Morphometric and oil content variation of allspice (*Pimenta dioica* (L.) Merr.) fruits in Mexico

Variação morfométrica e do teor de óleo de frutos de pimenta da Jamaica (*Pimenta dioica* (L.) Merr.) no México

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ABSTRACT
This study was carried out with the objectives of quantifying the oil content and determining the morphometry of the fruits of allspice (*Pimenta dioica* (L.) Merr.) of 23 selected genotypes, to establish if the fruits meet the current quality standards and provide quantitative elements for the selection of outstanding genotypes in fruit size and oil content. From each selected genotype, 3 samples of 250 g of fresh pimento fruits were obtained, which were dried at 25 °C. Subsequently, 3 samples of 5 g of dried fruits were taken to measure the equatorial diameter and length of each fruit with a digital vernier and then determine the area, volume, roundness index (IR), and aspect ratio (RA). Ground and sifted dried fruits were used to determine gravimetrically the oil content in a Soxhlet Büchi E-816 SOX equipment using hexane as a solvent with three replicates per genotype. An analysis of variance was performed on the obtained data, followed by a comparison of means by Tukey's method ($\alpha = 0.05$). A cluster analysis was also performed to group genotypes with similar characteristics. The results showed significant differences ($p \leq 0.05$) between genotypes for each of the measured variables. The overall average values of the fruits were 7.22 ± 0.69 mm for the equatorial diameter, 8.21 ± 0.74mm for the length, 47.14 ± 8.23 mm^2 for the area, 233.22 ± 61.93 mm^3 for the volume, 0.88 ± 0.05 for the roundness index, 1.14 ± 0.06 for the aspect ratio and 4.96 ± 0.15% for the oil content. The genotypes were grouped into six groups with similar fruit characteristics of dimensions, morphometry, and oil content. The obtained results indicate that all the genotypes meet the specifications of oil content and equatorial diameter indicated in the current quality standards; however, six genotypes stand out for their oil content greater than 5.4%.

Keywords: Allspice, pimento, species, roundness index.

RESUMO
Este estudo foi realizado com os objetivos de quantificar o teor de óleo e determinar a morfometria dos frutos de pimenta da Jamaica (*Pimenta dioica* (L.) Merr.) de 23 genótipos selecionados, para estabelecer se os frutos atendem aos padrões de qualidade vigentes e fornecer dados quantitativos elementos para a seleção de genótipos de destaque em tamanho de fruto e teor de óleo. De cada genótipo selecionado, foram obtidas 3 amostras de 250 g de frutos de pimentão frescos, que foram secos a 25 °C. Posteriormente, foram retiradas 3 amostras de 5 g de frutos secos para medir o diâmetro equatorial e comprimento de cada fruto com um vernier digital e, em seguida, determinar a área, volume, índice de arredondamento (IR) e razão de aspecto (RA). Frutos secos moídos e peneirados foram utilizados para determinar gravimetricamente o teor de óleo em um equipamento Soxhlet Büchi E-816 SOX utilizando hexano como solvente com três repetições por genótipo. Foi realizada análise de variância dos dados obtidos, seguida de comparação das médias pelo método de Tukey ($\alpha = 0.05$). Uma análise de agrupamento também foi realizada para agrupar genótipos com características semelhantes. Os resultados mostraram diferenças significativas ($p \leq 0.05$) entre os genótipos para cada uma das variáveis medidas. Os valores médios gerais dos frutos foram 7.22 ± 0.69 mm para o diâmetro equatorial, 8.21 ± 0.74 mm para o comprimento, 47.14 ± 8.23 mm^2 para a área, 233.22 ± 61.93 mm^3 para o volume, 0.88 ± 0.05 para o índice de arredondamento, 1.14 ± 0.06 para a proporção e 4.96 ± 0.15% para o teor de óleo. Os genótipos foram agrupados em seis grupos com características de frutos semelhantes em dimensões, morfometria e teor de óleo. Os resultados obtidos indicam que todos os genótipos atendem às especificações de teor de óleo e diâmetro equatorial indicadas nas normas de qualidade vigentes; entretanto, seis genótipos se destacam pelo teor de óleo superior a 5.4%.

Palavras-chave: Pimenta da Jamaica, pimento, espécies, índice de redondeza.

1 INTRODUCTION

Pimento or allspice (*Pimenta dioica* (L.) Merr.) is native to Mexico, Central America and the neighbouring islands of the Caribbean (Wisse, 2002). This species is distributed in Mexico on the slope of the Gulf of Mexico, from the north of Puebla and Veracruz states to the south of the Yucatan Peninsula (Martínez, *et. al*., 2013; CONABIO, 2018).

