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Germination patterns in coconut populations (*Cocos nucifera* L.) in Mexico

Daniel Zizumbo-Villarreal* & Jose Arellano-Morín
Centro de Investigación Cientifica de Yucatán A.C., AP. 87. Cordemex, Mérida, Yucatán, CP. 97310 México (Author for correspondence: e-mail: dzizumbo@cicy.cicy.mx)*

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Abstract

Lethal yellowing disease has drastically affected the coconut populations on the east coasts of Mexico and is threatening to invade all the production areas in Mexico. For the purpose of defining the existence of genetically differentiated coconut populations that eventually could have a differential response to this disease, we studied the germination patterns in 20 representative coconut populations using 90 nuts per population in three lots under similar growing conditions. Following the emergence of the leaf through the plumuler fissure, the following were calculated weekly: (1) percent emergence of the first leaf, percent mortality between germination and emergence, and percent germination capacity; (2) time required to reach 25%, 50%, 75%, and 100% of germination; (3) mean time to complete germination, coefficient of the rate of germination, and uniformity of germination; and (4) sigmoid curve parameters of accumulative percent germination, adjusted to a model of nonlinear regression (log scale). The results showed three population groups: (a) with early and uniform germination; (b) with early and heterogeneous germination, and (c) with late and heterogeneous germination. The same population groups were previously observed using fruit morphological traits. This suggests the presence in Mexico of three tall coconut genotypes. Late and heterogeneous populations have been almost totally eliminated by the disease and some precocious populations have been shown very low levels of mortality. This suggests a correlation between precocity and resistance. The geographical distribution of the ecotypes suggest that the mortality will be deferential when the disease arrives to the other coconut producing areas in Mexico.

Introduction

Flotation is considered the principal means of dispersion of the coconut under natural conditions (Sauer, 1994; Harries, 1995). It is accepted that the coconut evolved in a habitat confined to the narrow coastline in the Indo-Pacific region, dispersing throughout the islands and reefs, and establishing itself with little further movement on beaches in moist climates without prolonged dry periods and with readily available fresh water. The natural selection under this conditions could have favored fruits with a high content of mesocarp and late germination that would increase their ability and capacity to colonize distant places (Harries, 1978).

Human selection during domestication could have favored fruits with a high content of liquid endosperm, thus, lowering the percentage of mesocarp, while increasing the density of the fruit and decreasing its floating ability. On the other hand, human selection of seedlings could have favored fruits with early germination which would have a negative effect on long distance dispersion. Thus, two changes that have been observed in the domestication process of plants that are grown for seeds (Ladizinsky, 1985), which might respond to human selection: (1) changes in the mode of seed dispersal and (2) reduction of seed dormancy.

Studies on germination in coconut populations in different parts of the world indicate two general patterns: (1) late germination, when the populations require more than 75 days to reach 25% of germination,

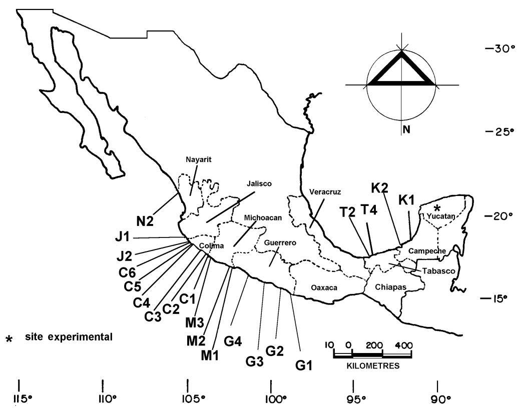

Fig. 1. Sites sampled of 20 coconut populations studied in Mexico.

more than 90 days to reach 50% and more than 105 days to reach 75%; and (2) early germination, when they require less days to reach these percentages (Harries, 1981a). This differentiation has been considered a product of the long term domestication process in the Malesian region (Harries 1990).

