RESEARCH ARTICLE

Phenotypic Diversity of Haitian Benzolive (*Moringa oleifera* Lam.)

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ABSTRACT

Moringa (MO) is a plant with great nutritional value distributed in almost all subtropical and tropical countries including Haiti. MO is relatively present in all departments of Haiti. But till now, there are no data available for the phenotypical diversities of Haitian MO. The current survey is aimed at evaluating the morphological diversity of Haitian MO. From June to September of 2018 year, 90 samples of MO were collected in the 10 departments of Haiti. Characters registered per plant were submitted to statistical analysis using IBM SPSS, version 22.0. Results revealed that Haitian MO grain yield (GY) were ranging from 0.20 to 3.26 t/ha. MO from Grand'Anse and South are significantly more yielded than the other districts (p< 0.05). MO grain yield was positively related with all registered characters. The two maximal GY correlations were observed mainly with number of branches plant (ρ=0.74; p<0.001) and number of pods per branch (ρ=0.60; p<0.001). Haitian MO was classified into two separate clusters. MO of South, Southeast and Grand'Anse departments formed one cluster and the other departments constituted the largest one. The greatest genetic diversity was detected in MO from Southeast and West departments. Crossing materials from Southeast and West department is well recommended for creating possibly new accessions. Additional investigation regarding molecular classification is deeply required for better understanding the genetic diversity of Haitian MO.

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Keywords: Moringa, Morphological diversity, Phenotypic diversity, Haiti

INTRODUCTION

Moringa (MO), a plant with great medicinal and nutritional values, is from Himalaya (Leone et al., 2015). MO is actually distributed in almost all tropical and subtropical areas (Olson and Carlquist, 2001; Ogunsina et al., 2014). A total of 13 species of MO constitute the family Moringaceae (Leone et al., 2015). Among all, *Moringa oleifera* is the most documented (Yang et al., 2006).In Francophone countries, MO is calledMouroungue, Ben ailé, Moringa ailé, PoisQuénique, Néverdié and, particularly in Haiti, Benzolive (Gigon et al., 2004). MO is cultivated easily in arid as well as in semiarid region (Price, 1985). The tolerance of MO to water stress is mainly resulted from the morphological adaptation and the biochemical response of its vegetative parts (Teixeira et al., 2014). MO is mainly growing for its edible parts such as leaves, seeds and derived products like leaves powder and oil (Aristil, 2018). Environmental factors could affect leaves and seeds composition of MO (Anwar, 2007). MO is propagated by using its vegetative parts and by seeds (Leone et al., 2015). Leaves of MO are rich in vitamins, antioxidants and contain several cure-diseases properties. The nutritional and curative values of MO are worldwide documented (Dahiru et al., 2006; Chumark et al., 2008). Fruits, flowers and immature pods of MO are utilized as legumes (Anwar et al., 2006; Ouazine, 2017). MO wood is also an important source of paper (Thurber and Fahey, 2009). MO seed contain up to 40% of oil and after the oil extraction, the residues are used for water purification and facilitate the organic and inorganic materials sedimentation (Boucher, 2006;Foidl et al., 2001; Leone et al., 2016). MO is also growing in the Caribbean Region. Large genetic diversity was detected in MO materials from Panama, Belize, Mexico, Brazil and Venezuela (Shahzad et al., 2013). According to the literature available, Cuba is the first country with the most studies conducted on MO in the Caribbean Sea (Marrero Delange et al., 2014;Morton, 1991). In Haiti, MO is also present and grows mainly in agroforestery system. Meanwhile, data relative to the genetic as well as phenotypical diversities of MO accessions in Haiti are inexistent. Therefore the current survey is aimed at evaluating the phenotypical diversity of MO grows in Haiti for starting a breeding program with aims to increase leaves and seeds production.