The dried fruits of allspice, either whole or ground, are used as condiments in the food industry and in cooking, which has increased its interest because the fruits contain the characteristic flavour and aroma combination of four species: cloves, nutmeg, cinnamon and pepper, for which it is also known as allspice (Wisse, 2002).

Worldwide, the use of fruits as a domestic condiment is 5 to 10% and the food industry uses between 65 and 75%, while the oil of the fruit is 20 to 25% (Wisse, 2002).

It is considered that the best quality of allspice is that from Jamaica, which is why international standards are based on the physical-chemical characteristics of pimento from that country. The fruit diameter of Jamaican pimento is between 6.5 and 9.5 mm with approximately 13 fruits per gram and an essential oil content of 3.5 to 4.5%, which is reflected in its higher value per ton in the international market (USAID, 2011; Gayle, 2013). These characteristics make the quality of Jamaican allspice superior to that of other producing countries.

In international trade, the demand for allspice has grown approximately 3.5% annually, where the main producers worldwide are Mexico and Jamaica, followed by Honduras and Guatemala (USAID, 2011). Annually, Mexico exports 95% of its production (on average 7,259 tons) to 30 countries, with the United States, Europe and the Middle East being the most important markets (Córdoba, 2017). Despite its commercial importance, allspice practically continues to be a product harvested from isolated backyard trees, boundary trees on producer lands, and wild trees. The area indicated by the SIAP (2019) is 3,433 hectares distributed in Puebla, Veracruz, Tabasco, Chiapas, Oaxaca and Campeche, Mexico

In Mexico, there are limited studies on the size of pimento fruits and their oil content. However, these characteristics are important in the selection of genotypes for the establishment of commercial plantations and marketing, since current allspice quality standards (SCFI, 1987; ISO, 1999), indicate that the fruits must have a minimum equatorial diameter of 4.0 mm and an oil content of 3% for whole fruits and 2% for ground fruits.

The oil content of pimento fruits in Mexico varies from 1.9% to 9.0% depending on the origin, the extraction method and the type of solvent used for the extraction of oil (García-Fajardo et al., 1997; Cruz-Olivares *et al*., 2007; Guzmán, 2011), while the size of the equatorial diameter of the fruit is between 4.0 and 4.3 mm (Flores, 2009).

On the other hand, the morphometry of fruits and seeds is a quantitative measure to evaluate their shape, which is analysed with methods that involve different characteristics and indices (Cervantes *et al*., 2016). The morphometric study allows the description and analysis of intra and interspecific variability that can be used in comparative taxonomy, genetics, physiology, biochemistry and description of genotypes and cultivars for the registration of new varieties (Dana and Ivo, 2008; Cervantes et al., 2016; Vasanthan *et al*., 2019). It is also essential for the design and adaptation of equipment for harvesting, drying, cleaning, classifying, peeling and storage, to obtain higher yields in processing operations (Silva 2008; Pradhan *et al*., 2009). Therefore, since the harvest and processing of pimento fruits are done manually, morphometry can help in the design of equipment to improve the processing of pimento fruits.

Therefore, the present work was carried out with the objectives of quantifying the oil content and determining the dimensions of the allspice fruits, as well as their morphometry. These objectives will help to know if the fruits comply with the current quality standards for their commercialization and provide quantitative elements for the selection of outstanding genotypes in oil content and fruit size, from which vegetative material can be obtained for propagation by grafting.

2 MATERIALS AND METHODS

The study was carried out at the experimental allspice plantation established in September 2011 at the Las Margaritas Experimental Site, located in the northeast of the state of Puebla (20°00'12.79” N, 97°18'33” W), altitude of 450 m, with a humid subtropical climate Af(c), average annual rainfall of 3000 mm and average annual temperature of 21°C. The plantation consists of 1250 grafted trees with a spacing of 4 m x 4 m, in 25 rows and 50 trees per row, in an area of 2 hectares. Since 2013, annual growth and green fruit yield data have been taken from 110 trees, which were randomly selected. During the yield assessment of green pimento in 2017, a random sample of 20 trees (genotypes) was selected. From each tree, three samples of 250 g of mature green pimento fruits were obtained. For comparison purposes of oil content, ripe fruits were also sampled from four trees. The fruit samples from each tree were mixed, weighed and dried indoors at 25 °C until a constant weight was obtained. Subsequently, three samples of 5 g of dried fruit were obtained from each tree, measuring the equatorial diameter and length of each of the fruits with a digital vernier. With the obtained data, four morphometric descriptors were determined: projected area (area), volume, roundness index, and aspect ratio. The area was determined with the ellipse formula and the volume with the ellipsoid formula. The roundness index (RI) and the aspect ratio (AR) were calculated using the following expressions (Neal and Russ, 2012; Cervantes et al., 2016):