Germination patterns have been used in the botanical characterization of coconut varieties and have been considered a useful tool in the study of interpopulation variability (Harries, 1981b; Whitehead, 1965). The rate of germination has been used in genetic improvement programs as a marker for the selection in the nursery of hybrid individuals which are products of the crossing of two progenitors with different germination patterns (Rognon, 1972; Wuidard, 1981;). Agronomic studies have demonstrated that characteristics such as high percentage of germination and precocity present a positive correlation with production as well as high inheritability (Mathew & Gopimony, 1991). This suggests that the selection of precocious seeds leads to superior plants.

In Jamaica the evaluation of different coconut populations of the world, in relation to Lethal yellowing disease (LY), suggests a positive correlation between early germination and survival, indicating that it could be a useful marker for the selection of plants resistant to LY (Whitehead, 1968; Harries, 1973). LY entered Mexico via the Caribbean coast in 1977, dispersing along the coasts of the Gulf of Mexico and the Caribbean, and is now threatening all the coconut production areas of Mexico and Central America (Oropeza-Salin & Zizumbo-Villarreal, 1997). In order to ascertain the morphological variation and genetic diversity of coconut in Mexico, first, we studied the pattern of morphological variation in 41 populations *in situ*. In this study, four morphotypes of coconuts were defined in Mexico: 'Malayan Dwarf', 'Atlantic Tall', 'Pacific Tall 1' and 'Pacific Tall 2' (Zizumbo-Villarreal & Piñero, 1998).

We considered it important to analyze the germination patterns in representative coconut populations because they have been used to describe intra-specific variability and this is a character which could be correlated with productivity and resistance to LY. We also investigated the relationship between germination and different fruit morphological characteristics in order to confirm the presence of different genetic populations in Mexico.

Materials and methods

Seed collection

In 1989, we defined nine important coconut production areas in the country, which included the possible sites of early introduction and the principal plantation areas. The morphological variation pattern of 41 populations in these nine areas was described *in situ* based on the components of the fruit (Zizumbo-Villarreal et al., 1993). For the germination study, we selected 19 of these populations with tall coconuts, representative of the production areas. On the west coast of the states of Nayarit, Jalisco, Colima, Michocan and Guerrero, and on the east coast, of the Tabasco and Campeche states (Fig. 1). A population of yellow dwarf coconuts (C5) from the state of Colima was also included.

From each population, we obtained a sample of 90 fruits produced by open pollination. They were collected when they were physiologically mature. The collection was carried out between April and May of 1989. The period between collecting and planting was approximately 21 to 28 days for fruit collected in the state of Guerrero, 14 to 21 days for those from the state of Michoacan, 7 to 14 days for those from the states of Colima, Jalisco, Nayarit and Tabasco, and 2 to 7 days for those from the state of Campeche.

Data collection and experimental design

We studied a total of 1,800 fruits with 90 fruits per population divided in three lots of 30 fruits each. All the lots were planted under similar environmental conditions in nurseries prepared with a soil layer of 0.25 meters deep composed of 50% sand and 50% soil of the *cambisol* type (Duval, 1968). Irrigation and weeding were carried out similary for all the plants.

Planting was done on the 16th of June, 1989 in nursery conditions in Merida, Yucatan, Mexico (Fig. 1).

Germination was registered as the emergence of the first leaf from the plumuler fissure after passing through the mesocarp, since the thick mesocarp did not allow direct observation of embryo differentiation, and mesocarp removal is not convenient because it alters germination as it changes embryo conditions such as temperature, humidity, and aeration (Harries 1981a).

Fruits that emitted the first leaf were counted weekly for 40 weeks after being planted. At the end of this period, the nuts that showed no sign of germinating were opened in order to observe the condition of the embryo. Thus, we observed a number of seeds that began germination but die before emitting the first leaf.

Analysis of data

Different methods were used (Bewley & Black, 1985; Gonzalez- Zertuche & Orozco-Segovia, 1996):

Descriptive methods: (1) percentage of seeds that emitted at least one leaf (E), (2) percent mortality between germination and emergence (M), (3) germination capacity (C), that is defined as the percentage of seeds that included those that emitted at least one leaf, plus those germinated but did not emit any leaf (C), and (4) the time (days) required to reach 25%, 50%, 75% and 100% germination and emergence of the first leaf.