MATERIALS AND METHODS

Sampling

From June to September 2018, a total of 90 trees of MO were investigated across the 10 departments of Haiti at rate of 9 per department. Moringa trees investigated had ± 10 years old. All these plants were grown in agroforestry system with 4 m x 4 m as distance of plantation corresponding to a plant density of 625 plants per hectare (Leone et al., 2015;Mendieta-Araica et al., 2013). Two categories of data were registered per plant: vegetative and productive characters. Some of these characters were collected in field and others in the laboratory of Université Notre Dame d'Haiti (UNDH). Productive and yield characters of each plant were registered in the laboratory of UNDH located at Torbeck, South, Haiti. Data registered in field included number of branches per plant (NBP), number of pods per branch (NPB). From each plant, a total of seven dried pods was selected and transported to the laboratory of UNDH for collecting data such as number of grains per pod (NGP), pod length (PL), pod circumference (PC), mass of 1 grain/seed (M1G) and mass of 100 grains/seeds (M100G). A Fisher balance was used for weighting M1G and M100G, which were weighted in gram. PL and CP were in cm and a scale meter was used for registering the last two traits. The grain yield (GY) of investigated MO tree was calculated by: GY (t/ha) = M1G (g) x NGP x NPB x NBP x 625 ÷ 1000,000 (Aristil, 2019).

Statistical Analysis

Registered traits were submitted to statistical analysis using SPSS version 22.0 (Corp, 2013). Moringa traits were submitted firstly to one-ways analysis of variances (ANOVA) using provenance of materials as random and traits as fixed. 'Ryan-Einot- Gabriel- Welsch' test has been completed for establishing difference among means of each trait at (p< 0.05). Pearson's rank correlation coefficients (ρ) were computed for all recorded traits and obtained results were used for computing a correlation matrix (Kwon and Torrie, 1964). Similarity among MO accessions was computed by Clustering Analysis (CA) using *Hierarchical Cluster Method based on Euclidean*distance(Crossa and Franco, 2004).

RESULTS AND DISCUSSION

MO is one of the most important plants cultivated in Developing country like Haiti. Phenotypic and genetic diversities could be detected among materials inside the Country/Haiti. Yet, there is, till now, no study conducted on phenotypical diversity of Haitian MO. Study conducted on Haitian MO are mainly related to fungal and aflatoxins contamination of seeds (Aristil et al., 2017; Aristil et al., 2019). The present survey was conducted to evaluate the morphological/phenotypical diversity of Haitian MO. A total of 8 morphological traits were registered on 90 MO trees across the 10 departments of Haiti and submitted to statistical analysis using SPSS. One-way ANOVA results revealed that significant difference was noted among accessions (p< 0.05). NBP varied from 32 to 163 (Table 1).

Six of the 10 departments showed NBP › 50. The two most important NBP were detected mainly in materials from Grand'Anse and South departments with respectively 162.89 and 104.67. Similar results suggest considerable phenotypical diversities among accessions. By addition, NPB varied from 3 to 18 per department. MO accessions from Grand'Anse were significantly different from the others (p‹ 0.05). No significant difference was noted between South and Southeast departments (p› 0.05). Similar findings are consistent with those of (Ali et al., 2010). PL of tested MO are ranging from 26 to 39 cm. Almost 50% of accessions revealed PL› 30 cm. Accessions from Grand'Anse, South and North showed no significant difference (p› 0.05). Findings of the currents survey regarding PL are differing from that of Osman and Abohassan, (2012). This difference could be due to the origin of MO accessions. Environmental variation could affect significantly traits of materials including MO trees (Gomaa and Picó, 2011; Raja et al., 2013; Galloway, 2001). Five classes of MO were detected by putting emphasis on PC. These classes were identified by the different letters a, b, c, d and e. CP of accessions varied from 7 to 9 cm. No significant differences were noted among South, Grand'Anse, Artibonite and Center accessions, which suggest possible homogeneity inside these materials regarding CP. Similarly, NGP are ranging from 13-18. Almost 40% of accessions showed NGP›17, which is congruent with (Ayerza, 2011). Maximal (17.96) and minimal (13.42) NGP were respectively noted in materials from South and Grand'Anse.M1G of Haitian MO is ranging from 0.27 and 0.90 g. M1G from South material represent three times of that of Artibonite and North. Present findings support data reported by (Foidl et al., 2001). M100G of materials also varied from 27.81 to 89.79 g. Sixty % of the MO accessions are › 30 g, which is consistent with (Osman and Abohassan, 2012). Little variability was detected among Haitian MO regarding GY. GY of accessions are ranging from 0.23 to 3.26 t/ha. More than 80% of MO accessions showed GY› 0.50 t/ha. Materials from Grand'Anse and South departments are largely more grain yielded than others (p‹ 0.05). GY of South accessions represent almost 8 times of that of Artibonite. The current study is the first one reported data regarding MO grain yield in Haiti. Conducting others studies for comparing current findings is evident.