$$RI = \frac{4\ x\ area}{\pi\ (Major\ axis)^2} \tag{1}$$

$$AR\ \frac{Major\ axis}{Minor\ axis} \tag{2}$$

The extraction of oil from the dry fruits was carried out with an automated and programmable Soxhlet Büchi E-816 SOX equipment, which at the end of each extraction, it allows the washing and drying of the sample, so it is possible to determine the oil content gravimetrically. To do this, 35 grams of dry fruits from each tree were ground in a coffee grinder, and then the ground material was sieved between 40 mesh (0.425 mm) and 60 (0.250 mm), using the material retained in the 60 mesh with three repetitions. Each repetition consisted of ten grams of ground material and 150 mL of hexane. The extraction was carried out for 30 cycles in 5 hours. The moisture content of the ground material was determined with a thermogravimetric balance, previously calibrated, just before starting the extraction process. The oil content was calculated as the ratio of the weight of the oil and the dry weight of the sample.

An analysis of variance (ANOVA) was performed on the morphometric data and oil content of the fruits, considering the selected and sampled trees as a source of variation, followed by multiple comparisons of means with the minimum significance method (α = 0.05). Subsequently, a cluster analysis was carried out with the values of a) the morphology characteristics, b) the oil content, and c) selected variables of all the measured characteristics. The SAS program (SAS, 2009) was used for the analyses of variance and selection of variables with the GLM and VARCLUS procedures, respectively. Cluster analyses were carried out with RStudio (version 2022.07.1+554) with cluster, factoextra and dendextend packages, Ward method and Euclidean distances (Kassambara, 2017).

3 RESULTS AND DISCUSSION

The ANOVA results indicated significant differences ($p < 0.0001$) between genotypes for the morphometric descriptors and oil content of pimento fruits (Table 1).

Table 1. Summary of Variance Analysis

Source	Degrees of Freedom	F Value	Pr > F
Diameter (mm)	23	74.86	<.0001
Length (mm)	23	131.43	<.0001
Area (mm^2)	23	106.27	<.0001
Volume (mm^3)	23	98.4	<.0001
Roundness index (RI)	23	117.3	<.0001
Aspect ratio (AR)	23	113.37	<.0001
Oil content (%)	23	148.61	<.0001

The equatorial diameter of pimento fruits varies from 5.10 mm to 10.62 mm, with a global average of 7.22 ± 0.69. The comparison of means between genotypes (Table 2) shows that the diameter is larger in ripe fruits of the genotypes H16P17R, H14P04R, H16P25R and H20P14R, and smaller in mature green fruits of the genotypes H18P13 and H14P08. The values obtained are higher than those reported (4.0 - 4.3 mm) by Flores (2009) for pimento fruits from Cuetzalan, Puebla. The current standards specify a minimum equatorial diameter of 4 mm (SCFI, 1987; ISO, 1999), for which the fruits of the studied genotypes comply with the standard specification of the equatorial diameter size for their commercialization.

Pimento fruits have an overall average length of 8.21 ± 0.74 mm, with values between 5.33 mm and 12.58 mm. When comparing the length mean of the genotypes (Table 2), the H12P14 genotype stands out from all the genotypes, as it has the longest fruit length, while the H04P17 and H14P08 genotypes have the shortest length. The length of ripe fruits of the genotypes H14P04R and H16P17R is close to that of the genotype H12P14.

Table 2. Comparison of the average diameter, length, and area of pimento fruits.

