ISSN: 2395-4108

Abrahamia

An International Journal of Plant Sciences

Impatiens parasitica Bedd.

VOLUME 6 • NUMBER 1 • 2020

DEPARTMENT OF BOTANY, UNIVERSITY OF KERALA
Kariavattom, Thiruvananthapuram, Kerala, India - 695581

Abrahamia

EDITORIAL BOARD

Printed and Published by
Head
Department of Botany, University of Kerala, 2020

Printed at: University Press, Palayam Campus, University of Kerala
Cover Design & Layout : Godfrey's Graphics, 9447009651

Abrahamia
Vol. 6 (1)
16-25
2020
ISSN: 2395-4108

Proximate and nutritive value screening of *Moringa oleifera*, a multipurpose tree, and identification of elite germplasm

Drisya Ravi R. S.[1], Bindu R. Nair[2] & E. A. Siril[2*]
[1]Department of Biotechnology, University of Kerala, Kariavattom, Trivandrum-695581
[2]Department of Botany, University of Kerala, Kariavattom, Trivandrum-695581
Tele-fax: +91-471-230 8301
*Corresponding author: easiril@yahoo.com
Institutional email: easiril@keralauniversity.ac.in
ORCID: E.A. SIRIL: https://orcid.org/0000-0002-4956-8428

Abstract

Moringa oleifera Lam. (drumstick tree), belonging to the Moringaceae family, is a highly valued vegetable crop, distributed in the tropics and subtropics. Immature pods, fresh leaves and flowers of *M. oleifera* are used for culinary purposes. The leaves and young pods contain a significant amount of minerals and vitamins. Based on yield parameters, 23 candidate plus trees (CPTs) were collected from various parts of Kerala, Tamil Nadu and Karnataka states of India and nutritive values were compared to screen the best germplasm of *M. oleifera*. Biochemical factors such as carbohydrate, protein, fat and vitamins (A, B, and C) of leaves and fruits in various collections were determined using standard analytical methods. Nutritive values of 23 *M. oleifera* accessions were estimated based on carbohydrate, fat and protein content. Vitamin C content in leaf ranged from 185.30mg/100g (CPT7) to 227mg/100g and was higher in CPT17. In fruits, maximum vitamin C (130mg/100g) content was estimated in CPT17. Nutritive value-based screening recommends the accession CPT17 as elite accession. The variability among the drumstick collections can be utilized for evolving new types with quality attributes.

Keywords: Biochemical screening, CPTs, *Moringa oleifera*, Nutritive value, Vitamin C

Introduction

Moringa oleifera Lam. is a multipurpose tree vegetable belongs to the monogeneric family Moringaceae. *M. oleifera* grows best in the tropical regions of the world that have semi-arid or monsoonal climates (Ramachandran *et al.,* 1980). *M. oleifera* is indigenous to the sub-Himalayan tracts of Northern India (Qaiser, 1973; Olson, 2002).

Plant resource as a whole considered as nature's gift to humanity. Fruits and vegetables are important among them and are considered as rich sources of essential dietary constituents. Therefore, people widely recognize fruits and vegetable as "functional foods" in their diet. The benefit of fruits and vegetables cannot be attributed to isolated nutrients. Phytochemicals present in fruits and vegetables are diverse, such as ascorbic acid, carotenoids and phenolics compounds (Yahia *et al.,* 2001; Liu, 2004; Singletary *et al.,* 2005; Percival *et al.,* 2006). Naturally occurring phytochemicals possess anti-carcinogenic and other beneficial properties referred to as chemo preventers. Among the most investigated chemoprevention, some vitamins, plant polyphenols, and pigments are important.

