Pertanika J. Trop. Agric. Sc. 42 (3): 1147 - 1156 (2019)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Agro-Morphological Characterization "*In situ*" of *Tamarindus indica* L. in the Dry Forest of Ecuador

Hugo Álvarez[1], Ricardo Limongi[1], Geover Peña[1], Bernardo Navarrete[1], Eddie Zambrano[1] and William Viera[2]*

[1]National Institute of Agricultural Research, Portoviejo Experimental Station, Km 12 of the Portoviejo-Santa Road, PO Box 130118, Portoviejo, Manabí, Ecuador
[2]National Institute of Agricultural Research, Tumbaco Experimental Farm, Av. Interoceánica Km 15 and Eloy Alfaro, PO Box 17-171363, Tumbaco, Pichincha, Ecuador

ABSTRACT

Tamarind (*Tamarindus indica* L.) is a species of high economic potential in local markets in Ecuador. This species is mainly used for its nutritional, industrial, medicinal and/or therapeutic attributes, in addition to its use as an ornamental tree. However, scarce information has been generated about this little explored species. In order to identify individuals with outstanding quality and production characteristics, an *in situ* morphological characterization of 32 individuals was carried out in the provinces of Manabí, Guayas and Loja. Qualitative and quantitative traits were evaluated using descriptive, parametric and multivariate analysis. The date of flowering and harvesting were determined as qualitative discriminant variables; while the discriminant quantitative traits were plant height, seed number per pod, pulp percentage, peel percentage and fruit-rib percentage. Cluster analysis established six groups; however, little variability was observed based on the morphological genetic distance, thus it could indicate that there is a low genetic abundance of *T. indica* in the dry forest of Ecuador.

Keywords: Accessions, breeding, descriptors, Fabaceae, tamarind

ARTICLE INFO

Article history:
Received: 26 February 2019
Accepted: 03 May 2019
Published: 19 August 2019

E-mail addresses:
agustin.alvarez@iniap.gob.ec (Hugo Álvarez)
ricardo.limongi@iniap.gob.ec (Ricardo Limongi)
geover.pena@iniap.gob.ec (Geover Peña)
jose.navarrete@iniap.gob.ec (Bernardo Navarrete)
eddie.zambrano@iniap.gob.ec (Eddie Zambrano)
william.viera@iniap.gob.ec (William Viera)
* Corresponding author

ISSN: 1511-3701
e-ISSN: 2231-8542

INTRODUCTION

There are more than 250 species of tropical fruits worldwide, nevertheless only a few of them are commercially exploded, due to the little research, lack of promotion and alternatives for their trade (Cruz & Deras, 2000). *Tamarindus indica* L. (Fabaceae/ Caesalpiniodeae), is a fruit tree native of tropical Africa, and now distributed in several tropical regions in semi desert conditions, with restrictions to low temperature (Tapia et al., 2012). Despite all of this, the origin of tamarind is still a controversy (Diallo et al., 2008). Considered as the "king of the fruits" by the Sakalava people of Madagascar (Ballarin & Raison, 2000), the main product of tamarind is the pulp of the fruit, which has an acid or sweet flavor and it is used in industrial and traditional meals in Asia, Africa and America (Zetina et al., 2012), feed for livestock and medicines (Caluwe et al., 2010; El-Siddig et al., 2006; Graf et al., 2016).

Tamarind has an important role in local economies (El-Siddig et al., 2006). The main producers of this fruit are India (300,000 tons) and Thailand (140,000 tons). On the other hand, in the American continent, the production is found mainly in México (37,820 tons) and Costa Rica (220 tons) (Zetina et al., 2012).

In Ecuador, this species is present in several provinces of the pacific coast in elevations from 0 to 1,500 meters above sea level, in zones with low rainfall, high luminosity and low nutritional soils; however, tamarind is cultivated in disperse ways such as backyards and other land uses as part of urban landscape instead of commercial level plantation exploitations.

The propagation of tamarind in Ecuador has been mainly by seed, without a selection process. On the other hand, farmers and forestry programs have contributed to the degradation of the species, by establishing new growths using trees with unknown origins and possibly with undesirable phenotypics characters. Nowadays countries such as Mexico have put interest in this fruit tree in subjects like genetic erosion, plant breeding and the selection of population *in situ* (Fandohan et al., 2010), this last methodology allowing the identification of plus or elite trees with outstanding characters in yield and quality with the objective of future incorporation in plant breeding programs (Zetina et al., 2012).