Analytical methods: (1) mean time to complete germination, $\bar{t} = \sum(t \cdot n)/\sum n$, were t is the numbers of days, starting from day 0, the day of sowing, and n is the number of seeds that emitted the first leaf on day t; and (2) coefficient of uniformity of germination, CUG = $\sum n/\sum[(\bar{t} - t)^2 \cdot n]$.

Cumulative percentage of germination was adjusted to a sigmoid curve on a log scale, using INPLOT (1992). The four parameters of the logistic equation were calculated, where A is the bottom of the plateau, B is the top of the plateau (A and B are expressed in units of the Y axis), C is the value of the X axis at the middle of the curve, and D is the Hill coefficient or slope factor which has no units.

Means and standard deviations were obtained from three repetitions for each index, coefficients and parameters of the curve. Differences between populations were analyzed by ANOVA using the procedure included in the Statistical Analysis Systems Release 6.04 (SAS, 1985). Comparison of means was done with Bonferroni test for multiple comparisons (α = 0.05). The percentage data were transformed with arcosin function before applying ANOVA. In order to ascertain the effect of the time lapse between collection and planting on the germination, a linear regression analysis was carried out between said time lapse and the coefficients and parameters of the curve.

Results

Means and standard deviations of percentage of emergence of at least one leaf, percentage mortality between germination, and percentage germination capacity are presented in Table 1. Germination capacity was 87.3%, with 83.4% of the seeds emitting leaves, while 3.9% died before leaf emergence, due to the attack of a fungus, presumably *Phytophthora* spp. The populations from the coast of the Gulf of Mexico (T2, T4, K1 and K2) registered no mortalities. The populations, G1, M1, M2 and M3, presented a mortality rate of between 11.1% and 13.3%, significantly higher than the rest of the populations. Populations such as C5, C3 and G2 presented a mortality between 4.4% and 6.7%, not significantly different from the rest of the populations.

The mean and standard deviation of the number of days necessary to reach 25%, 50%, 75% and 100% germination and emergence of the first leaf are presented in Table 1. Significant differences were found between two groups of populations for the four indexes (Table 2): (a) early-germinating populations, composed of all the populations distributed on the west coast and two populations on the east coast (T2 and T4), which required between 49 and 75 days to reach 25%, between 65 and 98 days to reach 50%, between 81 and 102 days to reach 75% and between 129 and 159 days to achieve 100%, and (b) late-germinating populations, composed of the populations K1 and K2 of the east coast, which required between 142 and 154 days to reach 25%, between 172 and 175 days to reach 50%, between 191 and 193 days to reach 75% and between 229 and 238 days to reach 100%.

Means and standard deviations of $\bar{t}$ and CUG are presented in Table 3. Significant differences were found between populations regarding the mean time to complete germination. The populations, K1 and K2, of the east coast took longer to germinate (between 170 and 172 days) than populations distributed on the west coast, which took between 67 and 83 days to germinate. There were also significant dif-

Table 1. Code, name of the population, state, mean, and standard deviation (Std) of percent emergence at first leaf (E), percent mortality between germination and emergence (M), percent germination capacity (C), and 25%, 50%, 75%, and 100% germination and emergence of the first leaf in 20 coconut populations in Mexico