Genotype	Diameter (mm)		Length (mm)		Area (mm^2)	
H02P15	7.58 ± 0.56[ǂ]	c d e[¥]	7.95 ± 0.57	e d	47.50 ± 6.51	g h i
H02P32	6.84 ± 0.68	j k i	7.97 ± 0.67	f g h	43.12 ± 7.50	k l i j
H04P17	7.16 ± 0.62	f g i h	7.34 ± 0.58	i g h	41.51 ± 6.51	k l j
H04P22	6.94 ± 0.91	g i h	8.19 ± 1.05	c d	45.31 ± 11.27	g h i j
H06P37	6.83 ± 0.80	j k i	7.41 ± 0.85	e	40.18 ± 8.79	l m
H06P45	7.55 ± 0.67	d e	8.84 ± 0.78	i g h j	52.76 ± 8.81	d e f
H08P25	7.70 ± 0.64	c d	9.04 ± 0.75	f g	54.95 ± 8.39	d c
H08P42	6.89 ± 0.73	j i h	7.52 ± 0.72	b	41.04 ± 7.82	k l m j
H12P14	7.94 ± 0.73	c b	10.74 ± 0.84	c	67.29 ± 10.26	a
H12P25	6.98 ± 0.60	g i h	7.98 ± 0.67	f	43.96 ± 7.04	k l i j
H14P08	6.34 ± 0.66	l	7.30 ± 0.68	f g h	36.61 ± 7.08	m
H14P33	7.76 ± 0.72	c d	8.86 ± 0.80	a b	54.33 ± 9.24	d c
H14P04R	8.37 ± 0.81	a	10.50 ± 0.92	e d	69.40 ± 11.65	a
H16P10	6.55 ± 0.65	j k l	7.92 ± 0.69	j	41.03 ± 7.29	k l m j
H16P25	7.57 ± 0.55	c d e	8.13 ± 0.53	f g	48.50 ± 6.16	g h f
H16P25R	8.36 ± 0.80	a	9.37 ± 0.83	a	61.97 ± 10.56	b
H16P17R	8.45 ± 0.79	a	10.28 ± 0.98	i h j	68.72 ± 12.19	a
H18P13	6.49 ± 0.73	k l	7.92 ± 0.81	c d	40.79 ± 8.37	k l m
H18P40	7.24 ± 0.60	f g e h	7.64 ± 0.61	e d	43.65 ± 6.56	k l i j
H20P45	7.28 ± 0.74	f g e	8.59 ± 0.96	i j	49.64 ± 10.02	g e f
H20P14R	8.14 ± 0.66	a b	9.01 ± 0.59	f	57.85 ± 7.70	b c
H20P50	7.39 ± 0.69	f d e	7.72 ± 0.64	i j	45.06 ± 7.59	k h i j
H22P27	7.43 ± 0.59	f d e	7.90 ± 0.62	f g	46.33 ± 6.99	g h i
H22P38	7.67 ± 0.62	c d	8.82 ± 0.58	f g	53.32 ± 7.15	d e

R= Ripe fruits, [ǂ] Standard deviation, [¥]Values with the same letter are not significantly different ($p \leq 0.05$).

The average area of all the fruits is 47.14 ± 8.23 mm^2, with values from 21.73 mm^2 to 98.51 mm^2. The volume is between 75.17 mm^3 and 693.29 mm^3 with an overall average of 233.22 ± 61.93 mm^3. As both the area and volume depend on the dimensions of the diameter and the length of the fruits, the greater values of these variables are related to the largest dimensions of diameter and length.

The genotypes H14P04R, H16P17R and H12P14 present the highest values of area and volume (Tables 2 and 3) because the diameter and length dimensions of the fruits are greater (Table 2); in contrast, the values of area and volume are lower in the genotype H14P08 due to the smaller dimensions in diameter and length of its fruits.