According to Sarmiento et al. (2017), Ecuadorian tamarind genotypes have showed a reasonable degree of genetic diversity that can be used as basis for hybridization. Consequently, the objective of this study was to identify outstanding tamarind individuals under *in situ* conditions by the morphological characterization of 32 accessions of this fruit tree recollected in three provinces of Ecuador and to establish a baseline for the genetic breeding of this species. In addition, morphological variability of this species (32%) has been reported in the dry forest of Colombia (Álvarez et al., 2018). For this reason, this study evaluated different accessions of Tamarind located in the Ecuadorian dry forest, in order to perform a morphological characterization and identify elite plant traits.

MATERIALS AND METHODS

This research was carried out between January and December of 2015 in the coastal provinces of Manabí, Guayas and Loja; 32 farms were visited, corresponding to 22 sites and nine cantons (Table 1).

Each farm was georeferenced and once the tamarind population was identified, the best individual of that population was selected on the basis of information provided by the owner of the farm, in relation to the alternation of the harvest, productivity, phytosanitary status, vigor in the productive stage and presence of fruits of high quality. A total of 32 individuals (accessions) were selected based on the above criteria.

Table 1
Geographic location of each in situ selected tamarind tree

Accession code	Location			Coordinates		Altitude (masl)
	Site	County	Province	Longitude	Latitude	
TI-ECUM-001	Joa	Jipijapa	Manabí	26°36´2,0"	01°05´49,1"	79.3
TI-ECUM-002				26°36´2,0"	01°05´48,7"	
TI-ECUM-003				26°36´1,6"	01°05´48,3"	
TI-ECUM-004	Cantagallo		Manabí	80°48´27,3"	01°17´01,2"	105.8
TI-ECUM-005				80°43´27,8"	01°17´00,7"	
TI-ECUM-006	El Cady	Portoviejo	Manabí	80°24´19,6"	01°07´04,5"	62.8
TI-ECUM-007	Maconta		Manabí	80°21´16,6"	01°02´17,8"	83.2
TI-ECUM-008				80°21´16,8"	01°02´19,4"	
TI-ECUM-009	Tabacales	Rocafuerte	Manabí	80°26´43,2"	00°56´32,2"	36.6
TI-ECUM-010	Valdez		Manabí	80°26´31,8"	00°56´52,6"	45.4
TI-ECUM-011	El Cardón		Manabí	80°23´62,5"	00°54´55,7"	44.2
TI-ECUM-012	La Balsita		Manabí	80°23´38,5"	01°00´25,8"	44.8
TI-ECUM-013	La Horma		Manabí	80°23´44,9"	00°54´41,2"	78.3
TI-ECUM-014	Las Flores		Manabí	80°21´22,4"	00°55´37,5"	104.9
TI-ECUM-015	Zapatón		Manabí	80°28´22,9"	00°53´14,7"	21.0
TI-ECUM-016				80°28´22,5"	00°53´14,3"	24.9
TI-ECUM-017	Cristo Rey	Sucre	Manabí	80°29´39,1"	00°49´05,4"	35.9
TI-ECUM-018	El Blanco		Manabí	80°29´45,9"	00°49´02,1"	26.5
TI-ECUM-019	Costa Rica	Portoviejo	Manabí	80°27´43,0"	00°59´54,8"	28.4
TI-ECUM-020	El Retiro		Manabí	80°28´37,5"	00°59´31,6"	39.6
TI-ECUM-021	Lodana	Santa Ana	Manabí	80°23´16,8"	01°10´13,6"	73.2
TI-ECUM-022			Manabí	80°38´3,99"	01°19´96,6"	65.5
TI-ECUM-023				80°38´3,54"	01°19´96,2"	
TI-ECUM-024	Mate		Manabí	80°33´23,0"	01°22´87,5"	96.0
TI-ECUM-025	Los Tillales	24 de Mayo	Manabí	80°25´3,39"	01°15´0,86"	113.7
TI-ECUM-026	El Guarango	Rocafuerte	Manabí	80°24´14,3"	00°53´4,39"	43.3
TI-ECUG-027	Valle de la Virgen	Pedro Carbo	Guayas	80°11´46,2"	01°44´33,9"	77.4
TI-ECUM-028	Guale	Paján	Manabí	80°12´29,3"	01°40´50,4"	110.3
TI-ECUL-029	Garza Real	Zapotillo	Loja	80°13´58,3"	04°18´24,3"	236.0
TI-ECUL-030	Garza Real	Zapotillo	Loja	80°13´58,0"	04°18´24,0"	236.0
TI-ECUL-031	Garza Real	Zapotillo	Loja	80°13´57,7"	04°17´58,5	233.0
TI-ECUL-032	Garza Real	Zapotillo	Loja	80°13´17,1"	04°17´59,6"	232.0

