Characterization and evaluation of drumstick (*Moringa oleifera Lam.*) accessions for yield and quality

By

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(2017-12-002)

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Characterization and evaluation of drumstick (*Moringa oleifera Lam.*) accessions for yield and quality"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Date: 09/08/2019

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CERTIFICATE

Certified that this thesis entitled **"Characterization and evaluation of drumstick (*Moringa oleifera Lam.*) accessions for yield and quality"** is a bonafide record of research work done independently by **Ms. Anitta Judy Kurian (2017-12-002)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory committee of **Ms. Anitta Judy Kurian (2017-12-002)**, a candidate for the degree of **Master of Science in Horticulture** with major field in **Vegetable Science**, agree that this thesis entitled **"Characterization and evaluation of drumstick (*Moringa oleifera Lam.*) accessions for yield and quality"** may be submitted by **Ms. Anitta Judy Kurian** in partial fulfillment of the requirement for the degree.

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Anitta Judy Kurian

CONTENTS

LIST OF TABLES

LIST OF TABLES (Contd.)

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

1. INTRODUCTION

Drumstick (*Moringa oleifera* Lam.), belonging to the mongeneric family Moringaceae is one of the best useful tree with a variety of potential uses. Drumstick commonly known as 'horseradish tree', 'miracle tree' or 'tree of life' is native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan (Paliwal *et al.,* 2011). This tree has been planted around the world and was utilized by the ancient Romans, Greeks and Egyptians. It is now widely cultivated and has become naturalized in many locations in the tropics. Every part of the plant has got great value because of its nutritional, medicinal and industrial properties. It is a tree with minimal growth needs and can be grown in a wide range of climatic conditions, from humid tropics to arid lands. Drumstick tree is cultivated and used as a vegetable (leaves, green pods, flowers, roasted seeds), for spice (mainly roots), for cooking and cosmetic oil (seeds) and as a medicinal plant (all plant parts). The leaves can be eaten fresh, cooked, or stored as a dried powder for a long time without any major loss of its nutritional value.

Drumstick tree is economically useful as a vegetable, natural medicine, animal fodder, natural coagulant for water purification, fertilizer, living fence, and as a bio-fuel (Pandey *et al*., 2012). Leaves, pods and seeds are suggested as a viable supplement of digestible proteins, vitamin C, vitamin A, minerals like calcium, iron, magnesium, potassium, manganese, phosphorus, zinc and antioxidant compounds such as flavonoids, phenols, carotenoids, and vitamin E. It contains vitamins like vitamin A, vitamin B such as folic acid, pyridoxine and nicotinic acid, vitamin C, D and E. Research revealed that drumstick seed oil contains around 76 per cent of Poly Unsaturated Fatty Acids (PUFA) such as linoleic acid, linolenic acid and oleic acid that has the ability to control cholesterol. In fact, drumstick is said to provide 9 times more protein than yoghurt, 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 25 times more iron than spinach and 15 times more potassium than bananas (Rockwood *et al*., 2013).

Multiple biological properties of drumstick were attributed to the presence of functional bioactive compounds such as phenols, flavonoids, alkaloids, phyto-sterols, natural sugars, vitamins, minerals, and organic acids. Different plant parts have been used to treat inflammations, cardiovascular problems, anti-carcinogenic effects, gastrointestinal illnesses, nervous disorders, infectious diseases *etc*... They also contain active components like glucomoringin which is responsible for inducing apoptosis and anti-cancerous activities (Maldini *et al*., 2014).

Even though countries like Philippines, Nigeria and Kenya cultivate this crop, drumstick cultivated in India is superior in quality and quantity. India contributes about 80 per cent of world drumstick production. The total area is estimated as 43,600 Ha with a production of 22,000 tons per annum (APEDA, 2018). The crop is commercially cultivated in Tamil Nadu, Andhra Pradesh, Karnataka, Odisha and in Kerala, drumstick cultivation is limited to home gardens to meet the family requirement. Fruits, leaves and dried products are mainly exported to China, USA, Canada and South Korea.