The roundness index (RI) is used to describe the deviation of objects from having a circular or spherical shape, where the value of 1.0 is for a circle (Neal and Russ, 2012). The RI of all the pimento fruits ranges between 0.61 and 0.99, with an overall average of 0.88 ± 0.05. In the comparison of means, the fruits of the genotype H04P17 have the highest RI (Table 3), indicating

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that the shape of the fruit is closer to a spheroid, while the fruits of the genotype H12P14 have the lowest RI, so they resemble more closely to an ellipsoid.

Table 3. Comparison of the average volume, RI, and AR of pimento fruits.

Genotype	Volume (mm^3)		Roundness index (RI)		Aspect ratio (AR)	
H02P15	242.29 ± 49.92[ǂ]	e[¥] f	0.95 ± 0.03	a b	1.06 ± 0.04	l m
H02P32	199.88 ± 53.41	g h i j	0.86 ± 0.05	g h i	1.17 ± 0.07	f e
H04P17	200.77 ± 47.71	g h i j	0.96 ± 0.03	a	1.05 ± 0.04	m
H04P22	216.33 ± 80.97	g f h i	0.85 ± 0.05	j k i	1.18 ± 0.07	d e
H06P37	187.31 ± 61.80	k i j	0.92 ± 0.06	d c	1.09 ± 0.07	i k j
H06P45	269.27 ± 67.81	e d	0.86 ± 0.05	g h i	1.17 ± 0.07	f e
H08P25	285.45 ± 65.54	c d	0.85 ± 0.06	g h i	1.18 ± 0.08	f e
H08P42	192.10 ± 55.03	h i j	0.91 ± 0.05	d e c	1.10 ± 0.06	i k j
H12P14	360.59 ± 86.18	a b	0.74 ± 0.06	n	1.36 ± 0.11	a
H12P25	207.12 ± 49.33	g h i j	0.88 ± 0.04	f g	1.15 ± 0.06	f h g
H14P08	157.61 ± 47.47	k	0.87 ± 0.04	f g h i	1.15 ± 0.06	f e g
H14P33	285.14 ± 73.24	c d	0.87 ± 0.05	f g h	1.15 ± 0.07	f e g
H14P04R	392.76 ± 101.28	a	0.80 ± 0.06	m	1.26 ± 0.09	b
H16P10	182.31 ± 49.96	k j	0.83 ± 0.05	j k l	1.21 ± 0.07	d c
H16P25	246.69 ± 47.28	e f	0.93 ± 0.04	d b c	1.08 ± 0.04	l k j
H16P25R	350.83 ± 90.35	b	0.89 ± 0.05	f e	1.12 ± 0.06	i h g
H16P17R	393.18 ± 103.04	a	0.82 ± 0.05	m k l	1.22 ± 0.07	c
H18P13	180.44 ± 57.60	k j	0.82 ± 0.05	m l	1.23 ± 0.08	b c
H18P40	213.06 ± 47.79	g f h i j	0.94 ± 0.04	a b c	1.07 ± 0.05	l k m
H20P45	245.76 ± 72.28	e f	0.85 ± 0.05	j h i	1.18 ± 0.07	d e
H20P14R	317.02 ± 65.83	c	0.90 ± 0.05	d e	1.11 ± 0.07	i h j
H20P50	225.14 ± 57.91	g f h	0.95 ± 0.04	a b	1.06 ± 0.04	l m
H22P27	232.03 ± 52.08	g f	0.94 ± 0.03	a b c	1.07 ± 0.04	l k m
H22P38	275.45 ± 57.38	e d	0.87 ± 0.05	f g h i	1.15 ± 0.07	f e g