The descriptors used were established based on scientific literature (Fandohan et al., 2011; International Plant Genetic Resources Institute [IPGRI], 1980; Zetina et al., 2012). Tamarind individuals were evaluated on six qualitative traits (vigor, harvest alternation, cup shape, pod type, flowering date and harvest date), and 14 quantitative variables (plant age, plant height, trunk diameter, seed/pod number, number of fruit/bunch, pod length, pod diameter, pulp/seed ratio, pulp percentage, shell percentage, seed percentage, nervure percentage, pulp + seed yield and fresh fruit yield). For the variables percentage of pulp, percentage of shell, percentage of seed and percentage of nervure, a random sample of 25 mature fruits was taken; the parts of the fruit were separated, weighed and the percentage of all components estimated.

Qualitative traits were analyzed using Chi square test to determine statistical differences, Cramer and Pearson coefficients were estimated. Quantitative variables were analyzed using descriptive statistics (frequency, mean range and coefficient of variation). In order to determine the structure of the clusters, we used multivariate statistics such as cluster analysis (Ward algorithm) using the minimum variance method. The quantitative variables inside the groups were evaluated by analysis of variance and comparison of means by the Duncan test. Analyzes were performed using the statistical package INFOSTAT version 1.1.

RESULTS AND DISCUSION

Of the selected individuals, 84% came from the province of Manabí, 13% from the province of Loja and 3% from the province of Guayas. Generally, farms own few tamarind trees and the majority were dispersed, predominating mainly in systems of home orchards or forming small units of production.

Qualitative Traits

In the 6 qualitative traits, Chi square test indicated statistical significance (P> 0.01) for the discriminant variables: flowering date and harvest date (Table 2), which would indicate that there are variability in these characters and possibly respond

Table 2
Chi square values, Cramer and Pearson contingency coefficients obtained in the qualitative traits of 32 individuals of tamarind selected in situ

Descriptor	Chi square	Cramer coeficient	Pearson coeficient	P value
Vigor	1.75	0.23	0.23	0.4169
Alternation	4.00	0.35	0.33	0.1353
Top shape	10.94	0.58	0.50	0.0042
Type of sheath	6.13	0.44	0.40	0.0133
Flowering date[D]	44.50	1.18	0.76	<0.0001**
Harvest date[D]	31.00	0.98	0.70	<0.0001**

[D] Discriminant traits
** Significative at 1%

to the prevailing conditions of each zone, where out-of-season rainfall or irrigation immediately after harvest would mark the phenological rhythms. The higher values of Cramer coefficient (1.18 and 0.98) and Pearson coefficient (0.76 and 0.70) for these two variables confirm their discriminant character.

Quantitative Traits

Of the selected trees, 56% were between 10 and 22 years of age, followed by 25% between the ages of 23 and 35, and the most adult individuals (> 36 years) accounted for 19% (Figure 1). This indicates that most of the individuals under study would not be in their full productive age, due to the life cycle of tamarind can range from 20 to 80 years (Troup, 1921). Generally, farmers do not usually prune the tamarind trees. Tree height was concentrated in its highest percentage (43%) between 9 and 12 m; while 28% of individuals reached a height between 5 and 8 m (Figure 1). Zetina et al. (2012) established that a suitable height to carry out an optimal management of this fruit tree would be of 2.5 to 3 m with pruning and giving the shape to the tree top to have lateral branches where the production would be generated. The individuals analyzed exceed this height notably because there was no pruning or other activity to reduce the top. Some observed individuals (6%) even reached heights of 17 to 20 m. In addition, this height condition makes harvesting and phytosanitary management of trees difficult. In several tropical fruit trees, pruning has been shown to reduce the tree height and diameter by 10 to 14% (Vásquez et al., 2009). In terms of tamarind, pruning is not a common practice and knowledge about its productive and physiological function (unknown by the farmers) would be useful to be more efficient in the use of the resources (water and nutrients) by the plant, especially in dry forest conditions. Most of the selected trees (85%) had diameters smaller than 41 cm; the remaining 15% of the individuals had diameters between 42 and 71 cm (Figure 1), a characteristic associated with the age of the plant because the trunk increases its thickness and vigorosity as the years advance (Zetina et al., 2012).

