Article

Bursera simplex Rzed. & Calderón fruits and seeds in different sites and tree structure

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Abstract:

The territory of *Oaxaca* State has the greatest biodiversity in Mexico; the most abundant vegetation is the low deciduous forest with *Bursera* species of economic and biological importance. In the present study, the structural composition and phenotype of *Bursera simplex* seed trees and the characteristics of the site in which they grow were evaluated; their production of fruits and seeds were described according to the tree from which they were harvested. During 2015, a sampling of 23 sample units was conducted towards the best phenotypes with high production of fruits and seeds and their inventory was made. The data were analyzed through structural indexes and analysis of variance to compare the production of fruits and seeds, in relation to the tree from which they were taken, as well as the characteristics of the site, altitude, slope and position of the place where the specimens grew. Those of greater size are associated with slopes ≤ 25 % and altitudes ≤ 1 278 m, where they produce 29 259 seeds kg^{-1}. The population structure is of irregular type, with important densities of *Bursera simplex* associated with the western exposure; the forest value index, the importance value index and the complexity index affect the morphological characteristics of fruits and seeds.

Key words: Altitude, *Bursera simplex* Rzed. & Calderón, orientation, *Oaxaca*, slope, structural indexes.

Introduction

Most vegetation types registered worldwide are present in Mexico. In addition, there is a wide range of climates, which condition the processes of soil formation, as well as the diversity and interaction between species (Villaseñor, 2003; Hernández *et al.,* 2011; Dzib-Castillo *et al.,* 2014).

The *Oaxaca* state has the highest biodiversity in the country, and much of the territory predominates the type of vegetation of low deciduous forest (SBC) (López *et al.,* 2005); these ecosystems have been modified mainly by anthropogenic activities, which affect the populations of *Bursera* spp. which are important in the biological and economic field, being used as a raw material for obtaining aromatic resins and essential oils.

Natural resources, soil, water, flora and fauna are not used sustainably in many parts of the country. In the particular case of the low spiny forest and of *Bursera* species in particular, their populations are decreasing, since the natural regeneration by seeds does not counteract the levels of use. It has been documented that the trees of *Bursera simplex* Rzed. & Calderón have high percentages of vain seeds, a condition resulting from possible crosses with *B. biflora* Rzed. & Calderón; to this fact it should be added the clear reduction in the number of trees in the reproductive stage, that induces inbreeding, which negatively affects plants by reducing their viability (Cuevas and Abarca, 2006; Rzedowski and Calderón, 2006; Nora *et al.*, 2011).

Bursera simplex is endemic of *Oaxaca* state, and is found only in the middle portion of the *Tehuantepec* river basin (Rzedowski and Calderón, 2006); where it is an important component of the tropical deciduous forest and it is used, daily, to extract

aromatic resin for ceremonial purposes. It has potential for other uses based on the findings of Gigliarelli *et al*. (2015) who identified their content of moric acid and 3-epi-lupeol, lupane and olanean skeletons, which according to Cano (2013) are components used as anti-tumor, anti-inflammatory, anti-HIV, anti- microbial, hepa and cardioprotective, analgesic, anti-mycotic, anti-chemopreventive, among others.

The structural diversity of plant communities is one of its most relevant aspects since it is related to the habitat of various animals and plants; in the same way does the stability against different biotic and abiotic factors, as well as with the direct (products) and indirect benefits (carbon fixation, landscape, soil protection, among others) (Del Río *et al*., 2003). It is therefore important to know the structure of the ecosystem, which is influenced, mainly, by the type, number, spatial arrangement and temporal ordering of its constituting elements (Corral *et al.,* 2005; Ledo *et al.,* 2012), that can be measured by structural indexes and morphological variables (diameter, height, basal area, density among others). The ratio of sizes between trees is important because the species will show morphological differences that give rise to structural contrasts (Castellanos *et al.,* 2008; Jiménez *et al*., 2009).

The morphological variability of trees results from intraspecific differences but also from the effect of biological and physical factors, which have a close correlation with reproduction because any environmental factor that influences growth will do so in the same way with reproductive performance (Enríquez *et al.,* 2004).