R= Ripe fruits, [ǂ] Standard deviation, [¥]Values with the same letter are not significantly different ($p \leq 0.05$).

The aspect ratio (AR) is the ratio between the width and height of an object or image that indicates the deviation from having a square shape, which has a value of 1.0 (Neal and Russ, 2012). The AR of pimento fruits fluctuates between 1.00 and 1.64, with an overall average of 1.14 ± 0.06. The AR is inversely related to the RI so that the low values of the AR correspond to high values of the RI and this is observed in genotype H12P14, which has the highest AR indicating that the fruits are more elongated with the lowest value of the RI. The opposite case is for the H04P17 genotype, which presents the lowest AR, but the highest RI (Table 3).

Table 4. Comparison of the average oil content of pimento fruits.

Genotype	Oil content (%)				
H02P15	4.23 ± 0.05ǂ		k	l¥	
H02P32	6.28 ± 0.18	a			
H04P17	4.62 ± 0.02	j	k	h	i
H04P22	4.36 ± 0.02	j	k	l	
H06P37	4.54 ± 0.10	j	k	l	i
H06P45	5.45 ± 0.05	b	c	d	e
H08P25	4.92 ± 0.26	f	g	h	i
H08P42	5.62 ± 0.06	b	c		
H12P14	4.15 ± 0.07	m		l	
H12P25	5.44 ± 0.25	b	c	d	e
H14P08	3.76 ± 0.04	m	n		
H14P33	5.02 ± 0.04	f	g	h	e
H14P04R	2.30 ± 0.08	o			
H16P10	5.18 ± 0.15	f	c	d	e
H16P25	5.60 ± 0.15	b	c		
H16P25R	6.59 ± 0.22	a			
H16P17R	5.65 ± 0.05	b			
H18P13	4.71 ± 0.34	j	g	h	i
H18P40	4.38 ± 0.15	j	k	l	
H20P45	3.43 ± 0.08		n		
H20P14R	6.56 ± 0.04	a			
H20P50	3.64 ± 0.05		n		
H22P27	5.14 ± 0.17	f	g	d	e
H22P38	5.49 ± 0.13	b	c	d	

R= Ripe fruits, ǂ Standard deviation, ¥Values with the same letter are not significantly different ($p \leq 0.05$).

The oil content of pimento fruits is variable between genotypes and ranges between 2.22% and 6.87% with a total average of 4.96 ± 0.15%. According to Wisse (2002), pimento ripe fruits contain less oil content than mature green fruits; however, in this study, only the ripe fruits of genotype H14P04M exhibited the lowest oil content, while the ripe fruits of genotypes H16P25M, H20P14M and H16P17M showed a higher oil content (Table 4). Furthermore, ripe fruits in the same genotype (H16P25) presented 1% more oil than green fruits. Considering only green fruits, the H02P32 genotype stands out from the rest of the genotypes for its high oil content (Table 4). The lowest oil contents were found in the genotypes H20P45, H20P50 and H14P08.

In general, the oil content of green pimento fruits in all genotypes is greater than 3.4%, so they meet the specifications of the current standards for allspice, which indicate a minimum oil content of 3% (SCFI, 1987; ISO, 1999).

Some of the genotypes present similar and not significant morphometric variables and oil content, so it is possible to group them by considering one or several variables. The cluster analysis allows for grouping genotypes that tend to be similar and different from other groups (SAS, 2017).