Large variability exists in drumstick with respect to flowering time, tree habit, tree shape and resistance to hairy caterpillar. Collection, evaluation and characterization of drumstick germplasm are the prerequisites for identifying the variability existing within the germplasm. The genetic variability pattern has to be studied for successful breeding and improvement of crop. The knowledge on variation is helpful in selection of suitable genotypes and for developing efficient breeding and improvement programme for purpose of improving the plant yield and quality. Therefore, the present study was undertaken in drumstick with the following objectives:

(i) To characterize drumstick accessions with respect to yield and quality and to identify the superior accessions(s)

(ii) To evaluate drumstick accessions for variations in biochemical characters

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Drumstick (*Moringa oleifera* Lam.) is a multipurpose tree vegetable cultivated widely for edible as well as medicinal purposes. Since drumstick is a cross-pollinated tree and also naturalized in many areas, high heterogeneity with respect to form and yield is reported. Considering the multiple uses and wide range of adaptability, drumstick is a crop that yet to be fully exploited. Limited efforts has been undertaken to characterize the existing germplasm in contrast to the variability existing in the crop. The present study was envisaged to evaluate the magnitude of genetic diversity in this crop and exploit them for future crop improvement programmes. The available literature on above aspect is reviewed here.

2.1 Taxonomy

Drumstick, commonly known as the miracle tree, belongs to the monogeneric family Moringaceae. The systematic position of this family is controversial. Many taxonomists such as Bessey (1915) and later Wettstein (1935) included it in Rhoeadales, being allied to Capparidaceae. The true systematic position as it appears should be under Parietals with respect to zygomorphy of flowers, perigyny and parietal placentation. According to Erdtman (1952), the pollen grains of drumstick show similarity to those of Capparidaceae and Resedaceae. Verdcourt (1986) developed a taxonomic key for the genus moringa and classified it into14 species from tropical and subtropical climates that ranges in size from tiny herbs to massive trees. There are two common species, *M. oleifera,* medium sized tree with tripinnate leaves and *M. concanensis,* large tree with bipinnate leaves, the former being the vegetable species. Morton (1991) reported that the most common species are *M. peregrina, M. arabica., M. zeylanica, M. stenopetala, M. borziana, M. longituba, M. concanensis, M. ovalifolia, M. drouhardii, M. hildebrantii, M.oleifera, M. pygmaea, M. rivea.* Later, Chase *et al.* (1993) reported that, Moringaceae are closely related to family Brassicaceae and Caricaceae, with which they share glandular appendages at the apex of the petiole.

2.2 Variability

2.2.1 Morphological characters

2.2.1.1 Plant habit

Palada (1996) described drumstick as a slender, deciduous tree with brittle branches and stem that grows to about 10- 12 m tall with corky bark and drooping leaves.

Olson and Carlquist (2001) classified the drumstick into four habit classes based on gross appearance in the field while examining wood anatomical correlations: bottle trees, sarcorhizal trees, slender trees, and tuberous shrubs. Among the classes, all of species exhibited similarity except for the two species of sarcorhizal trees such as *M. arborea* and *M. ruspoliana* with marked anatomical differences despite habitual similarity. According to Foidl *et al.* (2001) drumstick is a perennial rapidly growing tree, with a maximum height of 7-12 m and a diameter of 20-40 cm at chest height. Tree will grow as a straight stem which starts to branch at a height of 1.5-2 m in a disorganized manner having umbrella shaped canopy.

Vijayakumar (2001) studied the influence of month of sowing on biometric observations in annual moringa and found that that maximum tree height of 4.66 m was observed in March sown plants and least height of 2.84 m was recorded in September sown annual drumstick. Same trend was observed in case of number of primary branches like highest report in March sowing (27.7) and the lowest report in September sowing (20.1). Olson (2002) reported that drumstick is a slender-trunked tree with purplish or greenish-white, hairy barked young shoots and mature bark with whitish-grey colour and is surrounded by thick cork.

Orwa *et al.* (2009) described drumstick as a soft wooded tree that grows to height of 8 m and 60 cm girth. Tree bark is smooth with dark grey coloured; straight growing stem with hairy twigs and shoots and umbrella shaped, wide opened crown.