Code	Population	State	E (%) Mean	Std	M (%) Mean	Std	C (%) Mean	Std	25% (days) Mean	Std	50% (days) Mean	Std	75% (days) Mean	Std	100% (days) Mean	Std
G1	Marquelia	Guerrero	63.3	10.0	12.2	7.7	75.6	5.1	70.0	0.0	86.3	4.0	98.0	0.0	179.7	35.9
G2	El Carrizo	Guerrero	76.7	10.0	6.7	0.0	83.3	10.0	49.0	7.0	70.0	0.0	88.7	4.0	151.7	74.8
G3	Nuxco	Guerrero	100.0	0.0	0.0	0.0	100.0	0.0	60.7	8.1	77.0	0.0	91.0	7.0	147.0	48.5
G4	Tecpan	Guerrero	90.0	3.3	3.3	0.0	93.3	3.3	49.0	12.1	67.7	4.0	81.7	4.0	147.0	14.0
M1	El Caiman	Michoacan	75.6	6.9	11.1	8.4	86.7	3.3	70.0	7.0	79.3	8.1	91.0	7.0	128.3	4.0
M2	El Manglar	Michoacan	67.8	9.6	13.3	3.3	81.1	6.9	63.0	0.0	77.0	0.0	86.3	4.0	126.0	37.0
M3	Coahuayana	Michoacan	68.9	10.2	11.1	5.1	80.0	8.8	60.7	4.0	72.3	4.0	84.0	7.0	123.7	8.1
C1	Callejones	Colima	78.9	6.9	5.6	3.8	84.4	5.1	65.3	8.1	79.3	4.0	93.3	4.0	158.7	32.3
C2	C. Ortega	Colima	88.9	1.9	0.0	0.0	88.9	1.9	56.0	0.0	74.7	4.0	88.7	4.0	156.3	35.9
C3	Tecoman	Colima	90.0	3.3	4.4	5.1	94.4	3.8	58.3	4.0	65.3	4.0	79.3	4.0	98.0	14.0
C4	Cuyutlan	Colima	82.2	5.1	2.2	1.9	84.4	6.9	60.7	4.0	74.7	8.1	81.7	8.1	116.7	21.4
C6	Centinela	Colima	91.1	3.8	0.0	0.0	91.1	3.8	72.3	4.0	79.3	4.0	95.7	4.0	144.7	46.6
J1	Cihuatlan	Jalisco	91.1	1.9	2.2	1.9	93.3	3.3	74.7	4.0	86.3	4.0	98.0	0.0	137.7	10.7
J2	B. Navidad	Jalisco	86.7	3.3	1.1	1.9	87.8	1.9	74.7	8.1	93.3	4.0	105.0	7.0	161.0	14.0
N2	Matanchen	Nayarit	78.9	7.7	1.1	1.9	80.0	8.8	58.3	26.5	84.0	7.0	102.7	10.7	128.3	21.4
T2	San Laquito	Tabasco	95.6	1.9	0.0	0.0	95.6	1.9	65.3	4.0	98.0	0.0	114.3	4.0	158.7	16.2
T4	Dos Bocas	Tabasco	94.4	3.8	0.0	0.0	94.4	3.8	53.7	10.7	77.0	14.0	95.7	4.0	135.3	4.0
K1	Champoton	Campeche	91.1	6.9	0.0	0.0	91.1	6.9	142.3	4.0	175.0	12.1	193.7	10.7	228.7	8.1
K2	Cd. Carmen	Campeche	72.2	3.8	0.0	0.0	72.2	3.8	154.0	0.0	172.7	16.2	191.3	8.1	238.0	12.1
C5	Tecoman	Colima	84.4	6.9	4.4	3.8	88.9	6.9	67.7	4.0	72.3	4.0	88.7	8.1	114.3	8.1

ferences between populations relating to the rate of germination (Table 2). The populations, K1 and K2, presented significantly lower values (between 0.58 and 0.59) compared to the rest of the populations (between 1.1 and 1.5). Regarding the coefficient of uniformity, significant differences were also found between two groups of populations (Table 2): (a) populations with high values between 0.35 and 0.39, indicating relatively uniform germination, included M2, M3, C3, C4, C5, and J1; and (b) populations with low values between 0.07 and 0.016, indicating a relatively heterogeneous germination, included G1, G4, C1, C2, J2, T2, T4, K1 and K2. The populations, G3, G2, M1, N2 and C6 were intermediate and were no significantly different from the two groups.