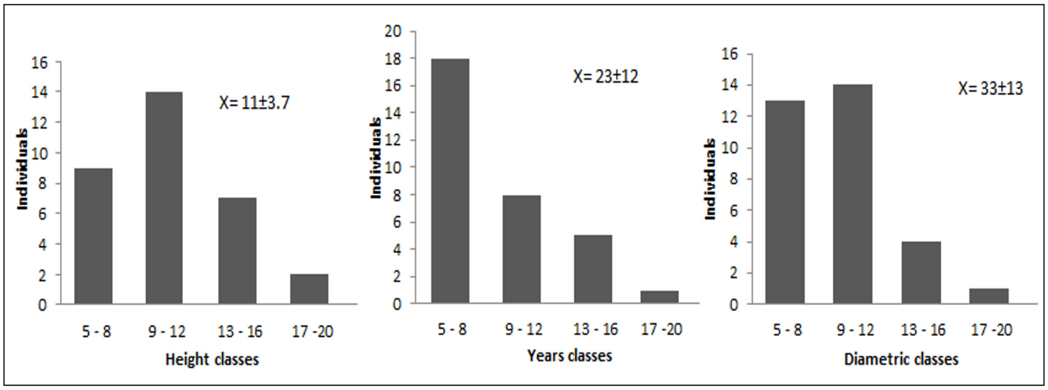

Figure 1. Frequency analysis for the variables plant age, plant height and stem diameter of the 32 individuals of tamarind selected *in situ*

Descriptive statistics of the quantitative traits are presented in Table 3. Of the fruit components, pulp represented 48.5%, which indicates that the accessions evaluated have a good productivity potential. In general, the 32 individuals had a percentage of pulp which ranged from 40 to 59%. Two trees (TI-ECUM-003 and TI-ECUM-004) from Jipijapa (Joa and Cantagallo sites) did not present pulp midrib; however, in other individuals when this trait was present, values were between 1 and 2 %. The evaluated individuals showed heterogeneity in the pod length, being observed a range of 7 to 13 cm, where 17 individuals (53%) obtained values greater than 10 cm, which is considered a suitable sheath size that would directly affect a greater pulp yield. In terms of number of pods per bunch, it was observed a range of 3 to 9 pods per bunch. The pod diameter was very homogeneous (about 2 cm).

Fruit yield per tree varies markedly depending on tree age, genetic potential and edaphoclimatic conditions in the environment in which it develops (Feungchang et al., 1996). In Asia, young tamarind trees produce from 20 to 30 kg; while trees in full production (> 20 years) produce up to 200 kg (Chapman, 1984). The average yield per tree in India reported by Gunasena and Pushpakumara (2007) was 80 to 90 kg; with yield potential up to 263 kg when improved materials were used (Rao, 1995). In Mexico, yield varies from 150 to 222 kg; however trees with yields of up to 800 kg have been found (Orozco, 2001). Jambulingam and Fernández (1986) established that yield began to decline after the plant reached 50-year-old age.

Table 3
Descriptive statistical parameters of the quantitative traits of 32 individuals of tamarind selected in situ

Descriptor	Average	Varation coefficient (%)	Range	Minimum value	Maximum value
Tree age (year)	23.16	55.68	50	10	60
Plant height (m)	10.92	33.90	15	5	20
Trunk diameter (cm)	32.38	40.09	58	12	70
Number of seed/pod	3.97	24.36	4	2	6
Number of pod/bunch	5.81	22.47	6	3	9
Pod lenght (cm)	9.44	15.91	6	7	13
Pod diameter (cm)	2.28	20.02	1	2	3
Relation pulp/seed (%)	74.09	5.08	14	66	80
Pulp percentage	48.47	7.67	19	40	59
Fruit skin percentage	24.19	15.16	14	18	32
Seed percentage	25.72	10.60	12	20	32
Midrib percentage	1.63	69.46	5	0	5
Fruit yield (kg/tree)	66.56	47.39	118.90	22.92	141.82
Yield of pulp + seed (kg/tree)	53.18	47.05	95.45	18.19	113.64