Mgendi *et al.* (2011) used morphological markers to assess variations between and within cultivated and non-cultivated species of drumstick and variations were observed with respect to bark colour such as, white, grey or pale buff along with textural differences like corky, rugose or smooth texture. While Obuobi (2012), reported the stem bark colour variations of the accessions comprising whitish/ silvery, green and dark brown. Same study also considered variability in growth habit pattern of accessions and found an intermediate growth form between erect and compact for four accessions and compact growth for two accessions. The remaining accessions reported to have erect growth form.

Animashaun *et al.* (2013) conducted a comparative study on root development in trees developed from seeds and cuttings and found that longer roots were observed for trees whose planting material was seed compared to that of cuttings having much shorter roots. Raja *et al.* (2013) reported that first branch emerges from a height of 23.0 to 59.6 cm with mean of 39.18 cm.

Selvakumari (2013) carried out an investigation on 34 genotypes of drumstick to study the extent of genetic variability and relationship among different morphological parameters. Plant height of 34 genotypes recorded a low mean value of 3.16 m (MO 10) and highest mean value of 8.09 m (MO 15).Trunk girth ranged from lowest mean value of 74.08 cm (MO 24) to highest mean value of 250.40 cm (MO 15). Heritability observed for plant height and trunk girth was 85 and 97.4 per cent respectively. Study also revealed the positive and significant correlation between plant height and trunk girth (0.420).

Kumar *et al.* (2014) conducted a study on morphological diversity on 300 genotypes of drumstick trees belonging to 12 populations located at Tamil Nadu and Himachal Pradesh. Variation was observed for tree height ranging from 2.40 m to 5.56 m and trunk girth from 0.54 m to 2.19 m. Tree shape also showed variation except for accession MO 5 and MO9 which were upright, others had semi spread type of tree shape. Correlation study among different morphological characters showed significant positive correlation between tree height and fruit girth. Leone *et al.* (2015) reported pruning or pollarding can be practiced for the vigorous growth of lateral branches and provide bush shape for trees.

Popoola *et al.* (2016) conducted a study for analyzing phenotypic intraspecific variability among 40 accessions of drumstick. Variability was observed with respect to stem bark colour exhibiting grey colour in all the accessions except two accessions knN078 and oyN003 with whitish grey bark.

2.2.1.2 Leaf

Brown (1958) studied leaf characteristics and reported that drumstick leaves have feathery texture, pale green colour, compound, tripinnate, 30-60cm long, with 3 to 9 leaflets and the elliptical shaped lateral leaves which are smaller than obovate shaped terminal ones. Stanley (1982) characterized drumstick leaves with ovate, elliptic or oblong shaped leaflets with larger, obovate terminal leaflet which are puberulous when young and glabrous at maturity. Pal *et al.* (1996) observed macroscopical characters of the leaflets were and described drumstick leaflets as green, elliptical shaped leaflets having entire margin, acute apex, reticulate venation and a length of 10-12 mm.

Studies conducted at AVDRC have revealed that there is variation in leaf size and shape of leaflets (AVDRC, 2002). The drumstick leaves are pale green, compound, tripinnate, 30-60 cm in length (Patel *et al.*, 2010). While Abubakar *et al.* (2011) conducted an variability analysis on leaves of 21 drumstick accessions using morpho-antomical features and reported the highest leaf length range (58.85-61.75 cm) and leaflet length (34.55-37.25 cm) were recorded by accession 16BAU and 5ZRKD respectively, while the highest leaflet width (1.85-1.87 mm) by 12BDZM. The accession 2JHJG (3.45 mm^2) showed the highest leaf area in all the samples studied suggesting the existence of variation among the samples.

Characterization of local and exotic accessions of drumstick were carried out by Obuobi (2012) and reported some variations in leaf colour and petiole pigmentation. Colour of leaf ranged from light green to dark green and petiole with purple, dark purple and green colour.

Kumar *et al.* (2014) conducted a study on 300 genotypes of drumstick trees. Variation was observed for leaf let shape with oblong and elliptical shapes. Robiansyah *et al.* (2014) identified a new biotype of drumstick later suggested as a hybrid between *M. oleifera* and *M. peregrine* produced from spontaneous pollination and fertilization between the two drumsticks. New bio types characterized by round, elliptic or oblanceolate shaped leaflets which are combination between leaflets shapes of *M. oleifera* (round) and *M. peregrine* (linear, elliptic or oblanceolate).