The graphic relation, $\bar{t}$ / CUG, indicates three population groups with different germination patterns: (a) populations with early and uniform germination, which include C3, C4, C5, J1, M2, M3, M1, G3 and C6; (b) populations with early and heterogeneous germination, which include G1, G2, G4, C1, C2, J2, N2, T2 and T4; and (c) populations with late and

Table 2. ANOVA for eleven indixes, coefficients and parameters of the accumulative germination, in 20 coconut populations from Mexico.

Indexes, Coefficients, and parameters	*F*	*P*
Percent emergence of the first leaf	8.2	0.0001
Percent mortality germination/emergence	7.8	0.0001
Germination capacity	5.1	0.0001
Days to 25% of germination	28.0	0.0001
Days to 50% of germination	56.0	0.0001
Days to 75% of germination	77.3	0.0001
Days to 100% of germination	3.6	0.0001
Mean time to germination ($\bar{t}$)	83.1	0.0001
Uniformity of germination (CUG)	3.4	0.0002
Botton plateau (A)	1.5	ns
Top plateau (B)	8.1	0.0001
Days at the halfway point to the curve (C)	70.8	0.0001
Hill coefficient or Slope factor (D)	6.1	0.0001

Table 3. Mean and standard deviation (Std) of the mean time to complete the germination ($\bar{t}$), coefficient of uniformity of germination (CUG), and the parameters of the logistic equation: bottom plateau (A), top plateau (B), days to the halfway point of the curve (C), and Hill coefficient or slope factor (D), in 20 coconut populations of Mexico.

Code	$\bar{t}$		CUG		A		B		C		D	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
G1	88.8	2.2	0.11	0.04	−0.05	0.31	18.7	2.7	80.4	1.1	0.027	0.007
G2	74.3	7.6	0.15	0.10	−0.60	0.56	22.2	3.6	72.2	7.8	0.031	0.008
G3	78.0	4.5	0.24	0.20	0.64	0.46	29.7	0.5	74.7	2.5	0.049	0.015
G4	67.9	3.3	0.14	0.01	0.34	0.28	26.6	1.4	64.2	2.8	0.031	0.002
M1	82.4	6.8	0.29	0.04	−0.30	0.07	22.6	2.1	77.2	7.0	0.040	0.002
M2	78.0	3.1	0.35	0.18	−0.12	0.08	20.3	2.8	73.2	1.4	0.046	0.006
M3	76.5	1.6	0.37	0.10	0.52	0.13	20.6	3.2	70.5	3.3	0.044	0.002
C1	81.5	1.5	0.13	0.03	0.11	0.90	23.4	1.9	76.3	3.1	0.036	0.010
C2	78.2	4.7	0.14	0.02	−0.90	0.06	26.5	0.7	68.6	5.5	0.031	0.003
C3	67.6	5.9	0.39	0.10	0.11	1.20	27.0	1.0	64.3	3.2	0.049	0.005
C4	73.6	4.2	0.36	0.20	0.06	1.00	24.5	1.4	67.2	9.2	0.059	0.021
C6	83.1	4.4	0.27	0.15	0.15	0.79	27.2	1.0	78.8	3.4	0.042	0.003
J1	87.1	1.2	0.37	0.06	−0.10	0.28	27.3	0.6	82.6	1.4	0.051	0.002
J2	93.6	4.6	0.18	0.02	−0.29	0.22	25.8	1.0	87.7	3.5	0.036	0.004
N2	79.2	9.3	0.11	0.04	0.70	1.80	23.9	2.4	79.5	12.7	0.030	0.015
T2	92.8	1.3	0.12	0.02	−0.73	0.75	28.9	0.5	88.2	1.2	0.022	0.003
T4	78.8	5.8	0.13	0.00	−1.90	1.90	28.4	1.1	70.0	8.5	0.022	0.002
K1	172.2	9.2	0.09	0.02	−0.33	0.21	28.7	2.7	172.2	11.0	0.018	0.003
K2	170.7	8.2	0.08	0.02	0.33	0.52	21.7	0.9	169.6	7.5	0.027	0.006
C5	78.5	3.4	0.39	0.09	−0.50	0.30	25.3	2.1	73.5	3.1	0.044	0.006

heterogeneous germination, which include K1 and K2 (Fig. 2).