Vegetables provide all the nutrient components like carbohydrate, protein, fat, vitamins, minerals and water along with roughages which are the essential constituents of a balanced diet. *M. oleifera* has been used for such a broad variety of purpose, so that it has been reported as a 'multipurpose tree. Fruits and leaves of drumstick are a rich source of proteins, vitamins and minerals (Saini *et al.*, 2016; Sagona *et al.*, 2020; Singh *et al.,* 2020). Different parts of this plant contain a profile of important minerals and a good source of protein, vitamins, β-carotene, amino acids and various phenolics (Palada and Ebert, 2012; Abd Rani *et al.*, 2018; Singh *et al.*, 2020; He *et al.*, 2020). Extracts derived from various parts of *M. oleifera* especially seeds, leaves and bark have wide and diverse medicinal properties including antihypertensive, diuretic, cholesterol-lowering activities, antispasmodic, antiulcer, hepatoprotective activities, antibacterial, antifungal, antitumor and anticancer activities (Stevens *et al.,* 2013; Magaji *et al.,* 2020; Ayirezang *et al.,* 2020; Singh *et al.,* 2020; Muhammad *et al.,* 2020; Sagona *et al.,* 2020).

An important step in the crop improvement is the characterization and assessment of available germplasm to screen phenotypes/genotypes for the direct use as selected superior germplasm or in the future breeding programs. Germplasm characterization is primarily performed through morphological traits. However, the use of morphological traits mostly depends on biochemical traits, thus morphological characterization alone has limited use in the cultivar selection. According to Ranjan *et al.* (2012), biochemical characterization is employed to quantify the genetic diversity in plants. Genetic diversity studies have been carried out for crop improvement programs to select elite germplasm with better qualities (Burow *et al.,* 2012; Divya, 2013; Rao *et al.,* 2013; Egbadzor *et al.,* 2014; Udensi and Edu, 2015). Enzymatic and non-enzymatic biochemical markers are widely used to understand genetic variability, gene flow, hybridization, recognition of species boundaries and phylogenetic relationships in natural populations (Murphy *et al.,* 1990). The importance of biochemical methods in the identification of germplasm was reported (Kottawa *et al.,* 2011; Vanzetti *et al.,* 2013; Chauhan *et al.,* 2014). Use of biochemical marker has proven to be of immense help to breeders, in improving the important agronomic traits in food crops. Therefore the present study, biochemical variability in terms of nutritional quality among the candidate plus trees (CPTs) of *M. oleifera* collected from south India was conducted that ultimately contributed to the selection of 'elite' or plus trees. The identified superior germplasm can be used for crop improvement programs.

Materials and Methods

Selection of plant material

An exploration survey was carried out in Karnataka, Kerala and Tamil Nadu states of India during May–June 2014 primarily to record healthy, morphologically and biochemically distinct drumstick trees. Based on fruit yield data and single fruit weight, mean fruit yield and mean fruit weight among surveyed 120 trees, 23 gave more than 50% fruit yield and single fruit weight than average of 120 trees. Each selected tree was designated with CPT number for future identification.

Experimental design

Sixteen biochemical traits (leaves and fruit pulp) with three replications for three consequent years (2014, 2015 and 2016) were estimated. Data were subjected to analysis of variance (ANOVA). Mean separation was performed using Duncan's Multiple Range Test ($P \leq 0.05$). Correlation analyses were performed to determine the intensity of association between traits. Nutritive value (AOAC, 2000) of leaves and fruits were considered to propose elite germplasm.

Proximal composition analysis of the fruits and leaves

Moisture content (%) of leaves and fruit was determined by Indian Standard method (Anonymous, 1990). Total protein was estimated according to Bradford (1976). According to Bligh and Dyer (1959) fat content was determined. Carbohydrate and vitamin C contents were estimated with standard procedures (Sadasivam and Manickam, 1992). Vitamin A, B1, and B2 contents of leaves and fruit were determined as described elsewhere (Atri *et al.,* 2012).

Nutritive value of leaf and fruits (AOAC, 2000)

The nutritional value was calculated from total carbohydrate, fat and protein contents using the formula,

Nutritive value = (4* % carbohydrate) + (9* % fat) + (4*protein)

Results and Discussion

Biochemical traits such as % moisture, carbohydrate, protein, fat and vitamin (A, B1, B2, and C) content of leaves and mature fruits of various collections showed significant variations (Table 1 and 2).