Zhigila (2014) evaluated 30 accessions of drumstick for external morphology of leaf and fruit and identified four types of leaflet shapes (ovate, cordate, obovate and elliptic). Study recorded 100 per cent frequency of ovate leaflet shapes in OTUs 3, 22 and 23 and 52.50 per cent of obovate leaflet shape in OTU 8 while 66.23 per cent of elliptical leaflet shape was recorded in OTU 29. In case of leaflet apex, OTU 7 recorded highest obtuse leaflet apex (91.50 %) and acute leaflet apex in OTU 29 (62.11 %).

2.2.1.3 Flower

Benthall (1946) reported the growth pattern in drumstick in north eastern India that starts after the tree shed the leaves in December – January, new flushes appear in February - March, followed by flowering and fruit set.

Muthuswami (1954) reported two flowering seasons such as March-April and July - August under South Indian conditions, while Nair and Singh (1974) observed only one season of flowering during February-March under Lucknow condition that confirms the dependence of flowering in accordance with geographical conditions.

Seemanthani (1964) reported that crop was obtained in two seasons namely July to September and March to April which was the main season.

Worldwide variations can be observed in drumstick flowering season which is highly in conformity with agro climatic conditions prevailing in that area. Flowering season falls on September and October in Maharashtra (Cowen, 1965), January to June in Bahamas (Correll and Correll, 1982), whereas the trees produces flowers throughout the year in Cuba (Clement *et al.,* 1954), Florida and Jamaica (Simmonds, 1854).

Ochse (1977) reported drumstick trees that rarely flower and cultivated exclusively for foliage in West Indies. Peter (1979) observed that drumstick flowers in March-April and July-September under Kerala condition and observed two seasons, March-May and July-September under Bangalore situation.

Ramachandran *et al.* (1980) reported drumstick flowering starts from 6-12 months after planting which again depends on variety and location. It may flower only once in April-June in cool North Indian regions while in southern India, there is two peak flowering seasons. Flowering may occur continuously throughout the year in regions receiving more constant seasonal temperature and rainfall.

Devar *et al.* (1981) recorded prolific and extended flowering on month of March-May. Mohideen and Shanmugavelu (1982) found that annual drumstick takes 85 to 120 days for first flowering while it extends for the perennial variety by more than after 6-8 months.

Drumstick flowers are white to cream, fragrant borne on axillary panicle of 8-30 cm long, ovoid flower buds with5 sepals and 5 petals (Verdcourt, 1986).

Drumstick flower four times a year starting from January, producing 30-50 cm long, triangular pods. (Jahn, 1996).Variability in flower colour was reported by Boulos (1999) as yellowish white to pink flowers.

Sindhu (2002) studied floral biology, anthesis and fruit development in drumstick using sixty bearing plants and reported that flowering occurs throughout the year except in the month of November and December with two flowering peaks viz., July - August and February – March. Flower buds took an average of 29.8 days for its complete development during rainy season and 24.8 days during summer season. Anthesis continued throughout the day with maximum at 14 hrs and 04 hrs.

Bhattacharya and Mandal (2004) reported flowering season of drumstick was from January to April with a peak in February. Flower anthesis takes place in forenoon (6.00 hrs to 12.00 hrs) after which pollen anthesis and nectar secretion occurs.

Resmi *et al.* (2006) assessed twenty eight accessions of drumstick from central and southern Kerala and found variations with respect to morphology yield and quality attributes. Out of all accessions evaluated three accessions from Thiruvananthapuram *viz.* MO 13, 24 and 26 exhibited three flowering peaks per year, while others showed one or two flowering peaks, while Kanthaswamy (2005) reported two peaks of flowering on October-November (rainy season) and April-May (summer season).

Muhl *et al.* (2013) studied effect of different irrigation treatment on flowering and found that highest flower bud initiation was observed at the 300 mm per annum and lowest at the 900 mm per annum for two consecutive growing seasons and concluded that medium moisture stress prior to floral initiation will stimulate flower initiation, followed by sufficient irrigation to ensure good pollination, fruit set and yield.