All the curves registered R^2 values higher than 0.98. Means and standard deviation for the four parameters of the curve are shown in Table 2. Parameter A was similar for all the populations. For parameter B, significant differences between populations were observed between population which showed 100% germination, and populations M1, M2, M3, and G1 which showed a high mortality between germination and emergence: For parameter C, significant differences were registered between the populations of the east coast, K1 and K2, which showed values between 169.4 and 172.2 days, compared to the populations on the west coast averaged between 64.4 and 88.2 days. In the case of parameter D, there were significant differences between two groups of populations: (a) populations with higher values, (between 0.042 and 0.049) such as M2, M3, C3, C4, C5 and J1; and (b) populations with lower values, (between 0.018 and 0.031) such as G1, G4, C2, J2, N2, T2, T4, K1, and K2. The parameter D for the populations, G2, N2, C6,

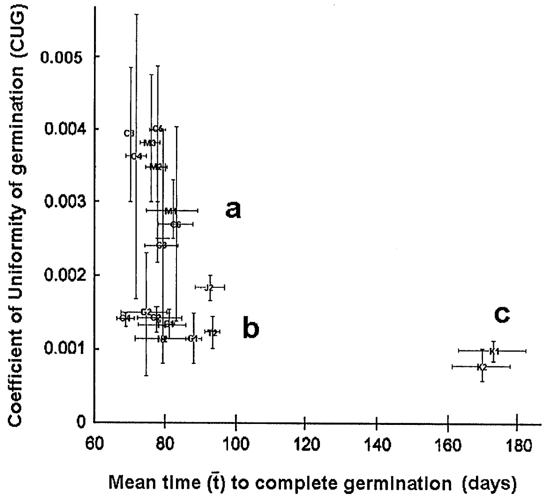

Fig. 2. Relation between coefficient of uniformity of germination (CUG) and mean time to complete the germination ($\bar{t}$), in 20 coconut populations in Mexico. Germination patterns: (a) early and homogeneous, (b) early and heterogeneous, and (c) late and heterogeneous.

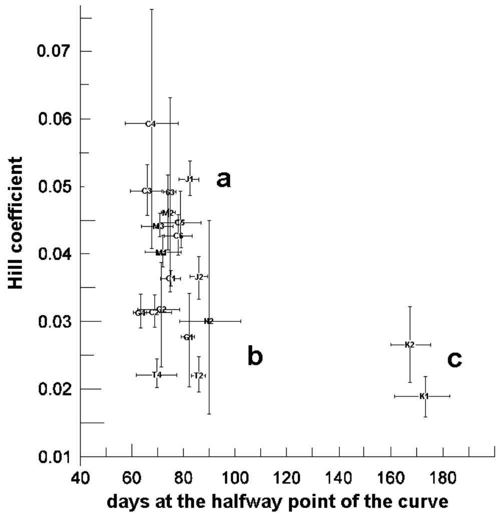

Fig. 3. Relation between the parameters of the sigmoid curve: days at the halfway point to the curve (C) and slope of the curve (D) in 20 coconut populations in Mexico. Germination patterns: (a) early and homogeneous, (b) early and heterogeneous, and (c) late and heterogeneous.

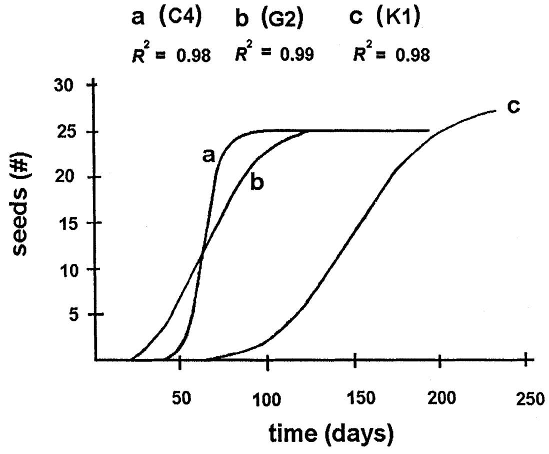

Fig. 4. Types of curves for the three germination patterns observed: (a) early and homogeneous germination, one repetition of population C4, (b) early and heterogeneous germination, one repetition of population G2, and (c) late and heterogeneous germination, one repetition of population K1.