Moisture content

The moisture content of leaves ranged 70.53 to 79.26%, while in fruits it varied between 79.26 to 89.18%. ANOVA revealed a non-significant variation of % moisture among leaf samples of CPTs compared. The percentage of total moisture content was low in leaves (79%) than in fruits (89%). Ramachandran *et al.* (1980) reported similar results in *M. oleifera* leaves (75%) and fruits (86.9%). Leaf moisture content was highest in CPT7 (79.26%) and lowest in CPT12 (70.53%) while the fruit moisture content was maximum in CPT5 (89.18%) and minimum in CPT15 (78.53%). The high moisture content essentially facilitates increased activity of water-soluble enzymes and co-enzymes that are needed for metabolic activities of leafy vegetables (Iheanacho and Udebuani, 2009). Leafy vegetables keep us hydrated and contribute to the growth and maintenance of tissues. Oduro *et al.* (2008) observed 76.53% moisture content in *M. oleifera* leaves.

Carbohydrate (CHs) content

Carbohydrate content in leaves ranged between 9.63g/100g (CPT1) and 14.02g/100g (CPT 8). The nutritional analysis of *M. oleifera* fruits revealed that carbohydrate content in fruits ranged between 2.20g/100g (CPT2) to 4.47g/100g (CPT 12). Witt *et al.*, (2013) reported 7.6-12.50g/100g carbohydrate in *M. oleifera* leaves. The non-structural carbohydrate (e.g., starch, sugar) contents, ranged from 24.98% in immature pods to 36.04% in flowers of *M. oleifera* (Dalia *et al.,* 2010). In *M. oleifera*, the lowest structural carbohydrate and lignin concentrations were found during the dry season at mid-elevation (Melesse *et al.,* 2012). The concentration of structural carbohydrates in *M. oleifera* was generally higher than those in *M. stenopetala* and suggested a relatively high availability of soluble carbohydrates in the *M. oleifera* parts. Proximate studies from Brazil, revealed 4.44% CHs in dehydrated leaf powder (Teixeira *et al.,* 2014). On dry matter basis, Falowo *et al.* (2018) reported a high amount of carbohydrate content in seeds (3.36–18.0g/100g) and leaves (13.41–63.11g/100g).

Protein content

The protein content was higher in leaves (7.50g/100g) than in the fruits (1.45g/100g). Protein content in leaves varied significantly among the samples tested. The amount of leaf protein was high in CPT16 (7.50g/100g) followed by CPT4 (7.36g/100mg) and least in CPT12. The fruit protein content was high in CPT8 (2.73g/100g). Joshi and Mehta (2010) recorded 6.70g and 23.66g/100g protein in fresh and dried leaves. *M. oleifera* tree is rich in several nutrients such as proteins, fibre and minerals (Jongrungruangchok *et al.,* 2010; Moyo *et al.,* 2011) that play an important role in human nutrition. The leaves of *M. oleifera* contain appreciable amounts of minerals *viz.,*calcium, potassium, magnesium, iron, manganese and copper (Hekmat *et al.,* 2015; Olusanya *et al.,* 2019; Singh *et al.,* 2020). With regards to its nutritional composition, *M. oleifera* leaves have been reported to have a higher proportion of vitamin C and A, calcium, potassium, iron and proteins than those found in other food products such as orange, carrots, milk, bananas, yoghurt and spinach, respectively (Rockwood *et al.,* 2013; Gopalakrishnan *et al.,* 2016). On dry matter basis, the crude protein content of *M. oleifera* leaf has been reported to be low as 10.74g/100g and high as 30.29g/100 g and revealed that *M. oleifera* leaf meal can be used as a protein source in poultry diets without causing any adverse effects on growth performance (Falowo *et al.,* 2018; Alwaleed *et al.,* 2020).

Fat content

Fat content in leaves ranged between 1.45g/100g and 2.30g/100g. The amount of leaf fat content was high in CPT17. The nutritional analysis of *M. oleifera* fruits revealed that fat content in fruits ranged between 0.11g/100g (CPT18) and 0.20g/100g (CPT5). Leaves contained higher fat than green pods. Grubben and Denton (2004) reported that the leafy parts of *M. oleifera* contained 1.40g/100g fat and is lower than those obtained from the current study. *M. oleifera* leaves, flower and tender pods are potential sources of polyunsaturated fatty acids, which may have some beneficial effects in *M. oleifera* based products (Saini *et al.,* 2014; Simopoulos *et al.,* 2016). According to Rubiu *et al.,* (2016), percentage of crude fat was found to be significantly higher (20.1%) in seed extract than other parts of the plant. On a dry matter basis, Falowo *et al.,* (2018) reported *M. oleifera* leaf and seed contain 6.50–20g/100g and 38.67–43.60g/100g fat, respectively.