Kumar *et al.* (2014) observed three forms of corolla colour with white, yellow and pinkish colour and reported flowering throughout the year with the peak during October - November and April- May with fruit production during October and May. Popoola *et al.* (2014) reported variation in days to flowering of 13 accessions of drumstick using 12 characters and found that least days to flowering (206 days) were recorded for Oy01 and highest days to flowering (260 days) for On11.

Tak and Maurya (2015) observed variability in flower colour and reported that white flower colour occurred in high frequency while genotypes like JWRM 5, JWRM-6, JWRM-7, JWRM-11, JWRM-13, JWRM-16, JWRM-26, JWRM-31 and JWRM-33 exhibited cream coloured flower and four genotypes produced white flower with red streaks. The present study also reported varied flowering peaks in a year. Genotypes like JWRM-1, JWRM-2, JWRM-3, JWRM-5, JWRM-6, JWRM-7 and JWRM-9 showed three flowering peaks. Agbogidi and Ilondu (2012) reported 8 months old drumstick tree produce cream coloured flowers from January and continues up to March.

Popoola *et al.* (2016) conducted a study for evaluating phenotypic variability in drumstick accessions and found that flower colour exhibited two forms like white with purple pigmentation or creamy white without pigmentation. Out of 40 accessions examined four accessions namely, enN053, goN068, knN078 and knN077 were recorded to exhibit white with purple pigmentation.

Taher *et al.* (2017) reported that drumstick tree takes 8 months for first bloom and continue every year from April to September.

2.2.1.4 Fruit

Mohideen and Shanmugavelu (1982) evaluated the seedling progenies of annual and perennial drumstick and reported that number of fruits ranged from 20-198 and weight from 0.93 to 9.81 kg.

Suthanthirapandian *et al.* (1989) suggested that annual drumstick improvement can be made possible by undergoing selection within the open pollinated seed progenies from the evidence of wide variations observed with respect to number of flowers per panicle (19.0 - 126.0), fruit weight (29- 231.5 g) and number of fruits per plant (1-155).

Suthanthirapandian *et al.* (1992) evaluated twenty seed moringa accessions and recorded range of fruit length from 42.75 cm to 63.85 cm and no significant variation was observed for fruit girth. Variability was again found with respect to the fruit weight (73.8 g to 15.4 g) and number of seeds per fruit (12.80 to 21.25) and opted genotypes MT 16, MT 11 and M 19 as superior based on yield performance.

Matured tree produce green 20 to 30 cm long pods, that turns to brown on maturing with numerous round or triangular seeds with three papery wings (Folkard *et al.*, 1999). Foidl *et al.* (2001) detailed drumstick pods as three lobed pods, 20-60 cm long containing 12 to 35 seeds.

Sindhu (2002) studied the floral biology of drumstick and reported that an average of 5.55 and 5.00 days were taken for fruit set in rainy and summer seasons respectively. The fruit maturity per cent was 2.7 for rainy days and 3.7 for summer days. To attain horticultural maturity, fruits take about 42 days in rainy season and 34 days in summer season. In case of physiological maturity it takes 70 days during rainy season and 59 days during summer season. The fruit production became maximum during July - August and March – April.

Raja and Bagle (2008) reported a positive correlation between fruit length, weight, number of primary branches and fruits per tree.

Raja *et al.* (2013) recorded fruit length of drumstick in the range of 32.5 cm to 123.1 cm. Variability study carried out by Mgendi *et al.* (2010) recorded pod length range from 30 to 60 cm in cultivated and non-cultivated drumstick varieties.

Selvakumari (2013) evaluated drumstick genotypes for genetic variation in fruit characters and reported variations in pod length ranged from 23.36 cm (MO 34) to 90.66 cm (MO 22), pod girth ranged from 6.50 cm (MO 10) to 12.66 (MO 2), pod weight from 31.24 g (MO 34) to 209.35 g (MO 12). Number of seeds per pod varied from 10.35 (MO 34) to 25.70 (MO 14).

Agoyi *et al.* (2014) conducted a comparative study on fruit characters between phytodistricts and found that pod length show significant variation between phytodistricts with record of long pods (34.20 cm) from the phytodistrict of Plateau and shortest (27.45 cm) from Oueme explained by the wider spacing followed in Plateau.