In addition, the seeds in a species can vary in size among individuals and populations, either because of genetic differences or because of differences in the life history of each plant. From this point of view, Alba and Márquez (2006) mention that the seed production potential of a forest species is influenced by the environmental conditions of a given site, as well as by its phenotypic characteristics, which allows to evaluate and weigh the potential for its management; or select outstanding individuals within a given population (Balcorta and Vargas, 2004; Cerón and Sahagún, 2005); when it is intended to propagate an arboreal species for reforestation purposes, it is important to manage rigorous criteria of the selection of trees in which seeds will be collected, which can have a genetic

gain in the next generation of trees (Vallejos *et al*., 2010). Therefore, the objective of this study was to evaluate the effect of tree structure and site variables on the weight and morphological characteristics of fruits and seeds of *Bursera simplex*.

Materials and Methods

Study area

The study was carried out during 2016 in *Santa María Zoquitlán*, municipality of the same name, which is a community of the Central Valleys of *Oaxaca*, located at 16°34 'N and 96°21' W, at an average altitude of 1 080 m. The predominant vegetation is the low deciduous forest, where *B. simplex*, an endemic species of the *Tehuantepec* River basin, is distributed. The genera that share the habitat are *Cephalocereus, Cercidium, Lysiloma, Ceiba, Neobuxbaumia, Escontria*, *Acacia*, Beaucarnea, among others. The predominant climate is the type BSo (h ') w "(w) i' g (Acosta *et al.,* 2003).

Sampling method and data collection

Selected samplings were carried out with the aim of identifying trees of the species of interest with outstanding phenotypic characteristics, of healthy appearance and that also had fruits, taking this as the main criterion for their selection. During October-December 2015, 27 trees were identified in the area called *El Paredón*, located in an altitudinal interval of 1 078-1 406 m; the trees were marked with progressive numbers and were taken as a reference point to establish 23 sample units (SU) of 100 m^2.

At each sampling site all the present species were counted and with the support of a Fiber-glass measuring tape of 1.52 m and a 5 m measuring tape (Chain brand, MGA

5020 model) the morphological variables corresponding to the collar diameter were measured and recorded (DP, cm), total height (AT, m) and crown diameter (DC, m) with which the crown area was calculated (AC= $1/4 \times \pi DC^2$, m^2).

In the sample units established with a Garmin DriveTM GPS, the site variables exposure, altitude (m) and slope (%) were recorded with a Suunto Finland clinometer Pm5/36pc.

From each of the selected *Bursera* specimens, part of the fruits presented was collected, which were placed in paper bags and moved to the facilities of the *Instituto Tecnológico del Valle de Oaxaca* (ITVO) (Technological Institute of the Valley of Oaxaca) (ITVO).

A random sample of 50 fruits of each tree was taken, in which they were measured with a Pretul vernier of 0.1 cm of precision, their polar diameter (Dp, mm) and their equatorial diameter (DE, mm); the form coefficient (FC = DE / Dp) was obtained and weighed (g) individually with an Ohaus Adventurer™ analytical balance with a maximum capacity of 210 g and precision of 0.1 g. to obtain the number of fruits kg^{-1}. Subsequently, for drying, they were placed under solar radiation for four days; next, the seed was separated from the tissues of the fruit, to then measure its polar and equatorial diameter; finally, they were weighed to obtain the number of seeds kg^{-1}.

With the morphological variables obtained, structural indexes were calculated and frequency histograms were made, using commercial diameter categories of 5 cm and height categories at intervals ≤1.5, (1.5 to 3), (3.1 to 4.5) and (4.6 to 6), > 6 in meters. Three structural assessment indices were determined (Zarco *et al.,* 2010; Santiago, 2013):

$$IVI = DRr + Dr + Fr$$

$$IVF = DPr + Ar + ACr$$

$$IC = \left[\frac{sdbh}{A}\right]$$

Where:

IVI = importance value index

DMr = Relative dominance or relative basal area (ABr)

Dr = Relative density

Fr = Relative frequency

IVF= Forest value index

DPr = Relative collar diameter (cm)