Cluster analysis of fruit morphometric variables (equatorial diameter, length, area, volume, RI and AR) showed that with a proportion of variance for the groups of 92.1% (R^2), the genotypes can be grouped into 6 groups (Figure 1). Group 1 is formed by the genotypes that have higher values in length, area, volume and aspect ratio of the fruits. Group 2 combines the genotypes with the next higher values in length, area and volume. Genotypes with fruit lengths between 8.5 mm and 9.0 mm are joined in group 3. Group 4 links genotypes with intermediate values in diameter, area and roundness of fruits. More spherical fruits of genotypes are combined in group 6, due to their greater roundness (RI, 0.93-0.96) and lower aspect ratio (AR, 1.05-1.08) values. Next to this group is group 5, represented by two genotypes with less rounded fruits (RI, 0.91).

As regards oil content, cluster analysis also shows that the genotypes can be grouped into 6 groups (Figure 2), with a proportion of variance for the groups of 98% (R^2). The genotype with the lowest fruit oil content (2.3%) is represented by group 2, while group 4 corresponds to the genotypes with the highest oil content (> 6.2%).

Figure 1. Dendrogram of morphometric variables of pimento fruits.

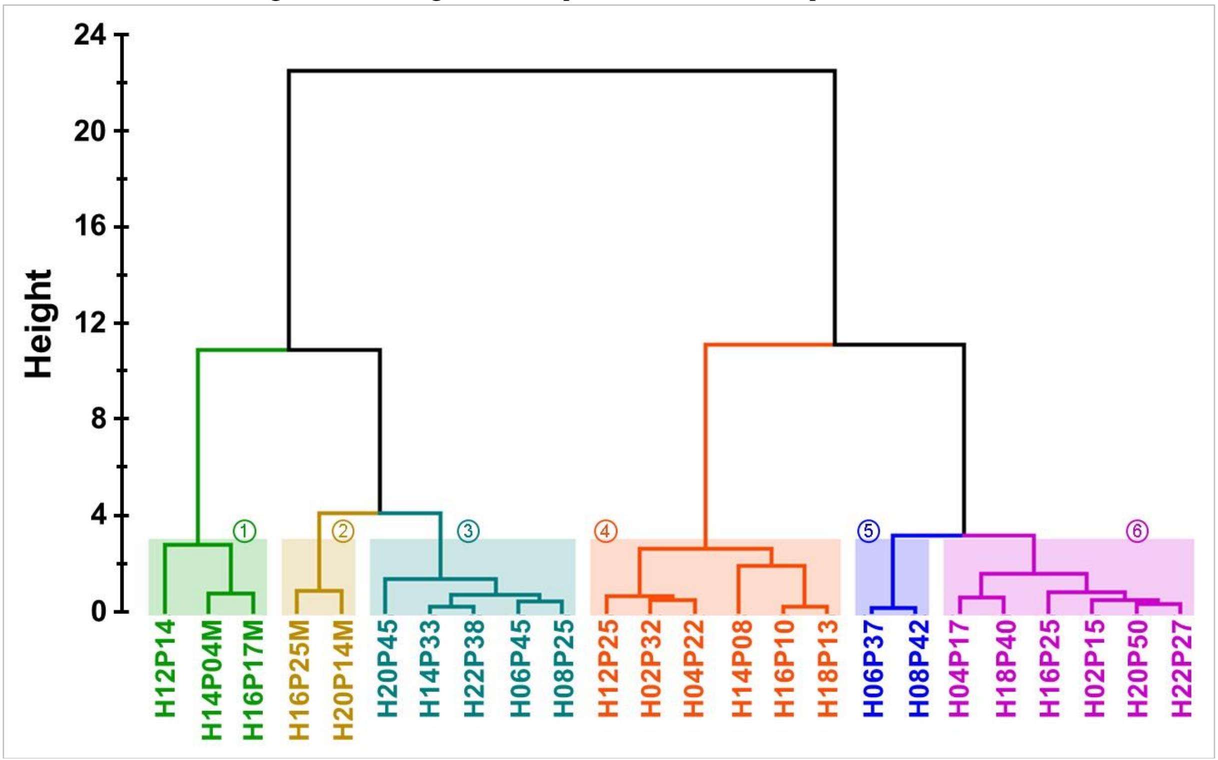
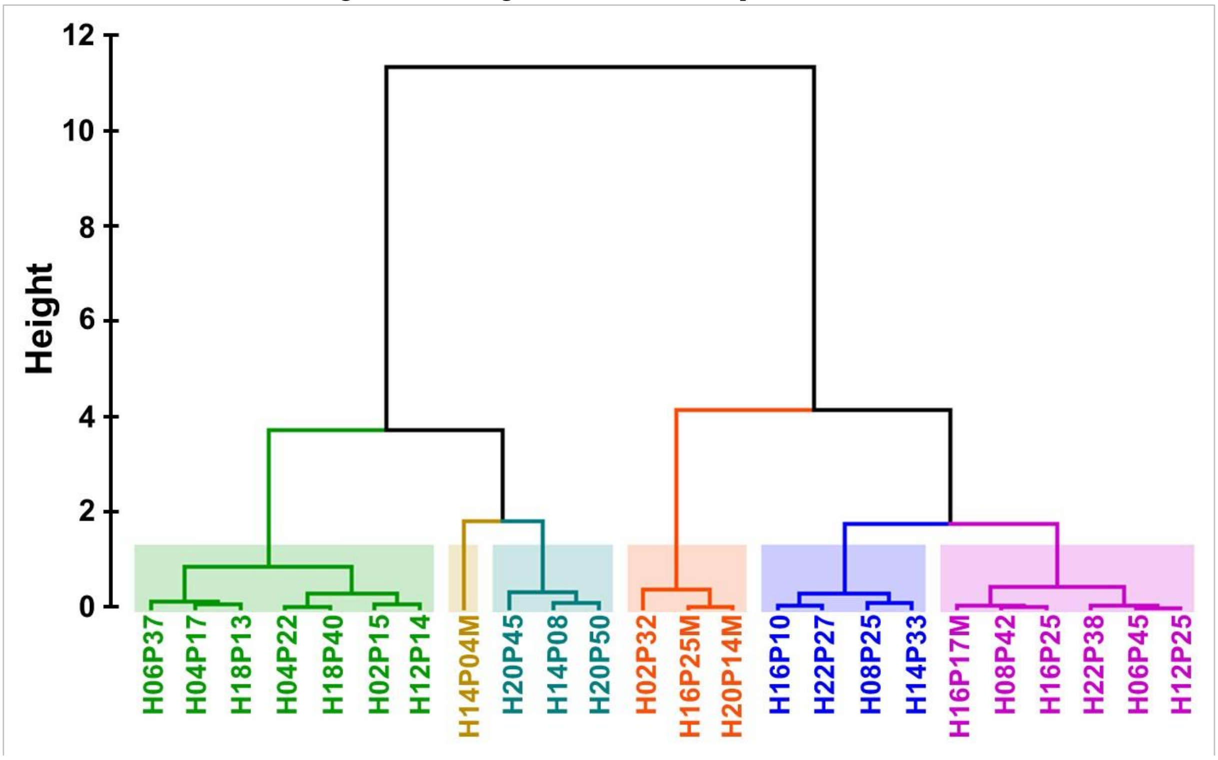