Kumar *et al.* (2014) found variations for fruit characters like fruit length (23.50- 79.95 cm), fruit girth (6.77- 10.24 cm), fruit weight (68.84- 145.68 g), number of fruits per tree (49- 193), number of seeds per fruit (11- 26) revealing positive correlation between trunk girth with fruit length, girth and weight. Popoola *et al.* (2014) reported that a significant correlation exists between pod length and pod width. Also a positive association among the number of seeds per pod with pod per peduncle, pod length, pod width and number of locules per pod was observed.

Zhigila *et al.* (2014) evaluated thirty accessions of drumstick and reported that accession OTU 26 showed the highest pod length 573.2 mm and number of seeds per pod of 23.40. While OTU 20 exhibited highest fruit stalk length 119.50 mm and OTU 28 recorded the highest pods width of 25.59 mm.

Hameed (2015) observed the influence of months of sowing on the number of seeds per fruit and found that pods from January sown seeds account for highest number of seeds (19.1) and lowest number of seeds on July sown trees (17.2). Tak and Maurya (2015) evaluated 18 genotypes of drumstick and reported high degree of variation regarding pod length (24.43 to 59.47 cm), pod girth (7.33

to 23.67 mm), pod weight (26.3766.43 g) and found that genotype JWRM -31 with more number of seed/pod.

Popoola *et al.* (2016) recorded the variability in fresh pod color (pale green and green), mature pod colour (brown and golden brown) and fruit shape (straight and curved). Number of pods per peduncle/panicle ranged from 2-6, number of pod per plant ranged from 10 to 62. Pod characters like pod length (25.45 cm to 43.87 cm) and pod weight (59.37 g to 91.34 g) also exhibited wide range of variation. Number of seeds per fruit was correlated with pod length and pod width at $r = +0.69$ and $+0.54$, respectively.

2.2.1.5 Yield

Among 122 accessions maintained at Kerala Agricultural University, earliness was observed in eight of the accessions namely MO 1, MO 2, MO 5, MO 10, MO 12, MO 120, MO 40 and MO 107. Once in a year each tree yields pods from 3 to 541. Genotypes MO 65, MO 70 and MO 52, were considered as superior genotypes yielding pods of length 45-60 cm. According to Gopalakrishnan (1978) and Peter (1979), drumstick accession, MO 70 recorded highest pod yield (26.25 kg per tree).

Mohideen and Shanmugavelu (1983) reported and positive correlation between the pod yield per tree and number of pods per tree and suggested, higher pod yield can be obtained from genotypes with low to medium height, low basal branches along with more number of branches and pods.

Plants raised from cuttings may starts to bear after 6–8 months of planting. Low fruit production in initial one to two years is compensated from third year onwards with a production of a 600–1,600 fruits/tree/year (Ramachandran *et al.* 1980; Morton 1991).

Suthanthirapandian *et al.* (1992) evaluated twenty seed drumstick accessions and noticed significant variation among the genotypes for fruit yield from first, second and ratoon crops.

Palada and Chang (2003) recommended that drumstick leaf yield can be improved by trimming and pinching which affect branching and leaflet production along with also with adoption of suitable planting methods.

Resmi *et al.* (2006) evaluated 28 drumstick accessions from central and southern Kerala and recorded variability in fruits per plant (174 to 612) and total fruit yield (8.94 to 70.46 kg per tree).

Prabhakar and Hebbar (2008) reported higher number of pods is the desirable factor for high yield per tree instead for fruit size. Raja and Bagle (2008) revealed the positive correlation of yield per plant with percent fruit set, fruit length, fruit pulp weight, fruit weight, number of primary branches and number fruits per plant at both genotypic and phenotypic levels. Number of seeds per fruit showed positive low direct effect and indicated strong positive association on yield per plant.