Results obtained for MC are listed on Table 2. More than 64% (18 of 28) of couples resulted from the analyzed traits are related (p‹ 0.05). Positive dependence was noted among all traits, which suggest that an increasing of one of these traits correspond systematically to the increasing of the predictive characters. Fifty % of traits are correlated at p‹ 0.001. The maximal correlation of couples was detected between M1G and M100G (ρ = 0.99, p‹ 0.001). Suggesting

the presence of more than 98% (R^2= 0.9801) of confidence to obtain M100G by using M1G as predictor which is consistent with (Dabre et al., 2016; Allam et al., 2018). GY was correlated with all the seven other characters registered, confirming the total dependence of GY to other MO traits in Haiti (Rafiq et al., 2010). The strongest correlation of GY was mainly noted with NBP (ρ = 0.74; p‹ 0.001) and NPB (ρ = 0.60; p‹ 0.001). Similar finding is not very promising for MO cultivation in Haiti because habitually farmers select grain based on the seed weight. Necessity to assure the formation of farmers with regard to other traits for selection becomes very evident. On the other hand, 36 % of the traits were noted correlated, suggesting the impossibility to use one of these characters as predictor in a breeding model. Maybe all these traits are related with other agricultural practices which were not investigated in the current survey. Similar findings were reported in studies conducted on cereals (Dhawi et al., 2017).
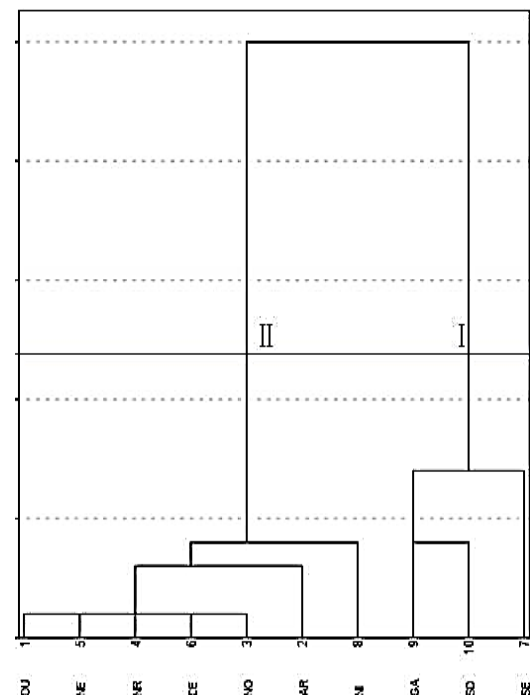

Figure 1:Dendrogram resulted from Clustering Analysis. OU: West, NE: Northeast, NR: North, CE: Center, NO: Northwest, AR: Artibonite, NI: Nippes, GA: Grand'Anse, SO: South, and SE: Southeast.

Figure 1 shows the results obtained for clustering analysis. Haitian MO was divided into two separated groups (GI and GII). GI is mainly constituted of 3 departments and GII with the others seven accessions. MO of GII is divided into three subgroups of one, one and 5 accessions. Materials constituting the first subgroup with the 5 accessions are from West, North, Northwest, Northeast and Center departments. Present results suggest that all