According to the average data obtained in this study, the yield of the individuals analyzed was 66 kg; value that is much lower than those reported in the cited studies. These low yield could be influenced by the absence of agronomic management (fertilization, pruning, phytosanitary control, supplementary irrigation, use of floral inducers, among others) observed in the farmer field. It should be noted that 5 trees from the provinces of Manabí and one from Loja (TI-ECUM-002, TI-ECUM-007, TI-ECUM-009, TI-ECUM-026, TI-ECUL-32) reached yields superior to the 100 kg/tree, which could be considered promising.

Diallo et al. (2007) mentioned that greater genetic variation in a tamarind population would cause larger margin of action related to natural or artificial selection. On the other hand, Zetina et al. (2012) indicated that among the selection criteria of outstanding individuals for a program of domestication and genetic improvement were: healthy trees with a low level of alternation, showing large fruits, thick fruit skin, high pulp proportion, small seeds, trees in productive state (> 10 years of age in grafted trees and 13 years in seed trees) and a homogeneity of production in at least five years.

Grouping Structure

Hierarchical cluster analysis shows the relationship in degree of dissimilarity among the 32 selected individuals (Figure 2). Six groups were determined based on the characters evaluated, this result is similar to that found by Álvarez et al. (2018) in Colombia, who reported five groups; thus the morphological variability was similar. There was no clustering related to the geographical distribution of the accessions, thus groups were formed based on the characters evaluated as described below. Based on the

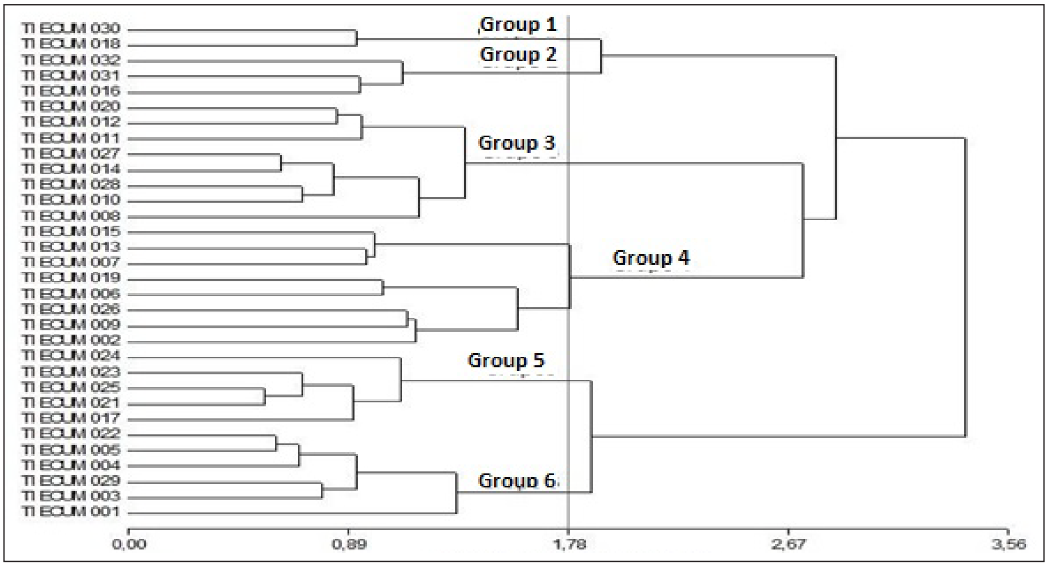

Figure 2. Dendrogram of the classification of 32 selected tamarind trees based on quantitative variables

genetic distance, it can be observed two major groups had little variation expressed at the agro-morphological level (phenotype). In addition, it is evident that groups 5 and 6 vary from the rest (groups 1 to 4).