Figure 2. Dendrogram of oil content of pimento fruits.



Genotypes with a fruit oil content from 3.4% to 3.8% are joined in group 3. Group 1, 5 and 6 combine genotypes with the following respective ranges of fruit oil content, 4.1% - 4.7%, 4.9% - 5.2% and 5.4% - 5.7%.

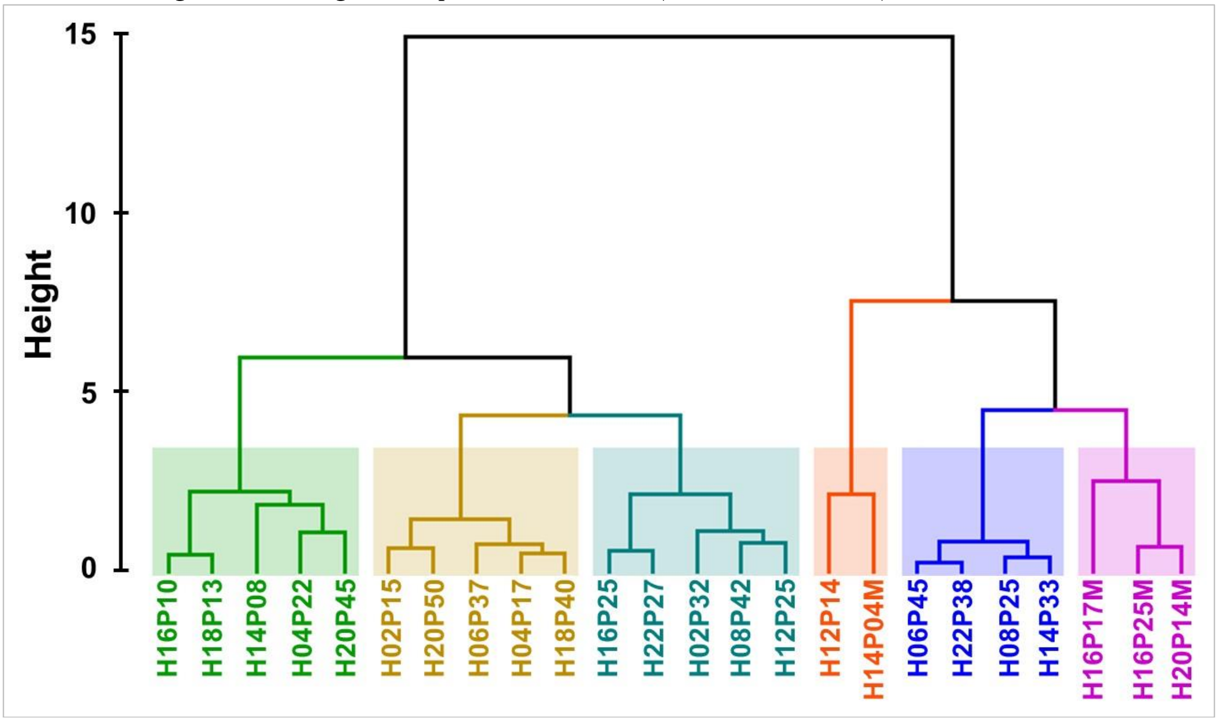
The SAS VARCLUS procedure is used as a method for the reduction of variables, in which it finds groups of variables that are the most correlated with each other and that are the least correlated with the variables of other groups of variables (SAS, 2017), so a selected variable from each group must have a high correlation with its group and a low correlation with the other groups. If a group has several variables, it is possible to select two variables from the group. If the groups are well separated, the value of R^2 for a variable with the closest group should be low. The 1-R^2 ratio is used to select variables, with small values indicating good grouping. Therefore, considering the value of R^2 and the proportion of 1-R^2 of the variables in each group, the selected variables were area and volume from group 1, RI from group 2 and oil content from group 3 (Table 4). These variables were used to perform a cluster analysis.

Table 5. Result of the VARCLUS procedure.

Cluster	Variable	R-squared with Own Cluster	R-squared with Next Closest	$1-R^2$ Ratio
Cluster 1	Length	0.9165	0.4907	0.1640
	Diameter	0.8915	0.0231	0.1111
	Area	0.9964	0.2676	0.0049
	Volume	0.9969	0.1961	0.0038
Cluster 2	Aspect ratio	0.9982	0.2254	0.0024
	Roundness index	0.9982	0.2088	0.0023
Cluster 3	Oil content	1	0.0327	0

Six groups were obtained for the selected variables of genotypes in the cluster analysis (Figure 3) with a proportion of variance for the groups of 83.4% (R^2). In group 1 are the genotypes with fruits containing low values in area and volume, and a roundness index of about 0.84. Genotypes located in group 2 have the most spherical fruits since the values of the roundness index and the aspect ratio are closer to 1. Group 3 is characterized by the genotypes with the higher oil content (> 5.1%) for mature green fruits and semi-spherical fruits (RI ≈ 0.90). Genotypes with the longest, higher volume, and more elongated fruits are combined in group 4. Large green fruit of genotypes with an oil content and roundness index around 5.0 and 0.85, respectively, are joined in group 5. Group 6 combines the genotypes with ripe fruits that have the highest oil content.

Figure 3. Dendrogram morphometric variables (area, volume and RI) and oil content.



The selection of genotypes to obtain vegetative material for propagation by grafting must combine fruit size and oil content; therefore, genotypes should be chosen based on greater values than what is specified by the allspice standards for equatorial diameter and oil content of fruits. In this study, the fruits of the genotypes meet the specifications of current standards (SCFI, 1987; ISO, 1999) in equatorial diameter (> 4.0 mm) and oil content (> 3%); however, the H02P32 genotype stands out, because the oil content of its fruits is 6.28%, followed by the H16P25, H08P42, H22P38, H06P45 and H12P25 genotypes, with an oil content between 5.44% and 5.62%.

4 CONCLUSIONS

The equatorial diameter is greater than 5.10 mm and the oil content of mature green pimento fruits in all genotypes is greater than 3.4%, for which they meet the specifications of the current standards for allspice.

Ripe fruits of three genotypes exhibited a high oil content (> 5.6%) and in one genotype the oil content was lowest (2.3%)

There are significant differences ($p < 0.0001$) between pimento genotypes for morphometric descriptors and the oil content of the fruits.

The H02P32 genotype has a high oil content in its fruits, followed by the H16P25, H08P42, H22P38, H06P45 and H12P25 genotypes, so these genotypes could be used to obtain vegetative material for propagation by grafting.

The morphometric descriptors and oil content of the pimento fruits allow the genotypes to be grouped into six distinctive groups with similar characteristics in each group, but with differences between groups.

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