Vitamin content

Moringa oleifera leaves, or leaf powder can be used as a complex food to nourish small children, pregnant women and nursing mothers as it serves as a rich source of vitamins A, B, C, calcium, iron and protein (Oz, 2014; Singh *et al.,* 2020).

The amount of leaf vitamin A was high in CPT15 (7.10mg/100g) followed by CPT2 (7.0mg/100g). In fruits, the maximum vitamin A was recorded in CPT8 (0.26mg/100g) followed by CPT5. In the present study, high content of vitamin A (7.0mg/100g) was estimated in the leaves of drumstick and is four times greater than vitamin A content of carrot (Okwu and Josiah, 2006). Rai *et al.*

(2004) studied the carotene content in drumstick, agathi and spinach, and reported that drumstick contained 6780µg/g of carotene. Subadra and Nambiar (2003) analyzed the nutritive value of kanjero (*Digera arvensis*) and drumstick leaves and suggested their potential use as a good source of dietary vitamin A. Rahim *et al.* (2007) reported that *M. oleifera* contains high amount of beta-carotene, protein, vitamin C and iron. *M. oleifera* leaves are reported to contain substantial amounts of vitamin A, C and E (Hekmat *et al.,* 2015).

Vitamin B1 and B2 were very low in the accessions studied. Vitamin B1 content in leaf ranged from 0.03mg/100g (CPT12) to 0.072mg/100g and was higher in CPT15. In fruits, maximum vitamin B1 (0.056mg/100g) content was observed in CPT17. The amount of vitamin B2 was high in leaf sample CPT2 (0.06mg/100 g) and pods of CPT5.

In the past, apart from vitamins A, other vitamins such as vitamin B (folic acid, pyridoxine and nicotinic acid), vitamin C, D and E were reported in *M. oleifera* (Mbikay, 2012). Witt *et al.,* (2013) reported dried *M. oleifera* leaves to contain 2.60mg/100g vitamin B1 and 1.29-20.50mg/100g vitamin B2. VitaminB1 is a key player in the production of energy from dietary carbohydrates and fats. It plays the role as the gatekeeper between the less efficient step of early carbohydrate breakdown- the energy-rich Krebs' cycle and electron transport chain. Since vitamin B1 has a crucial role in energy metabolism, severe and prolonged vitamin B1 deficiency can affect the nervous system. Vitamin B2 is important for body growth, reproduction and red blood cell production (Kumar *et al.,* 2012).

The study showed that all the accessions of *M. oleifera* under investigation were good sources of vitamin C and in leaf samples, it is ranging between 185.3mg/100g (CPT7) to 227 mg/100g (CPT17).In fruits, maximum vitamin C (130mg/100g) content was estimated in CPT17. *M. oleifera* leaves contain a high amount of vitamin C (Ahmed *et al.,* 2016). Prabhakar *et al.,* (2003) recorded 120mg vitamin C in 100g of fresh pod weight in the drumstick. Rai *et al.,* (2004) reported that drumstick leaves have high vitamin C content in comparison with other leafy vegetables. Joshi and Mehta (2010) recorded (220mg/100g) vitamin C in *M. oleifera* leaves. Vitamin C content of leaves was less compared to fruit and conforms to the earlier report (Resmi *et al.,* 2006). Vitamin C, is a most important vitamin, plays a significant role as an antioxidant, thereby protecting body tissue from oxidative damage and the harmful effects of free radicals, which are potentially damaging by-products of the body's metabolism (Kumar *et al.,* 2012).

Pearson correlation coefficient

Among various traits subjected to Pearson correlation analysis, moisture content did not show any noticeable correlation with the parameters studied. Leaf carbohydrate was positively correlated with leaf protein and leaf vitamin A, leaf vitamin B1 (Table 3). Leaf protein was positively correlated with leaf vitamin A. Similarly; leaf vitamin A showed a positive relation with leaf vitamin B1 and B2. Correlation matrix showed a significant correlation between leaf vitamin B2 and C. Leaf vitamin B1 showed a positive correlation with leaf vitamin B2 and C. Leaf vitamin B1 and A were highly correlated with leaf protein.