The discriminant value of a quantitative character is the number of significant differences detected by the Duncan test, expressed as a fraction of the total number of possible comparisons within a group of accessions. This comparison allowed selecting five quantitative characters with greater discriminatory power. These variables were: plant height, this variable in group 2 was different from the rest except for group 1; number of seed per pod where group 1 had a significantly lower value than group 5; pulp percentage where groups 2 and 6 obtained the highest values; fruit skin percentage that showed group 3 different from the rest because of its superiority; and midrib percentage where group 1 was different from the rest because it showed the highest value (Table 4).

CONCLUSION

The abundance of *Tamarindus indica* in the Ecuadorian dry forest is scarce, mainly in individuals with outstanding phenotypic characteristics. The qualitative and quantitative traits suggest a relatively low genetic variability, related to the phenotypic heterogeneity of the selected trees. The most discriminant quantitative and qualitative variables that influenced the variability of the groups were plant height, number of seed/pod, pulp percentage, fruit skin percentage, midrib percentage, date of flowering and date of harvest. In order to identify individuals with outstanding

Table 4
Average values for quantitative characters based on the six groups formed

Descriptor	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Tree age (year)	11.00b	11.33b	28.25a	16.63ab	31.00a	28.50a
Plant height (m)[D]	8.00bc	6.50c	11.13b	10.75b	16.00a	9.83ab
Trunk diameter (cm)	30.50a	13.67b	35.38a	29.50a	40.80a	35.17a
Number of seed/pod[D]	3.00a	4.33bc	3.38ab	4.00abc	5.00c	4.00abc
Number of pod/bunch	4.50b	4.33b	6.25a	6.00ab	6.60a	5.50ab
Pod lenght (cm)	7.50b	10.00a	9.38ab	10.25a	9.80a	8,50ab
Pod diameter (cm)	2.00b	2.67a	2.50ab	2.38ab	2.00b	2.00b
Relation pulp/seed (%)	70.50b	78.33a	70.00b	75.13a	75.20a	76.33a
Pulp percentage[D]	42.50c	51.33a	45.88bc	49.38ab	49.20ab	50.67a
Fruit skin percentage[D]	24.00b	19.33a	28.38c	23.38b	23.60b	22.67ab
Seed percentage	28.50b	27.00ab	24.13a	26.00ab	26.00ab	25.67ab
Midrib percentage[D]	5.00c	2.67b	1.50a	1.25a	1.20a	1.00a
Fruit yield (kg/tree)	62.37b	93.90a	96.90a	59.06b	37.68b	47.91b
Yield of pulp + seed (kg/tree)	49.19b	76.16a	76.03a	47.85b	30.54b	38.53b

[D] Discriminant traits (show ranges abc) characteristics, an individual selection should be made in the areas where the accessions of groups 2 and 3 were located, considering characteristics such as lower tree height, initial age (about 11 years) of the productive stage and higher yields. This study could serve as a reference for breeding programs of this fruit tree; however, more basic scientific knowledge is needed to make this species attractive for farming and trading; as well as to introduce foreign germplasm to improve the genetic variability.

ACKNOWLEDGEMENT

We are grateful to the farmers in Manabí, Guayas and Loja provinces for let us to identify, characterize and evaluate their tamarind plants, and to National Institute of Agricultural Research (INIAP) for facilities granted to carry out this research.

REFERENCES

Álvarez, V., Muriel, S., & Costes, J. (2018). Morphoagronomic characterization of *Tamarindus indica* L. in orchards of tropical dry forest from Antioquia (Colombia). *Biodiversity International Journal*, *2*(5), 396-403.

Ballarin, M., & Raison, F. (2000). *Les reliques royales à Madagascar: source de légitimation et enjeu de pouvoir, XVIIIe-XXe siècles* [The royal relics in Madagascar: A source of legitimization and the issue of power, 18th-20th centuries]. Paris, France: Editions KARTHALA.

Caluwe, E., Halomova, K., & Van Damme, P. (2010). *Tamarindus indica* L. – A review of traditional uses, photochemistry and pharmacology. *Africa Focus*, *23*(1), 53-83.

Chapman, K. (1984). *Tamarind*. Brisbane, Australia: Department of Primary Industries.

Cruz, E., & Deras, H. (2000). Colecta de frutales tropicales en El Salvador [Collection of tropical fruit trees in El Salvador]. *Agronomía Mesoamericana*, *11*(2), 97-100.

