
ORIGINAL RESEARCH ARTICLE

Cedrela odorata L. seed yield variation at two sites in Veracruz, Mexico

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ABSTRACT

With the purpose of identifying the characteristics of variation in fruit size and seed production (potential and efficiency) of *Cedrela odorata* L. between sites and progenies established in the ejido La Balsa, municipality of Emiliano Zapata, Veracruz, fruits were harvested from 20 trees in February 2013, preserving the identity of each one. Fruit length and width were measured, seed was extracted and developed and aborted seeds were counted to calculate Seed Production Potential (SPP) and Seed Efficiency (SE). The results showed significant differences between sites and between progenies and for fruit length between sites. The mean values found were: 32.52 mm (fruit length), 18.73 mm (fruit width), 39.9 seeds per fruit (SPP) and 57.51% (SE). The seed of this species for its use should be selected taking into account the production characteristics of crops and outstanding individual trees, in addition, due to the current regulatory restrictions on seed collection, the establishment of trials and plantations for germplasm production is a viable option for forest management of the species.

Keywords: *Cedrela Odorata*; Fruits; Seeds; SPP; SE

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1. Introduction

The renewability of forest resources and the establishment of plantations are directly proportional to their reproductive capacity and adequate management of the species that comprise them^[1], so the correct application of regeneration methods in the management of natural forests and the production of sufficient and high quality seedlings in commercial plantations are vital in this productive process^[2-5].

Seed production in a given site—rodal, area or seed orchard—depends on the processes that affect the production of male and female stromata, the biological and ecological conditions of the population and the potential losses during the maturation process of the reproductive structures until seed production^[6-8].

To compensate for years of low production and improve the quality of the seed and forest products, seed orchards were designed^[9], which are currently the most intensively managed and controlled plantations available. One of the best sources of information for orchard management is cone analysis^[10]. The main objective of this analysis is to determine the potential seed production per cone, the effective seed production and to find the probable causes of losses in order to adjust management practices^[11,12]. However, each component of the forestry production chain, such as seed collection and management, plant production, plantation establishment and field monitoring^[13], must be precisely addressed, taking into account that each step is the basis for the

success of the next, so that the quantity and quality of the seed used has an impact on the entire process and its final result.

Cedrela odorata L. is a species with a wide ecological distribution, but of low local abundance^[14,15], which, due to its use and commercial value, makes it a species in high demand in the warm zones of Mexico^[16].

Due to the importance and demand of the species, two provenance/progeny trials were established in La Balsa, municipality of Emiliano Zapata, Veracruz, Mexico in September 2000, including three provenances and twenty-two progenies distributed in six blocks with four replications. In order to identify the variation in fruit size and seed production characteristics (Potential and Efficiency) of *Cedrela odorata* L. between sites and progenies, the present study was conducted.

2. Material and methods

Fruits were collected in February 2013 from 20 trees from two provenance/progeny trials located in the ejido La Balsa municipality of Emiliano Zapata, Veracruz. The first is located at 19°20'46.63" North and 96°38'59.65" West, at an altitude of 414 masl, the second at 19°20'59.27" North and 96°38'43.58" West, at an altitude of 404 masl with a mean annual temperature of 25.1 °C and a total annual precipitation of 912.1 mm^[17].

Of these 20 parents, those numbered one to six are half-siblings present at both sites and eight (7 to 14) only showed seed at site one, with a total of 14 progenies being compared.

Most of the fruits were collected from each tree and then a random sample of 28 fruits per tree was taken, when the quantity was sufficient, otherwise all the fruits collected were taken, based on the methodology proposed by Bramlett *et al.*^[10]. The length and width of the fruit were measured with a Mitutoyo brand digital vernier to the nearest tenth of a millimeter and placed individually in paper bags, noting the tree number and fruit number on each bag. Once the fruits were opened, the seeds

were extracted for analysis.

Seed production potential refers to the maximum number of both developed and underdeveloped seeds contained in a given fruit. The value of this potential depends directly on the number of ovules in the ovary and indicates the biological limit of the fruit to produce a certain amount of seeds. By its nature, seed production potential is a characteristic subject to a strong genetic control and its value was calculated by adding the number of developed and underdeveloped seeds found in each fruit^[18].

Seed production efficiency refers to the ratio of developed seeds in a given fruit to its seed production potential. This characteristic is subject to a strong environmental control and its value varies from 0 to 100%, indicating the failure or success of the fruit to produce a certain number of seeds with an embryo potentially capable of germinating and giving rise to a new plant. The value of this index was calculated by dividing the number of seeds developed by the seed production potential by 100.