M1, C1, and J2, were not significantly different from the two groups. The graphic relationship between the C and D parameters indicates three general patterns of germination (Fig. 3). One curve type representative curve of each germination pattern is showed in the Fig. 4.

We found a very low positive correlation between the time elapsed between collecting and planting and the parameters studied: $\bar{t}$ (R^2 = 0.31), CUG (R^2 = 0.30); B (R^2 = 0.005) and D (R^2 = 0.02). This indicates that the time elapsed between collecting and planting had no important effect on germination.

Discussion

Overall germination capacity of the different populations was high. A group of populations consisting of G1, M1, M2 and M3 presented a high percent mortality from germination to emergence. Mortality was apparently caused by the same pathogen, thus indicating that these populations are less adapted to the environment into which they were introduced. This also suggests ecotypic differentiation from the rest of the populations of the Pacific and the populations distributed on the Gulf coast, which showed no mortality.

The germination pattern of the time required to reach 25%, 50%, 75% and 100% to germination and emergence of the first leaf, indicates the presence in Mexico of two populational groups with high differentiation, one group distributed on the west coast and another group on the east coast. This differentiation has been presented as a possible result of the domestication process, which took place in the Malesian region, a long time before its introduction into Mexico in the 16th Century (Harries 1990). Therefore, the coconut introductions must have be done independently on the two coasts with different genetic populations or ecotypes.

The graphic relations, $\bar{t}$ /CUG and C/D parameters of the curve, indicate three differentiated populational groups: (a) populations with late and heterogeneous germination, K1 and K2; (b) populations with early and uniform germination, M1, M2, M3, C4, C6, and J2; and (c) populations with early and heterogeneous germination, G1, G2, C1, and C2. This differentiation suggests that introductions were not made independently with different ecotypes on both coasts, but that there could have been several introductions with differentiated populations on the west coast.

Comparison between the patterns of germination and morphological variation

We observed the same populational grouping when comparing morphological characteristics of the fruit as when comparing germination coefficients and parameters. The populations with late and heterogeneous germination correspond to the morphotype, 'Atlantic Tall', presenting fruit with a high mesocarp content, low content of liquid endosperm, elongated fruit and seed, and fruit with pronounced aristas. The populations with early and uniform germination belong to the morphotype, 'Pacific Tall 1', presenting relatively large fruit with a low mesocarp content, a high content of liquid endosperm, and round fruit and seeds. The populations with early and heterogeneous germination belong to the morphotype, 'Pacific Tall 2', presenting medium sized fruit, with a low percentage of mesocarp, a high content of solid endosperm, and round fruit, characteristics pertaining to the 'domestic' type. However, individuals with the 'wild' type characteristics were also present in early and heterogeneous germination populations. The 'Malayan Dwarf' presented an early and uniform germination, forming part of the same group as the morphotype 'Pacific Tall 1'. Regarding the intra-populational variation, both the dwarf coconut and the tall populations M2, M3, C4, and C6, showed the highest values for homogeneity and the lowest profiles for morphological variability, while populations such as G4, G2, G3, and N2 of the morphotype 'Pacific Tall 2', showed the lowest values for germination uniformity and the highest profiles for morphological variability (Zizumbo-Villarreal & Piñero, 1998). Differentiation was observed in both morphological and physiological characteristics, therefore, genetic differentiation between the population groups is possible.