Diallo, B., Joly, H., Mckey, D., Hossaert, M., & Chevallier, M. (2007). Genetic diversity of *Tamarindus indica* populations: Any clues on the origin from its current distribution?. *African Journal of Biotechnology*, *6*(7), 853-860.

Diallo, B., Mckey, D., Chevallier, M., Joly, H., & Hossaert, M. (2008). Breeding system and pollination biology of the semidomesticated fruit tree, *Tamarindus indica* L. (Leguminosae: Caesalpinioideae): Implications for fruit production, selective breeding, and conservation of genetic resources. *African Journal of Biotechnology*, *7*(22), 4068-4075.

El-Siddig, K., Gunasena, H., Prasad, B., Pushpakumara, D., Ramana, K., Vijayanand, P., & Williams, J. (2006). *Tamarind Tamarindus indica* L. Southampton, United Kingdom: Southampton Centre for Underutilised Crops.

Fandohan, B., Assogbadjo, A., Glele, R., Kyndt, T., & Sinsin, B. (2011). Quantitative morphological descriptors confirm traditionally classified morphotypes of *Tamarindus indica* L. *Genetic Resources and Crop Evolution*, *58*(2), 299–309. doi: 10.1007/s10722-010-9575-3

Fandohan, B., Assogbadjo, A., Glele, R., Sinsin, B., & Van Dame, P. (2010). Impact of habitat type on the conservation status of tamarind (*Tamarindus indica* L.) populations in the W National Park of Benin. *Fruits*, *65*(1), 11–19. doi: 10.1051/fruits/2009037

Feungchang, S., Yimsawat, T., Chindaprasert, S., & Kitpowsong, P. (1996). Tamarind (*Tamarindus indica* L.) plant genetic resources in Thailand. *Thai Journal of Agricultural Science*, *1*(1), 1-11.

Graf, B., Rojas, P., & Baldeón, M. (2016). Discovering the pharmacological potential of Ecuadorian market plants using a screens-to-nature participatory approach. *Journal of Biodiversity, Bioprospecting and Development*, *3*(1), 1-9. doi: 10.4172/2376-0214.1000156

Gunasena, H., & Pushpakumara, D. (2007). *Tamarind* – Tamarindus indica. Nueva Delhi, India: World Agroforestry Centre.

International Plant Genetic Resources Institute. (1980). *Tropical fruit descriptor*. Bangkok, Thailand: Author.

Jambulingam, R., & Fernández, C. (1986). Multipurpose trees and shrubs on farmlands in Tamil Nadu State (India). *Agrofosrestry Systems*, *4*(1), 17-32. doi: 10.1007/BF01834699

Orozco, S. (2001). *El cultivo del tamarindo* (Tamarindus indica *L.*) *en el trópico seco de México* [The cultivation of tamarind (*Tamarindus indica* L.) in the dry forest of Mexico]. Tecomán, México: SAGARPA.

Rao, S. (1995). Tamarind economics. *Spice in India*, *8*(4), 1-11.

Sarmiento, L., Pérez, I., Díaz, B., Álvarez, H., & Viera W. (2017). Molecular marker-based characterization of Ecuadorian dry forest tamarind plus trees. *Bioagro*, *29*(3), 153-162.

Tapia, F., Mercador, P., & Gómez, S. (2012). Contribución a la citogenética de *Tamarindus indica* (Leguminosae: Caesalpinioideae) [Contribution to the cytogenetics of *Tamarindus indica* (Leguminosae: Caesalpinioideae)]. *Acta Botánica Mexicana*, *98*(1), 99-110.

Troup, R. (1921). *The silviculture of Indian trees*. Gloucester, United Kingdom: Clarendon Press.

Vásquez, V., Pérez, M., Osuna, J., & Urías, M. (2009). Intensidad de poda sobre el vigor, producción y peso del fruto, del mango 'Ataulfo' [Intensity of pruning on the vigor, production and weight of the fruit, of the mango 'Ataulfo']. *Revista Chapingo*, *15*(2), 127-132.

Zetina, R., Del Angel, A., Becerra, E., & Rebolledo, A. (2012). *Tecnología para la producción sustentable de tamarindo (Tamarindus indica L.) en el estado de Veracruz* [Technology for the sustainable production of tamarind (*Tamarindus indica* L.) in the State of Veracruz]. Veracruz, México: Alfa y Omega.