Ar = Relative height (m)

ACr = Relative crown area (m^2)

IC= Complexity index

s = Number of species

d = Density of trees larger than 2.5 cm DP

b = Basal area (m^2)

h = Height (m) of the three dominant trees

A= Sampling area (m^2)

Data handling and analysis

In the fruits, seeds and trees data, the assumptions of normality and homogeneity of variances were verified by the Shapiro-Wilk and Bartlett tests. The variables that did meet the assumptions of normality and homogeneity of variances were subjected to analysis of variance by a completely randomized design and comparisons of means were made by the Duncan test (α = 0.05), in which the classification variable was used tree of origin, exposure, altitude and slope; for these last two, three categories were formed individually.

For the analysis routine, the SAS computer program (2004) was used, with the GLM procedure. In the case of the variables that did not comply with the assumptions of normality and homogeneity of variances, they were analyzed by means of the Kruskal Wallis test with the NPAR1WAY Wilcoxon procedure, by using SAS statistical package (SAS, 2004).

Results and Discussion

Vertical and horizontal structure

The differences in the size of trees of the same species located in different exposure sites can be attributed to the fact that the magnitude of growth is a function of the potentials defined by the genotype, the environment and the interaction of both. Ramírez and Rodríguez (2004), comment that the difference in the growth of trees is attributed to the fact that in the northern hemisphere the southern exposure receives the greatest amount of solar radiation. In this sense, Ortiz-Pulido and Pavón (2010) mention that the exposure of the site and the amount of solar radiation that affects influences the sexual differentiation of the trees of *Bursera*, since the trees in sites facing east, have more frequency those of male sex and in the groups of trees facing west, female sex is more frequent.

Sánchez and López-Mata (2003) state that altitude is a physical factor that influences climatic conditions through variables such as temperature and precipitation, which, in turn, have a direct effect on plant growth and are correlated specifically in each site. Martínez *et al.* (2013) mention that relationships have been found between the growth of conifers and the factors of soil depth, altitude, slope and exposure. Rubio *et al*. (2011), when studying *Quercus* vegetation, attributed the observed differences to the plant successional state and that the early successional species produce smaller seeds.

The maximum heights in the different sample units (SU) were 6.60 m; for descriptive purposes of the vegetation, two strata were identified: inferior and superior. The lower stratum is constituted, mainly, by individuals ≤1.5 m, reunited, in its majority, in the western exposure (1 057 trees ha^{-1}) and 326 individuals ha^{-1} greater than 1.5 m. The lowest density of arboreal specimens in the lower stratum was counted (209 individuals ha^{-1}), in the sites located in the southwest exposure. The trees of *B. simplex* make up the upper layer with heights ≥ 2 m (Figure 1a).

a)   b)
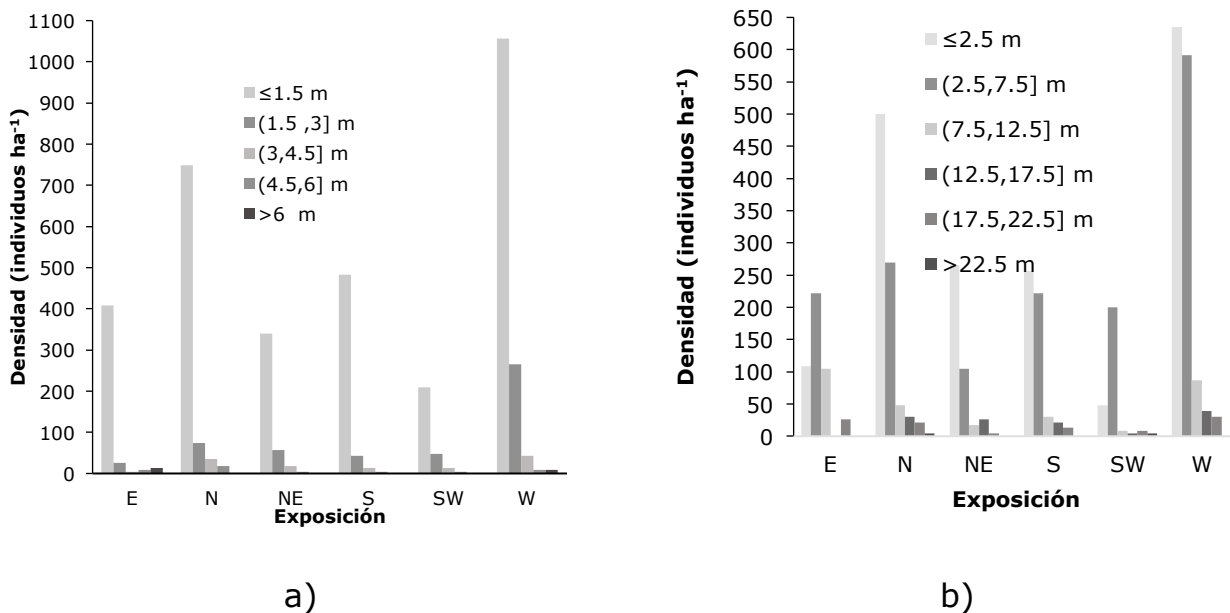
Densidad (individuos ha^{-1}) = Density (individuals ha^{-1}); *Exposición* = Exposure