The values obtained were captured in a database in the Statistica program^[19], where graphs, analysis of variance with the GLM procedure and comparison of means by Tukey's method were performed. The fixed effects model used was as follows:

$$Y_{ijk} = \mu + S_i + F_j + E_{ijk}$$

Where:

Y_{ijk} = Observed value of the variable

μ = Effect of the overall mean

S_i = Effect of the i-th site

F_j = Effect of the j-th progeny

E_{ijk} = Experimental error

3. Results

The results for fruit characteristics and seed production of *Cedrela odorata* L. established at La Balsa are shown in **Table 1**, with an average SPP of 39.94 seeds per fruit and an SE of 57.51%, which indicates an average production of 23 seeds per cone.

Table 1. Descriptive characteristics of fruit and seed production of *Cedrela odorata* L. in two provenance/progeny trials established at La Balsa Emiliano Zapata, Veracruz

Variable	N	Media	Minimum	Maximum	Variance	Des. Est.
Length	458	32.52085	20.27000	47.92000	17.5415	4.18826
Width	458	18.73568	12.70000	32.93000	4.1522	2.03770
SPP	458	39.34323	20.00000	54.00000	35.3666	5.94698
SE	458	57.51353	16.66667	93.75000	285.2359	16.88893

3.1 Length of the fruit

Site one presented an average of 32.83 mm and site two 31.53 mm. The analysis of variance showed that between sites there were no significant differences ($P \leq 0.05$), but between progenies there was a significant difference (**Table 2**).

Tukey's test showed the formation of three homogeneous groups, progenies 7, 9, 8 and 5, which presented the lowest values, were completely separated from progenies 11 and 12 with the highest means (**Table 3**).

Table 2. Analysis of variance of fruit length of *Cedrela odorata*

Length	G. L.	S. C.	C. M.	F	p
Site	1	21.7	21.7	1.06	0.161959
Progeny	13	2,971.5	228.6	20.64	0.000000
Error	443	4,9054	11.1		
Total	457	8,016.5			

Table 3. Comparison of means for fruit length of *C. Odorata*

Progeny	Average (mm)	1	2	3
7	29.78143	a		
9	29.09450	a		
8	30.27143	a		
5	30.68950	a		
14	31.01125	a	b	
13	31.58455	a	b	
3	31.88316	a	b	
6	32.18786	a	b	
2	32.33636	a	b	
1	33.83500		b	
10	34.07143		b	
4	34.14059		b	
11	38.18750			c
12	41.51313			c

3.2 Width of fruit

At site one the fruits were less wide (average 18.51 mm) than at site two (average 19.48 mm). Analysis of variance showed statistically significant differences ($P \leq 0.05$) between sites and between progenies (**Table 4**).

Tukey's test showed the conformation of seven homogeneous groups, progenies 1, 9, 14 and 11 separated from progenies 3, 10, 8, 12 and 4, showing a continuous but overlapping variation among all progenies, except progenies 1, 9 and 4 (**Table 5**).

Table 4. Analysis of variance of fruit width of *C. Odorata*

Width	G. L.	S. C.	C. M.	F	P
Site	1	52.74	52.74	17.55	0.000034
Progeny	13	487.91	37.53	12.49	0.000000
Error	443	1,330.99	3.00		
Total	457	1,897.57			

Table 5. Comparison of means for fruit width of *C. odorata*

Progeny	Average (mm)	1	2	3	4	5	6	7
1	16.67571	a						
9	16.82200	a						
14	17.51437	a	b					
11	17.86357	a	b	c				
6	18.46571		b	c	d			
5	18.58400		b	c	d	e		
7	18.61571		b	c	d	e	f	
2	18.65545		b	c	d	e	f	
13	18.73945		b	c	d	e	f	
3	19.12053			c	d	e	f	
10	19.64643				d	e	f	
8	19.97036					e	f	g
12	20.34937						f	g
4	21.72824							g

3.3 Seed Production Potential

The SPP for site one was 40.67 seeds per fruit, while for site two it was lower, 37.59 seeds per fruit. The analysis of variance presented significant differences ($P \leq 0.05$) both between sites and between progenies (**Table 6**).

