}	0.06^{b}	0.06^{b}
Libra	0.08^{b}	0.02^{f}	3.75^{a}	1.06^{a}	0.09^{b}	0.37^{a}
Régis	0.11^{b}	0.36^{cd}	0.97^{b}	0.43^{c}	0.04^{b}	0.04^{b}
Tropical	0.06^{b}	0.26^{de}	1.00^{b}	0.84^{ab}	0.05^{b}	0.05^{b}
CV(%)	37.20	16.54	15.29	11.49	37.05	38.42

*Mean values with common letters in the same column indicate that there is no significant difference between samples ($p \leq 0.05$) by Tukey's mean test.

In relation to the texture, it can be seen from the PCA (Figure 1) and from the table of means (Table 4) that the jelly obtained with the cultivar ‘Biuti’ is characterized by resulting in a jelly with the highest hardness, adhesiveness and gumminess values. That is, this cultivar originates a more rigid, firm, adhesive and gummy jelly. On the other hand, ‘Libra’ and ‘Diamante’ cultivar jellies have greater springness, cohesiviness and chewiness.

Several factors may explain the texture change among the jellies made from different peach cultivars. The amount of sugar present in each cultivar, pH, acidity and soluble pectin content are factors that can influence the gelation and, the texture of the final product.

Significant difference was verified among the jellies obtained from different peach cultivars for color and overall liking ($p \leq 0.05$) (Table 5).

Table 5. Sensory characteristics of the peach jellies obtained from different cultivars.

Formulations	Color	Taste	Consistency	Overall Liking
Aurora-1	7.33^{ab}	7.10^{a}	7.47^{a}	7.39^{ab}
Biuti	7.64^{ab}	7.50^{a}	7.41^{a}	7.53^{ab}
Bonão	7.25^{b}	6.82^{a}	7.10^{a}	6.97^{b}
Centenário	7.84^{a}	7.33^{a}	7.60^{a}	7.64^{a}
Diamante	7.61^{ab}	7.34^{a}	7.21^{a}	7.49^{ab}
Douradão	7.82^{ab}	7.22^{a}	7.41^{a}	7.40^{ab}
Libra	7.71^{ab}	7.37^{a}	7.42^{a}	7.37^{ab}
Régis	7.81^{ab}	7.47^{a}	7.32^{a}	7.50^{ab}
Tropical	7.61^{ab}	7.30^{a}	7.34^{a}	7.29^{ab}

* Mean values with common letters in the same column indicate that there is no significant difference among samples ($p \leq 0.05$) by Tukey’s mean test.

In general, the jelly formulations presented an excellent sensory acceptance for all the sensorial attributes evaluated, with average scores generally varying between the hedonic terms "moderately liked" and "liked very much" (Table 5). This clearly indicates that as expected, peach-based products are highly accepted and appreciated by Brazilians. In addition, it can be clearly observed that all cultivars studied have high processing potential.

It can be clearly seen that the formulation elaborated with the ‘Bonão’ was the least sensorially accepted. By the mean table (Table 5) it can be verified that this cultivar had lower scores than the others for the attribute, color, which may have influenced the lowest score observed for the overall liking attribute. The jelly obtained from the ‘Bonão’ was characterized by being different from the others by being darker and showing higher color intensity (Table 3 and Figure 1). This suggests that color has a great influence on the acceptability of peach jelly and that the consumer prefers lighter or clearer jellies. Although this cultivar has been the least accepted, it is still highly indicated for processing due to high sensory acceptance and the fact that color is an attribute that can be easily altered in order to please the consumer. It was previously observed that the jellies presented wide differences among themselves in relation to the physical-chemical and rheological attributes, however, since no significant difference in the acceptability was detected for the flavor attribute and the consistency, these attributes had no influence on the sensory quality of the jelly.

Generally the most suitable cultivars for processing are the least accepted for fresh consumption, thus, it is possible to provide a consumption destination for the all the cultivars in the best way. The cultivars ‘Aurora-1’, ‘Douradão’ and ‘Tropical’, for example, are destined for table consumption, thus, since there already is a large consumption destination, it may be less interesting to destine them for processing. However, the other cultivars that are destined for dual purposes (‘Biuti’ and ‘Régis’) or destined for processing (Diamante) may indeed, be more interesting and suitable for processing. In addition, as it is feasible to prepare jellies from all the studied peach cultivars, the adaptation, susceptibility to pests, production cost and yield of the different cultivars are some factors that should help to indicate which are the most interesting cultivars to be cultivated and destined for industrialization.

4 Conclusion

In this study it can be verified that the evaluated peach cultivars presented great variability among themselves in relation to physical, physical-chemical characteristics and in relation to the bioactive compounds and antioxidant activity. The jellies elaborated from the different peach cultivars, although presenting high variability in relation to the physical-chemical and rheological parameters, presented similar and high sensory acceptance. Therefore, it is concluded that all studied peach cultivars are indicated for processing.

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FINAL CONSIDERATIONS

For crops in the tropics, the cultivars ‘Centenário’, ‘Douradão’, ‘Kampai’ and ‘Régis’ a the most adaptable and stable in relation to precocious and productivity.

The most precocious cultivars, with the greatest adaptability for sprouting and flowering in the tropics, were ‘Aurora-1’, ‘Joía-3’, ‘Kampai’, and ‘Tropical’.

The time exposure, light colors did not affect postharvest fruit quality. However, fruits from the trees treatment of 45 $kg.ha^{-1}$ of nitrogen were the highest for the quality of fruits. Needs studies are necessary to determine the different and intensity colors of LED because this experiment served as a pilot has little influence on peach fruit quality in the postharvest.

Peach cultivars presented great variability among themselves in relation to physical, physical-chemical characteristics and in relation to the bioactive compounds and antioxidant activity. The jellies elaborated from the different peach cultivars, although presenting high variability in relation to the physical-chemical and rheological parameters, presented similar and high sensory acceptance.