Nutritive value and selection of elite germplasm

Chemical analyses of a wide range of nutrients in foods included in a database are not always practical. Considering many components that go into human nutrition, it is difficult to assess the overall nutritive value of a crop. Grubben (1978) proposed the average nutritive value of vegetables based on protein, fibre, Ca, Fe, carotene and vitamin C. Accordingly, we selected nutrient parameters for nutrient value calculation (AOAC, 2000).

Nutritive values of 23 *M. oleifera* accessions were calculated based on carbohydrate; fat and protein content (Table 4). The nutritive value based on leaves ranged between 75.85 (CPT1) and 100.90 (CPT17). Among 23 CPTs evaluated, 10 (CPT2, CPT4, CPT5, CPT8, CPT13, CPT14, CPT16, CPT17, CPT18 and CPT22) scored higher nutritive value than average value (88.27). Leaf nutritive value-based screening recommends the accession CPT17 as elite accession. The nutritive value based on fruit ranged between 17.56 and 27.13. The highest nutritive value was estimated for CPT8 (28.52) followed by CPT3 (27.13). Among 23 CPTs, 12 (CPT2, CPT3, CPT4, CPT5, CPT8, CPT9, CPT10, CPT13, CPT15, CPT19, CPT20 and CPT24) placed above the mean value (23.05). Further, we considered vitamin C content in leaves and fruits of *M. oleifera* accessions. Vitamin C content of leaves and fruits showed significant variation. Vitamin C content in leaves (227mg/100g) and fruits (130mg/100g) were highest in CPT17. This substantiates the selection of elite based on yield and nutritive character. The large variability in various nutrient parameters reveals that CPT17 provides an important opportunity for breeding the genotype for higher nutrient content. Likewise, Changan *et al.* (2017) identified promising lines of *Zea mays* based on carotenoids content for future breeding programmes, aimed to develop nutritionally improved maize varieties. The variability in nutrient content in *Gynandropsis gynandra* is associated with the geographic origin of the accessions and the recorded variability fueled the basis for breeding for higher levels of vitamin C, carotenoids or tocopherols in high-yielding cultivars (Sogbohossou *et al.,* 2019).

Conclusion

In the present study, overall ranking based on nutritive value and vitamin C indicates that CPT17, an accession from Cherthala, representing the agro-climatic zone of coastal sandy region is the best germplasm with remarkably high leaf nutritive value, leaf and fruit vitamin C content. In addition to these CPT17 contained a moderately high level of vitamin A, B1 and B2. In brief, the profound variability recorded among the drumstick accessions can be utilized for evolving new types with better yield and quality attributes. Biochemical variability recorded among the CPTs is to be further analyzed for its genetic basis through suitable markers, so that selected elite having distinct genetic makeup can be identified.

Acknowledgements

The authors are grateful to Head, Department of Botany, University of Kerala for the facilities provided. R. S. Drisya Ravi thanks the University of Kerala for granting research fellowship (No. Ac.EI/A2/10625/2016-I) to undertake the present work.

Author's contributions

DRS conducted the experiments. DRS and EAS analysed the data. DRS drafted the manuscript. EAS and BRN designed the experiments. EAS, BRN and DRS revised the manuscript. All authors read and approved the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