Tukey's test showed the formation of four homogeneous groups, where progenies 5 and 11 were completely separated from the rest, and progenies 3, 1, 2, 4, 10, 7 and 12, which were above the general mean, formed a separate group (**Table 7**).

Table 6. Analysis of variance of SPP of *C. odorata*

SPP	G. L.	S. C.	C.M.	F	P
Site	1	534.9	534.9	30.93	0.000000
Progeny	13	7,721.9	594.0	34.35	0.000000
Error	443	7,659.7	17.3		
Total	457	16,162.5			

Table 7. Comparison of means for PPS of *C. odorata*

Progeny	Average (S/F)	1	2	3	4
5	32.67500	a			
11	33.50000	a			
14	35.25000	a	b		
9	35.90000	a	b	c	
6	37.03571		b	c	
8	39.10714		b	c	
13	39.41818			c	
3	42.92105				d
1	43.53571				d
2	43.68182				d
4	43.88235				d
10	44.42857				d
7	44.89286				d
12	46.31250				d

3.4 Efficiency of seed production

Seed production efficiency presented an overall mean at site one of 56.32%, while for site two it was higher (61.40%); the analysis of variance shows significant differences ($P \leq 0.05$), between

sites and between progenies (**Table 8**).

Tukey's test showed five homogeneous groups, with progenies 10, 7 and 3 being the least efficient, while progeny 11 showed the highest efficiency (**Table 9**).

Table 8. Analysis of variance of SE of *C. Odorata*

EN	G. L.	S. C.	C. M.	F	P
Site	1	3411.0	3411.0	17.455	0.000035
Progeny	13	41652.3	3204.0	16.396	0.000000
Error	443	86568.7	195.4		
Total	457	130352.8			

Table 9. Comparison of means for ES of *C. odorata*

Progeny	Mean(%)	1	2	3	4	5
10	42.15492	a				
7	45.06216	a				
3	46.44347	a				
14	53.66295	a	b			
4	54.04801	a	b			
2	54.70346	a	b			
6	59.07851		b	c	d	
1	59.44750		b	c	d	
8	60.46395		b	c	d	
13	62.51414		b	c	d	
12	64.04179		b	c	d	e
5	68.95260			c	d	e
9	69.95462			c	d	e
11	75.07415					e

4. Discussion

Rodríguez^[20] found for trees from three provenances in Veracruz, a mean of 32.79 mm in length and 17.89 mm in width in fruits of *Cedrela odorata*, results similar to those of the present study; Alderete^[21] reported 3.40 cm in length and 1.96 cm in width for 22 families of this same species from the state of Campeche, slightly larger than those found in this study, perhaps due to differences in environmental conditions, genotypes and soil characteristics.

Studies have been carried out on seed production potential and efficiency in hardwood species, Niembro^[22] found a SPP between 54 and 89 seeds per fruit for trees in the China Experimental Field, Campeche, while De la Cruz Landero and Hernández^[23] obtained potentials of 57 to 70 seeds per fruit in 20 trees located in the state of Campeche, both for mahogany (*Swietenia macrophylla* King).

Chávez and Ramírez^[24] obtained a SPP between 34 and 47 seeds per fruit in 22 trees distributed in the state of Campeche; while Rodríguez *et al.*^[18] obtained an average SPP of 43 seeds per fruit in a population located in La Antigua, Veracruz, the seed production efficiency was 53.83%; both studies were conducted with cedar (*Cedrela odorata* L.)

and provide results similar to the present one. Mendizábal-Hernández *et al.*^[25], found for a previous harvest (2011) at the same site a SPP of 46.6 s/f, higher than that found in 2013 and an SE of 50.3% lower than the 57.5 of this study.

Viveros *et al.*^[26] report an average potential of 57 seeds per fruit, finding significant differences among thirty guazamo trees (*Guazuma ulmifolia* Lambert) from a coastal population in central Veracruz.

5. Conclusions

Thirteen years after the trials were established, fruit and seed production appear to be reaching the mature stand parameters of this species for the sites. Site one presented a higher Seed Production Potential but the fruits of site two were wider and presented higher Seed Efficiency. Regarding progeny, regardless of site, family four had the largest fruits and was in the group with the highest SPP but presented a low ES.

Seed of this species for nursery use should be selected taking into account the production characteristics of the crops and individual trees, in addition, due to current regulatory restrictions, the establishment of trials and plantations for seed

production is a viable option for the management of the species.

Conflict of interest

The authors declare that they have no conflict of interest.

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