Figure 1. Frequency of individuals according to their categories of height (a) and diameter (b) at different exposures.

Gutiérrez *et al.* (2011), in the vegetation of low deciduous forest in three localities of the state of *Yucatán*, recorded similar data, which they obtained from groupings with individuals of 1.5 to 4.4 m. Dzib-Castillo *et al.* (2014), when referring to the vegetation in the communities of *Pomuch* and *San José Carpizo* in the state of *Campeche*, calculated heights of 6.3 m

in low deciduous forest and diameters of 6.9 cm. On the other hand, in a low deciduous forest in *Xmatkuil*, *Yucatán* State. Gutiérrez and Zamora (2012) measured individuals from 4 to 12 m in height and Castillo *et al.* (2007), in the vegetation of *Veracruz* State, described three arboreal strata from 1 to 7 m.

In the present work, a greater density of individuals with diameters <2.5 cm in the horizontal structure was quantified in all exposures, followed by diameters greater than 2.5 and less than 7.5 cm, very related to the heights that were more pronounced in the west exposure (Figure 1b); this is explained by the frequency of individuals with higher diameters, which decreases as they reach greater dimensions, which means that the smaller diameter classes will always be more abundant.

The structural indexes (IVI, IVF, IC) showed significant statistical differences (p≤ 0.0001), in their effect on the morphological features of the fruits (Table 1). These differences are mainly due to the fact that the structure is determined by morphological characteristics of trees located in a specific area, as well as by density and competition, which implies dynamic relationships between individuals either to compete for nutrients or to obtain better development of its structures. Therefore, not always greater complexity will represent greater stability of the ecosystem; in addition, the spatial arrangement of individuals determines the particular morphology of the plant (Del Río *et al.,* 2003; Perreta y Vegetti, 2005). Alvis (2009) and Zarco *et al.* (2010) indicate that the IVI reveals the ecological weight of a species within a population.

Table 1. Fruit-seed morphological variables related to the structural indexes*.*

Index	Variable					
	Fruit weight (g)	Fruit FC	Fruits kg^{-1}	Seed weight (g)	Seed FC	Seed kg^{-1}
IVF	673.04**	585.16**	637.04**	656.56**	259.56**	256.56**
IVI	695.86**	690.44**	695.86**	802.1**	282.65**	802.1**
IC	644.34**	588.37**	644.34**	650.17**	241.52**	650.17**

IVF = Forest Value Index; IVI = Importance Value Index; IC = Complexity Index; FC = Form coefficient; **Highly significant (Duncan, 0.05).

Fruits and seeds characteristics

The fruits and seeds collected from 27 *Bursera simplex* trees showed significant statistical differences in weight, form coefficient (FC) and number of seeds kg^{-1} (p ≤ 0.0001), depending on the tree of origin. The greatest heterogeneity (VC> 65 %) was shown in the weight of the seed and number of seeds kg^{-1}; the lowest variation was recorded by the FC of the fruit and the FC of the seeds (VC = 7.42 and 13.36 %, respectively) (Table 2).