Northern Haitian accessions are from a common ancestor. Maybe one of these materials was transferred in the West and Center department by habitually exchange of materials detected among Haitian farmers. Accessions from Nippes and Artibonite departments are closer to the first GI compared with Northern ones. Materials from South, Grand'Anse and Southeast are forming GI. Similar result confirming the homogeneity detected between South and Grand'Anse departments suggesting by the ANOVA results. Maybe materials from Grand'Anse, South and Southeast departments are from, as the northern ones, a common parent, which is different from the others. Historically, after the Independence (1804), in 1806 year, Haiti was divided into two separate governments: North and South. The South including South department, Southeast and Grand'Anse was governed by Alexandre Pétion and the North one including North department, Northeast, Northwest and Center was governed by Henri Christophe. Agricultural activities and exchange of materials are commonly conducted among farmers inside the same department or Government, this could be resulted from this situation called in Haiti " La scission d'Haiti". The largest morphological variation was noted in accessions from West and Southeast departments, which confirm also the variability among Haitian MO. Variability of MO was documented prior by (Hassanein and Al-Soqeer, 2017). Predominance of variability among accessions could suggest presence of genes with great agronomic importance in Haitian MO (Shi et al., 2018). MO is used in Medicine, Nutrition, water purification and environment protection (Díaz et al., 2018; de Paula et al., 2018; Formentini-Schmitt et al., 2018).

CONCLUSION

MO is a plant with great medical and nutritional properties. It is cultivated in subtropical and tropical areas including Haiti. Data relative to Haitian MO are inexistent. In the current survey results revealed that Haitian MO grain yield are ranging from 0.20 to 3.26 t/ha. Materials from Southern and Northern are forming two separated clusters. Crossing materials from Southeast and West is well recommended in order to create possibly new accessions. Additional investigation regarding molecular classification is deeply required for better understanding the genetic diversity of Haitian MO.

ACKNOWLEGMENTS

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Table 1: Results of Variance Analysis

Characters								
Departments	NBP	NPB	PL	PC	NGP	M1G	M100G	GY
South	104.67 b	7.92bc	38.19d	8.65e	17.96d	0.90b	89.73b	2.37b
Southeast	73.44ab	9.77c	30.31bc	7.22abc	15.61abcd	0.41a	41.12a	0.99a
Grand'Anse	162.89 c	18.01d	36.47d	8.28cde	17.56d	0.37a	36.42a	3.26b
West	57.33ab	3.44a	32.31c	7.64abcd	16.31abcd	0.27a	27.86a	0.90a
Artibonite	32.67a	7.56bc	26.64a	7.04ab	14.78abc	0.28a	28.31a	0.23a
Center	54.01a	8.78bc	28.23ab	8.51de	16.64bcd	0.28a	27.81a	0.56a
North	52.11a	5.56ab	36.47d	8.14bcde	17.25cd	0.29a	29.14a	0.66a
Northeast	62.89ab	9.78c	29.44abc	7.03a	17.28cd	0.28a	28.28a	0.89a
Northwest	33.50a	8.01bc	26.25a	7.80abcde	13.42a	0.30a	30.21a	0.28a
Nippes	48.22a	6.01abc	29.28abc	7.74abcde	14.64ab	0.30a	29.70a	0.78a

NBP: number of branches par plant; NPB: number of pods per branch; PC: Pod circumference (cm); NGP: number of grains per pod; M1G: mass of 1 grain (g); M100G: mass of 100 grains (g); GY: grain yield (t/ha). Characters with different letter are significantly different at $p<0.05$.

Table 2: Correlation matrix resulted from the registered characters

	NBP	NPB	PL	PC	NGP	M1G	M100G	GY
NBP	1	0,79***	0,14**	0,12*	0,16**	-0,13[NS]	-0,01[NS]	0,74***
NPB		1	0,68[NS]	0,02[NS]	0,17**	0,02[NS]	-0,2[NS]	0,60***
PL			1	0,18**	0,50***	0,71[NS]	0,14**	0,23***
PC				1	0,21***	0,71[NS]	0,07[NS]	0,11*
NGP					1	-0,09[NS]	-0,10[NS]	0,16**
M1G						1	0,99***	0,55***
M100G							1	0,55***
GY								1

NBP: number of branches par plant; NPB: number of pods per branch; PC: Pod circumference (cm); NGP: number of grains per pod; M1G: mass of 1 grain (g); M100G: mass of 100 grains (g); GY: grain yield (t/ha). *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$ and, NS: not significant ($p>0.05$).