Table 1
Biochemical parameters of leaf samples of 23 *Moringa oleifera* CPTs

CPTs	Moisture (%)	Carbohydrates (g/100g)	Protein (g/100g)	Fat (g/100g)	Vitamin A (mg/100mg)	Vitamin B1 (mg/100mg)	Vitamin B2 (mg 100mg)	Vitamin C (mg/100mg)
CPT1	70.63^{a}	9.63^{de}	5.83^{c}	1.56^{c}	5.86^{bcdefg}	0.054^{defghi}	0.040^{gh}	212.3^{bcd}
CPT2	74.81^{a}	13.53^{a}	6.21^{c}	1.67^{abc}	7.00^{ab}	0.061^{cde}	0.060^{a}	220.4^{abc}
CPT3	75.16^{a}	11.53^{abcd}	6.40^{bc}	1.53^{c}	6.50^{abcde}	0.071^{ab}	0.054^{abcde}	220.9^{abc}
CPT4	76.73^{a}	13.43^{a}	7.36^{ab}	1.96^{abc}	6.61^{abcd}	0.063^{abcd}	0.046^{cdefg}	220.3^{abc}
CPT5	74.26^{a}	13.27^{a}	6.11^{c}	1.87^{abc}	6.86^{ab}	0.062^{bcde}	0.055^{abcd}	220.8^{abc}
CPT6	75.26^{a}	10.23^{bcde}	5.86^{c}	1.57^{c}	5.00^{g}	0.049^{ghi}	0.047^{cdefg}	211.6^{bcd}
CPT7	79.26^{a}	11.56^{abcd}	5.79^{c}	2.03^{abc}	5.67^{cdefg}	0.042^{j}	0.037^{gh}	185.3^{e}
CPT8	74.53^{a}	14.02^{a}	6.50^{bc}	1.60^{bc}	6.66^{abcd}	0.060^{cdef}	0.058^{ab}	221.8^{ab}
CPT9	73.26^{a}	10.47^{bcde}	5.60^{c}	2.27^{ab}	5.24^{fg}	0.054^{defgh}	0.043^{fgh}	215.7^{abcd}
CPT10	72.70^{a}	12.06^{abcd}	5.76^{c}	1.87^{abc}	5.64^{cdefg}	0.056^{cdefgh}	0.042^{fgh}	214.6^{abcd}
CPT11	72.23^{a}	9.73^{cde}	5.76^{c}	1.77^{abc}	5.06^{g}	0.051^{fghi}	0.042^{fgh}	208.2^{cd}
CPT12	70.53^{a}	8.10^{e}	4.54^{d}	2.10^{abc}	4.73^{g}	0.030^{k}	0.044^{efgh}	207.1^{d}
CPT13	72.68^{a}	13.20^{a}	6.10^{c}	2.10^{abc}	6.46^{abcde}	0.059^{cdefg}	0.048^{bcdefg}	215.0^{abcd}
CPT14	73.01^{a}	12.75^{ab}	6.13^{c}	1.67^{abc}	6.82^{abc}	0.061^{cdef}	0.056^{abc}	219.2^{abcd}
CPT15	76.63^{a}	11.53^{abcd}	6.23^{c}	1.45^{c}	7.10^{a}	0.072^{a}	0.055^{abcd}	219.7^{abc}
CPT16	76.73^{a}	13.43^{a}	7.50^{ac}	1.90^{abc}	6.77^{abcd}	0.062^{bcde}	0.042^{fgh}	218.2^{abcd}
CPT17	73.63^{a}	13.63^{a}	6.42^{bc}	2.30^{a}	6.66^{abcd}	0.064^{abc}	0.054^{abcde}	227.1^{a}

CPT18	71.40^{a}	12.22^{abc}	5.97^{c}	1.87^{abc}	6.24^{abcdef}	0.060^{cdef}	0.052^{abcdef}	216.4^{abcd}
CPT19	72.70^{a}	11.53^{abcd}	6.03^{c}	1.70^{abc}	4.98^{g}	0.047^{hij}	0.045^{defgh}	214.1^{bcd}
CPT20	75.96^{a}	11.56^{abcd}	5.88^{c}	1.51^{c}	5.61^{defg}	0.045^{ij}	0.034^{h}	186.9^{e}
CPT21	74.30^{a}	11.93^{abcd}	6.05^{c}	1.74^{abc}	6.68^{abcd}	0.053^{efghi}	0.052^{abcdef}	214.1^{bcd}
CPT22	74.84^{a}	12.44^{ab}	6.53^{bc}	1.67^{abc}	6.66^{abcd}	0.057^{cdefgh}	0.054^{abcde}	222.9^{ab}
CPT23	73.04^{a}	12.79^{ab}	5.70^{c}	1.53^{c}	5.38^{efg}	0.050^{cdefgh}	0.042^{fgh}	216.3^{abcd}
F value	1.735NS	3.915***	3.915***	1.585NS	4.642***	10.660***	4.941***	7.314***