Table 2. Summary of the analysis of variance of morphological variables of fruits and seeds of *Bursera simplex* Rzed. & Calderón.

Variable	Variation source	Degrees of freedom	Mean squares	Variation coefficient (%)	Standard deviation
Fruit weight	Tree	26	0.209**		
	Rep	49	0.014**	18.72	0.05
	Error	1 274	0.003		
	Total	1 349			
Fruit form coefficient	Tree	26	0.181**		
	Rep	49	0.008^{ns}	7.92	0.05
	Error	1 274	0.003		
	Total	1 349			
Seed weight	Tree	26	0.009**		
	Rep	49	0.001**	65.13	0.03
	Error	1 274	0.0009		
	Total	1 349			
Seed form coefficient	Tree	26	0.129**		
	Rep	49	0.008^{ns}	13.36	0.09
	Error	1 274	0.008		
	Total	1 349			
Number of fruits (kg^{-1})	Tree	26	40062159		
	Rep	49	2527007	20.55	724.24
	Error	1 274	524537		
	Total	1 349			
Number of seeds kg^{-1}	Tree	26	1955037863**		
	Rep	49	103220988**	22.21	5354.54
	Error	1 274	28671108		
	Total	1 349			

Rep. = Repetition; **High significant (Duncan, 0.05).

From tree 5, fruits of larger size and weight were selected (0.42 ± 0.09 g), so that the number of fruits kg^{-1} is low (2456 ± 571.46); these magnitudes were significantly different (Duncan, 0.05) from the sizes and weights of the fruits from trees 3, 9 and 16, which weighed 0.18 ± 0.03 g and the number of fruits kg^{-1} was 5 743.7 ± 1 138.21, 5 566 ± 998.51 and 5 743.7 ± 1 138.21, respectively.

Given the relation equatorial diameter-polar diameter, the FC in fruit in trees 1, 15, 19 and 23 was higher (0.81 ± 0.06 cm) as in tree 10 (0.81 ± 0.05 cm); this implies fruits of almost spherical shape.

The highest FC in the seeds was recorded in the fruits of tree 25 (0.79 ± 0.01 cm), which was statistically different (*p* = 0.0001). The tree 21 presented the seeds of greater weight (0.08 ± 0.13), which produce 16 179 ± 5 036 seeds kg^{-1}, while those of tree 3 were smaller, which would have 35 489 ± 10 209 seeds kg^{-1} (Table 3).

Table 3. Fruits and seeds from 27 *Bursera simplex* Rzed. & Calderón trees from *Santa María Zoquitlán, Oaxaca.*