Geographical distribution and origin of the germplasm

The populations of the morphotype 'Atlantic Tall' (K1 and K2), with late and heterogeneous germination, are distributed on the coast of the Gulf of Mexico, in the states of Yucatan, Campeche and Tabasco, while the populations of the morphotype 'Pacific 1', with early and homogenous germination, are distributed mainly in the area of Lazaro Cardenas in Michoacan (M1 and M2), on the border between the states of Michoacan and Colima (M3), in the Tecoman Valley in Colima (C3 and C4), and at the mouth of the river Marabasco on the border between the states of Colima and Jalisco (C6 and J1). The populations of the morphotype 'Pacific 2', with early and heterogeneous germination are distributed on the border between the states of Colima and Michoacan (C1 and C2), and in the regions of Costa Chica and Costa Grande in the state of Guerrero (G1 and G2) (Fig. 1).

Historical evidence indicates that the introductions of coconut into Mexico via the coasts of the Gulf of Mexico, originated from West Africa (Zizumbo-Villarreal, 1996). The germination and morphological patterns support this hypothesis. For instance, populations, K1 and K2, showed a late and heterogeneous germination similar to that reported for the varieties, 'West African Tall' and 'East African Tall' (Harries, 1981a). They also showed a marked morphological similarity to the imported variety, 'West African Tall' (Zizumbo-Villarreal & Piñero, 1998).

According to historical records, the populations distributed on the Pacific coasts came from independent introductions from Panama, from the Solomon Islands, and from the Philippine Islands (Zizumbo-Villarreal, 1996). The germination and morphological variation patterns support this hypothesis, as the populations distributed on the west coasts of Mexico germinated early, similar to that reported for populations from the region of the south Pacific (Harries, 1981a).

The populations with early and uniform germination of the morphotype, 'Pacific Tall1', showed a high morphological similarity to the imported population, 'Rennell Tall', while the populations with a heterogeneous germination of the morphotype, 'Pacific Tall 2', showed a high morphological similarity to the imported population, 'Tahiti Tall' (Zizumbo-Villarreal 1996). The presence of individuals in the 'Pacific Tall 2' populations that require between 210 and 231 days to germinate suggest the possibility that seeds of this populations could have dispersed naturally towards the American coasts. Ward and Bookfield (1992) found that coconut could have reached America between 5° Latitude south and 10° Latitude north, if the seeds remained viable for a period of 245 days. Historical records of the morphological diversity present in America around 1514, specifically indicate the existence of fruit similar to the morphotype 'Pacific Tall 2' on the west coast of Panama (Zizumbo-Villarreal & Quero 1998). The populations with late and heterogeneous germination, T2 and T4, distributed on the east coast, seem to originate from introductions carried out on the west coasts, near Acapulco on the coast of Guerrero or from the banks of the river Tehuantepec on the coast of Oaxaca, as these populations registered a germinative behavior and morphological similarity to the populations G2 and G1. Historical evidence also indicates introductions from Guerrero into Tabasco in this century (Zizumbo-Villarreal, 1996).

The possible impact of LY in Mexico

A positive correlation between precocity and resistance to LY has been suggested (Whitehead, 1965; Harries, 1981a). Late germinating populations such as K1 and K2 would be expected to have a high susceptibility to LY. Preliminary experimental results show a high mortality due to LY in these populations (Zizumbo-Villarreal et al., 1998). On the other hand, we would expect high levels of LY resistance in the early populations such as 'Malayan Dwarf'. We have observed high resistance in these early dwarf populations, while early tall populations have shown medium resistance levels. These results also suggest a correlation between precocity and resistance. The geographical distribution of the populations with different germination patterns indicates that the impact of LY will be different on the two coasts. On the east coast, where the late populations similar to K1 and k2 are distributed, we would expect high mortality rates, while in the state of Tabasco, where early population such as T2 and T4 are distributed, we would expect a lower rate of mortality. In the producing areas on the west coast, where early populations are distributed, we would expect medium resistance level. Possibly the highest levels of resistance in the populations that showed a similar germination pattern to 'Malayan dwarf' such as M2, M3, C3, C4, and J1. These populations could be selected to initiate a genetic improvement program. Although the existence of a direct correlation between precocity and resistance has not been demonstrated experimentally, experimental evaluation of in these populations in the next few years could lead us to demonstrate this hypothesis.

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