Means within a column followed by same letters are not significantly (p≤.05) different as determined by Duncan's Multiple Range Test. *** highly significant (p≤.001), NS-Non significant

Table 2
Biochemical parameters of fruit samples of 23 *Moringa oleifera* CPTs

	Moisture (%)	Carbohydrates (g/100g)	Protein (g/100g)	Fat (g/100g)	Vitamin A (mg/100g)	Vitamin B1 (mg/100g)	Vitamin B2 (mg/100g)	Vitamin C (mg/100g)
CPT1	79.83^{a}	2.56^{fgh}	1.97^{abc}	0.13^{a}	0.173^{bcde}	0.046^{b}	0.062^{ab}	111.33^{cde}
CPT2	86.51^{a}	4.47^{a}	1.644^{bc}	0.17^{a}	0.179^{abcde}	0.052^{b}	0.064^{ab}	96.65^{acde}
CPT3	84.53 ^{a}	3.80^{abcd}	2.66^{ab}	0.14^{a}	0.193^{abcde}	0.050^{b}	0.066^{a}	129.80^{a}
CPT4	82.80 ^{a}	3.26^{cdefgh}	2.33^{abc}	0.17^{a}	0.209^{abcd}	0.054^{b}	0.068^{a}	123.15^{abc}
CPT5	89.18 ^{a}	3.65^{abcde}	2.61^{ab}	0.20^{a}	0.236^{ab}	0.050^{b}	0.072^{a}	128.10^{ab}
CPT6	85.66^{a}	2.73^{efgh}	1.75^{abc}	0.18^{a}	0.137^{cde}	0.045^{b}	0.063^{ab}	93.50^{g}
CPT7	85.16^{a}	3.06defgh	1.87^{abc}	0.14^{a}	0.120^{de}	0.052^{b}	0.066^{a}	95.54^{fg}
CPT8	84.07^{a}	4.10^{abc}	2.73^{a}	0.13^{a}	0.263^{a}	0.052^{b}	0.070^{a}	123.46^{abc}
CPT9	84.69^{a}	3.07^{cdef}	2.63^{ab}	0.18^{a}	0.145^{bcde}	0.054^{b}	0.061^{ab}	112.80^{cde}
CPT10	83.60^{a}	2.83^{defgh}	2.63^{ab}	0.15^{a}	0.170^{bcde}	0.053^{b}	0.063^{ab}	115.13^{bcde}
CPT11	83.80^{a}	2.50^{gh}	1.87^{abc}	0.12^{a}	0.161^{bcde}	0.043^{b}	0.051^{bc}	108.23^{de}
CPT12	81.40^{a}	2.28^{h}	1.81^{ab}	0.13^{a}	0.163^{bcde}	0.028^{b}	0.042^{c}	109.26^{de}
CPT13	80.33^{a}	3.50^{abcdefg}	1.86^{abc}	0.19^{a}	0.108^{e}	0.030^{b}	0.062^{ab}	109.20^{abcde}
CPT14	82.85^{a}	3.66^{abcde}	1.45^{c}	0.14^{a}	0.176^{ab}	0.036^{b}	0.059^{ab}	125.60^{a}
CPT15	78.53^{a}	3.27^{bcdefgh}	2.66^{ab}	0.15^{a}	0.150^{bcde}	0.048^{b}	0.042^{c}	113.56^{abc}
CPT16	82.13^{a}	3.07^{fgh}	2.23^{abc}	0.13^{a}	0.172^{bdec}	0.051^{b}	0.061^{ab}	127.50^{ab}
CPT17	78.93^{a}	2.83^{defh}	2.08^{abc}	0.18^{a}	0.179^{abcde}	0.056^{b}	0.065^{ab}	130.23^{a}
CPT18	82.33^{a}	3.10^{defgh}	1.80^{abc}	0.11^{a}	0.223^{abc}	0.051^{b}	0.063^{ab}	90.30^{g}
CPT19	80.46^{a}	3.65^{abcde}	2.66^{ab}	0.16^{a}	0.187^{abcde}	0.051^{b}	0.066^{a}	96.80^{ef}
CPT20	82.36^{a}	4.13^{ab}	1.90^{abc}	0.16^{a}	0.201^{abcd}	0.051^{b}	0.070^{a}	115.50^{abcd}
CPT21	84.33^{a}	3.58^{abcdef}	1.90^{abc}	0.12^{a}	0.180^{abcde}	0.050^{b}	0.063^{ab}	110.40^{cde}
CPT22	79.03^{a}	2.85^{defgh}	1.90^{abc}	0.12^{a}	0.182^{abcde}	0.054^{b}	0.072^{a}	110.40^{bcde}
CPT23	83.06^{a}	3.45^{bcdefg}	2.46^{abc}	0.12^{a}	0.180^{abcde}	0.017^{a}	0.064^{ab}	106.50^{de}
F Value	0.066NS	3.353***	1.632NS	0.818NS	1.769NS	1.096NS	3.862***	8.415***