Tree	Fruit weight (g) (0.0001)	Fruit form coefficient (cm) (0.0001)	Fruits kg⁻¹ (0.0001)	Seed weight (g) (0.0001)	Seed form coefficient (0.0001)	Seeds kg⁻¹ (0.0001)
1	0.30±0.05 d	0.81±0.06 a	3 439.3±791.20 c	0.03±0.007 ghi	0.74±0.12 abc	29 328±6 694 c
2	0.25±0.05 e	0.70±0.06 e	4 142.4±991.18 b	0.04±0.008 defgh	0.70±0.09 bcd	22 318± 4 441 ghi
3	0.18±0.03 f	0.78±0.07 bc	5 743.7±1138.21 a	0.03±0.030 ghi	0.68±0.07 ghi	35 489±10 209 a
4	0.30±0.05 d	0.68±0.04 ef	3 438.4±704.60 c	0.03±0.006 hi	0.67±0.09 ghi	32 712±7 347 b
5	0.42±0.09 a	0.77±0.04 cd	2 456.0±571.46 e	0.06±0.010 bc	0.75±0.08 abc	17 283±4 157 klm
6	0.35±0.06 c	0.76±0.05 cd	2 878.1±544.05 d	0.05±0.070 bcde	0.76±0.08 abc	22 065± 5 000 hi
7	0.38±0.06 b	0.64±0.06 g	2 678.6±539.12 de	0.04±0.009 defgh	0.68±0.13 fgh	22 585±5 521 ghi
8	0.30±0.05 d	0.80±0.06 ab	3 430.5±821.21 c	0.03±0.005 fghi	0.72±0.08 cdef	25 476±3 648 ef
9	0.18±0.03 f	0.69±0.09 e	5 566.4±998.51 a	0.02±0.005 i	0.63±0.08 jkl	36 983±7 395 a
10	0.40±0.04 ab	0.81±0.05a	2 512.8±292.90 e	0.03±0.007 fghi	0.73±0.09 bcde	26 947±5 694 ed
11	0.29±0.07 d	0.75±0.05 d	3 615.2±1003.62 c	0.03±0.007 hi	0.69±0.09 efg	32 719±6 556 b
12	0.32±0.08 d	0.66±0.04 fg	3 279.4±757.19 c	0.03±0.006 ghi	0.64±0.09 hijk	28 658±5 709 cd
13	0.30±0.05 d	0.68±0.05 ef	3 427.7±686.91 c	0.04±0.005 fghi	0.69±0.09 efgh	24 671±3 465 fg
14	0.40±0.05 ab	0.80±0.06 ab	2 492.5±376.73 e	0.04±0.009 efgh	0.74±0.06 bc	23 198±5 262 gh
15	0.30±0.05 d	0.81±0.06 a	3 438.4±704.60 c	0.03±0.005 ghi	0.73±0.09 bcde	28 966±5 515 cd
16	0.18±0.03 f	0.78±0.07 bc	5 743.7±1138.21 a	0.07±0.010 b	0.66±0.07 ghij	14 964±4 020 m
17	0.30±0.05 d	0.80±0.06 ab	3 430.5±821.21 c	0.03±0.005 hi	0.72±0.07 cde	31 849±4 752 b
18	0.25±0.05 e	0.70±0.06 e	4 142.4±991.18 c	0.06±0.010 bc	0.63±0.08 ijk	17 046±4 198 lm
19	0.30±0.05 d	0.81±0.06 a	3 438.4±704.60 c	0.06±0.006 bcd	0.61±0.08 kl	16 790±2 022 lm
20	0.30±0.05 d	0.68±0.04 ef	3 438.4±704.60 c	0.04±0.010 cdefg	0.59 ±0.08 l	22 709±6 809 ghi
21	0.35±0.06 c	0.76±0.05 cd	2 887.1±544.05 d	0.08±0.13 a	0.67±0.08 ghi	16 179±5 036 lm
22	0.30±0.05 d	0.80±0.06 ab	3 430.5±821.21 c	0.04±0.007 defgh	0.72±0.08 cdef	21 982±3 572 hi
23	0.30±0.05 d	0.81±0.06 a	3 439.3±791.20 c	0.05±0.02 bcde	0.67±0.09 ghi	19 385±5 940 jk
24	0.30±0.05 d	0.80±0.06 ab	3 430.5±821.21 c	0.06±0.001 bcd	0.69±0.09 defg	17 512±4 748 kl
25	0.32±0.08 d	0.66±0.04 fg	3 279.4±757.19 c	0.04±0.008 defgh	0.79±0.01 a	22 127±4 279 hi
26	0.30±0.05 d	0.68±0.05 ef	3 427.7±686.91 c	0.05±0.02 bcde	0.76±0.09 abc	19 538±8 972 jk
27	0.40±0.05 ab	0.80±0.06 ab	2 492.5± 376.73 e	0.05±0.01 cdef	0.77±0.08 ab	20 606±5 160 ij

Accompanied mean by ±standard deviation. Different letters in columns represent significant statistical differences (Duncan, 0.05).

Possibly the morphological variations in fruits and seeds of the different trees result from *Bursera simplex's* own reproduction type, since its dioic condition promotes cross-pollination, and, therefore, greater diversity in the offspring (Edwards y Sharitz 2000; Enríquez *et al.,* 2004; Rzedowski y Calderón 2006; Magallán *et al*., 2009). The morphological variability observed in fruits and seeds could have a remarkable genetic component besides the environmental one (Gómez *et al.,* 2010).

On the other hand, Guzmán and Cruz (2014) report that the growth of the fruit is related to the available humidity, since with high temperatures with little humidity, the fruits become smaller, which varies according to the position they have on the tree; the large fruits develop in the upper part of the crown due to the greater availability of sugars and proteins produced by the photosynthetic area, in comparison with those of the lower part of the crown. Based on the above, Rubio *et al.* (2011) mention that the variation in the size of the seeds is important because it provides diverse capacities to settle in sites with different conditions.

Gonzáles and Cruz (1995) establish that fruits with FC close to the unit have homogeneous diameters (polar and equatorial) and have a spherical shape, while values that diverge from it describe elongated fruits. Site conditions such as altitude, exposure and the slope of the terrain where the tree grows influence the magnitude of its growth and these in turn influence the morphological characteristics of fruits and seeds ($p \leq 0.01$). Fruits of greater weight 0.34 ± 0.07 g were harvested from trees located in sites with southern exposure; seeds collected from trees growing in sites with southwestern exposure weighed 0.06 ± 0.07 g; in contrast, those of trees in north and northeast exposures weighed 0.03 g.

The FC of fruits and seeds reflects significant statistical differences ($p \leq 0.0002$); therefore, it is confirmed that the fruits with the highest FC were those harvested from trees in sites with east exposure with 0.81 ± 0.06 cm, which contrasts with the seeds from trees in southern exposure whose CF was 0.72 ± 0.10 cm. On the other hand, the seeds collected from trees in sites in southwest exposure had a higher FC ($p = 0.72 \pm 0.09$ cm). The amount of fruits and seeds kg^{-1} was statistically different ($p = 0.0001$), because the seeds collected from trees located

in northeast exposure accumulated 4 235 ± 1 338 kg^{-1} fruits, higher than the southern exposure, 3 054 ± 787 kg^{-1} fruits; similar case occurs in tree seeds in northeast exposure, which gave a total of 30 124 ± 8 746 (Table 4).

Table 4. Assessed variables in regard to exposure, slope and altitude.

Site variable	Fruit-seed variables (probability)					
	FP (g) (0.0001)	DPF (cm) (0.0001)	Fruits kg^{-1} (0.0001)	PS (g) (0.0001)	CFS (cm) (0.0002)	Seed kg^{-1} (0.0001)
Exposure						
South	0.34±0.07 a	0.72±0.10 c	3 054.6±787.66 d	0.05±0.01 b	0.69±0.11 bcd	20 048.4±5 722.6 d
West	0.33±0.09 ab	0.75±0.56 b	3 236.6±1 111.22 dc	0.05±0.02 b	0.70±0.11 abc	22 186.3±6 908.4 c
Southwest	0.32±0.06 bc	0.75±0.07 b	3 248.4±734.85 dc	0.06±0.07 a	0.72±0.09 a	19 233±6 686.4 d
East	0.30±0.05 c	0.81±0.06 a	3 439.3±791.20 c	0.05±0.02 ab	0.67±0.09 d	19 385.1±5 940.5d
North	0.27±0.07 d	0.75±0.09 b	3 879.8±1 168.08 b	0.03±0.01 c	0.68±0.09 cd	28 146.7±8 076.2 b
Northeast	0.25±0.07 e	0.76±0.07 b	4 235.2±1 338.91 a	0.03±0.01 c	0.71±0.01 ab	30 124.4±8 746.8 a
Slope (%)						
≤25	0.30±0.05 a	0.81±0.06 a	3 438.4±704.60 b	0.06±0.006 a	0.61±0.08 c	16 789±2 022.8 c
(25,40]	0.31±0.08a	0.75±0.08 b	3 421.4±1 131.96 b	0.04±0.03 b	0.71±0.10 a	23 898.8±8 082.0 b
>40	0.26±0.08 b	0.71±0.08 c	4 104.7±1 271.68 a	0.04±0.01 b	0.66±0.09 b	27 040±8 962 a
Altitude (m)						
≤1 178	0.24±0.07 c	0.76±0.08 a	4 441.81±1 375.15 a	0.03±0.01 b	0.72±0.10 a	29 259.4±8 974.6 a
(1 178-1 278]	0.36±0.08 a	0.74± 0.07 b	3 531.67±725.56 b	0.04±0.03 a	0.72±0.09 a	23 985.7±7 212.7 b
>1 278	0.30±0.08 b	0.75±0.08 ab	2 940.33±1 128.83 c	0.04±0.03 a	0.69±0.10 b	23 316.9±8 140.1 b