Means with in a column followed by same letters are not significantly (p≤.05) different as determined by Duncan's Multiple Range Test. *** highly significant (p≤.001), NS-Non significant

Table 3
Pearson's correlation coefficients between biochemical traits

	LM	LC	LP	LVit. A	LVit. B1	LVit. B2	LVit. C	FM	FC	FP	FVit.A	FVit.B1	Fvit. B2	FVit.C
LM	1													
LC	0.379	1												
LP	0.539	0.717**	1											
LVit. A	0.358	0.737**	0.675**	1										
LVit. B1	0.22	0.63**	0.683**	0.771**	1									
LVit. B2	-0.012	0.489*	0.286	0.701**	0.601**	1								
LVit. C	-0.245	0.446*	0.428*	0.522*	0.688**	0.757**	1							
FM	0.213	0.097	-0.08	-0.029	-0.041	0.112	-0.084	1						
FC	0.32	0.608**	0.302	0.469*	0.339	0.407	0.121	0.32	1					
FP	0.121	0.177	0.193	0.024	0.35	0.027	0.336	0.08	0.155	1				
FVit.A	-0.08	0.397	0.295	0.319	0.262	0.385	0.383	0.28	0.412	0.328	1			
FVit.B1	0.418	0.221	0.462*	0.32	0.276	0.169	0.055	0.1	0.131	0.204	0.289	1		
Fvit. B2	0.272	0.57**	0.428*	0.227	0.172	0.082	0.054	0.33	0.464*	0.138	0.448*	0.396	1	
FVit.C	0.191	0.345	0.398	0.535**	0.438*	0.337	0.364	0.34	0.492*	0.229	0.353	0.077	0.116	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed)

LM-Leaf moisture, LC-Leaf carbohydrate, LP-Leaf protein, LVitA-Leaf vitamin A, LVitaB1-Leaf vitamin B1, LVitB2-Leaf vitamin B2, LVitC-Leaf vitamin C, FM-Fruit moisture, FC-Fruit carbohydrate, FP-Fruit protein, FVitA-Fruit vitamin A, FVitaB1-Fruit vitamin B1, FVitB2-Fruit vitamin B2, FVitC-Fruit vitamin C

Table 4
Nutritive value of 23 genotypes of *Moringa oleifera*

CPTs	**leaf**	**Fruit**
CPT1	75.85	19.32
CPT2	93.96	25.986
CPT3	85.52	27.13
CPT4	100.77	23.92
CPT5	94.38	26.87
CPT6	78.46	19.54
CPT7	87.7	20.98
CPT8	96.48	28.52
CPT9	84.68	24.45
CPT10	88.08	23.199
CPT11	77.86	18.56
CPT12	69.46	17.56
CPT13	96.1	23.12
CPT14	90.58	21.73
CPT15	84.06	25.1
CPT16	100.82	22.34
CPT17	**100.9**	21.23
CPT18	89.56	20.56
CPT19	85.54	26.68
CPT20	83.35	25.53
CPT21	87.55	23.03
CPT22	90.88	20.08
CPT23	87.76	24.75
Mean	88.27	23.05

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Received: 8 April 2020
Revised and Accepted: 29 May 2020

Abrahamia
VOLUME 6 • NUMBER 1 • 2020

ISSN: 2395-4108

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Published by Department of Botany, University of Kerala
Kariavattom, Thiruvananthapuram, Kerala, India - 695581