Accompanied mean by ± standard deviation. Different letters in columns represent significant statistical differences (Duncan, 0.05); FP = Fruit weight; DPF = Polar fruit diameter; CFF = Fruit shape coefficient; PS = Seed weight; CFS = Seed shape coefficient.

The slopes of the evaluated sites showed significant differences (p ≤ 0.001); from trees in sites with 25 and 40 %, the fruits of greater size were collected, with an average of 0.31 g and the production of fruits kg^{-1} is favorable in slopes> 40 %, since they sum up an average of 4 104, with a FC equal to 0.71 ± 0.008 cm. From

trees located in places with small slopes, fruits that tend to be rounded were taken, unlike the fruits of sites with steeper slopes, which outline an elongated shape.

The same behavior was not observed does with the seeds collected from trees located in slopes <25 %, since between the slopes 25 and 40 %, they reached a greater weight (0.06 g), with shape form of 0.71, while the seeds from trees located at slopes> 40 % were smaller but more abundant (27 040 seeds kg^{-1}) in contrast to the seeds taken from trees located at sites on slopes <25 % that were larger, and that gave a total of 16 789 seeds kg^{-1} (Table 4).

The altitude of the sites in which the trees grow was also a factor with significant effect (p≤0.01), since in the altitudinal interval between 1 178 and 1 278 m, the weight of the fruits was 0.36 g, with the lowest FC (0.74); these data contrast with those occurring at altitudes ≤1 178 m, whose FC was 0.76, at this same altitude the fruit production was 4 441.

The seed had a similar response with 0.04 g at altitudes> 1 178 m; however, seed production was higher at altitudes ≤1 178 m (29 259.4) with form coefficients of 0.72 cm at altitudes ≤1 278 m (Table 4).

The morphological differences of the fruits and seeds in relation to the characteristics of the site (exposure, slope and altitude) can be understood as they are factors that influence the solar radiation that affects the plant, temperature and environmental humidity, conditions that affect the primary productivity of the species. In their study conducted in *Quercus*, Márquez *et al*. (2005) stated that the size differences are due to biological and physical factors, in addition to the size of the seeds in a species can vary between populations or between individuals, either for genetic reasons or for the life history of each plant (Griffiths *et al*., 2009; García *et al.,* 2015).

Conclusions

The population structure of the trees selected as *Bursera simplex* seedbeds is characterized by an irregular shape, characteristic of the low deciduous forest; according to the evaluated indexes, the structure in which the trees of *B. simplex* develop affects the weight and morphological characteristics of fruits and seeds.

In the west exposure sites, the highest number of individuals was counted, where there is a greater density of shrub type species, mainly, with heights ≤ 1.5 m, as well as larger individuals such as the burseras with 265 ha^{-1} individuals. From tree 21, the best selected as a nursery, the highest seeds were collected (0.08 ± 0.13 g), with 16 179 ± 5 036 seeds kg^{-1}; while the fruits of greater weight were associated to tree five (0.42 g) and 2 456 fruits kg^{-1} with low FC and elliptical shape. The slopes and altitudes of the sites influence the characteristics of the fruits and seeds, of the trees in sites with slopes ≤ 40 % heavier fruits were collected.

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Jesús Jonathan Luna Cedeño: field sampling; Gerardo Rodríguez Ortiz and Juan Ángel García Aguilar: data statistical analysis; José Raymundo Enríquez del Valle, Judith Ruíz Luna and Gisela Virginia Campos Ángeles: laboratory analysis.

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