Raja *et al.* (2013) evaluated the degree of genetic diversity within drumstick for yield contributing traits at diverse geographic area and found that some varieties exhibited highest stability for early height for first branch, number of fruits per plant and yield per plant under unfavorable environments (PKM-1) and favorable environment (MO-1, PKM-2) for commercial cultivation in arid regions. An investigation was carried out by Selvakumari (2013) in 34 genotypes of drumstick to study the extent of genetic variability and relationship among different morphological parameters and reported that the accessions viz., MO 25 and MO 27 can be further utilized in breeding programmes for high pod yield, leaf soluble protein and seed oil (ben oil) content. The highest number of pods per plant was reported in MO 27 (139.15) and isolated some genotypes that are capable of producing more number of pods: MO 1 (133.58), MO 8 (115.53), MO 12 (121.73), MO 20 (131.29), MO 24 (131.96) and MO 27 (139.15).

Hameed (2015) reported higher pod yield (28.7 kg) from trees sown during the month of January and lowest yield (18.9 kg) for trees sown during July. Tak and Mauya, (2015) revealed that the yield obtained from taller trees are more compared to shorter ones.

Karunakar *et al.* (2018) pointed out that the traits such as stem girth, length of pod, pod girth, number of pods per plant registered negative direct effect on yield per plant.

2.2.2 Biochemical characters

Drumstick is rich in nutrients owing to the presence of a variety of essential phytochemicals present in its leaves, pods, flowers and seeds. The pods and leaves of drumstick contain vitamins, minerals, antioxidants and other beneficial phyto-chemicals in reasonable quantities. The vital minerals present in drumstick include calcium, copper, iron, potassium, magnesium, manganese and zinc. Antioxidant compounds such as ascorbic acid, flavonoids, phenols and carotenoids are also present in drumstick in considerable amount. (Dillard and German, 2000; Siddhuraju and Becker, 2003).

Because of its high nutritional status and ability to thrive under unfavourable climatic conditions, drumstick is widely used to combat malnutrition as a source of protein and vitamin A in under developed countries. Since drumstick is also a rich source of iron it is widely recommended to anaemic patients (Siddhuraju and Becker, 2003). Dried drumstick leaf powder (8 g) meets per day nutritional requirement of child within ages 1-3 by providing 14 per cent of protein, 40 per cent of the calcium, 23 per cent of the iron, and almost all the vitamin A required by child (Fahey, 2005). Vitamins present in drumstick include vitamin A, B, C, D, E and K (Mbikay, 2012).

2.2.2.1 Vitamin C

Dogra *et al.* (1975) reported that the fruits and leaves of drumstick have found to be rich source of vitamin C. Verma *et al.* (1976) examined the vitamin C content in two common drumstick species and observed that *Moringa oleifera* (79-133 mg/100 g) contain higher vitamin C than *M.* concanensis (55-59 mg/100 g). Ramachandran *et al.* (1980) recorded 200 mg/100 g of vitamin C in fresh leaves.

Sreeramulu *et al.* (1983) studied the loss in vitamin C content from fresh leaves (204 mg/100 g) while cooking and observed 98·5 per cent of reduction in vitamin C after cooking.

Vijayakumar (2001) studied the influence of vitamin C content in leaves and the month of sowing. Result shows that September sowing recorded the highest content of vitamin C (228.5 mg/l00 g) followed by March and November and January sown trees recorded the lowest ascorbic acid content (22l.3 mg/l00 g).

Prabhakar *et al.* (2003) recorded 120 mg vitamin C in 100 g of fresh pod weight in drumstick. Rai *et al.* (2004) that reported drumstick leaves has a high vitamin C content of 220 mg.

Resmi *et al.* (2006) evaluated twenty eight accessions of drumstick and accession MO 18 recorded high amount of vitamin C in leaf (226 mg per 100 g) and fruit (129 mg per 100 g).

Price (2007) studied the oxidative loss of vitamin C in drumstick and reported lower level of vitamin C in dried leaves (18.7 mg/100 g) than in the fresh leaves (140 mg/100 g). Yang *et al.* (2006) observed cool-dry season favours vitamin C content in drumstick.

Sreelatha and Padma (2009) estimated the vitamin C content in mature leaf (6.60 mg/ g) and tender leaf (5.81 mg/ g). Radovich (2010), observed vitamin C (51.7 mg) in leaf.

Wangcharoen and Gomolmanee (2013) estimated 773± 91 mg of vitamin C in fresh leaves.

Ahmed *et al.* (2016) estimated the vitamin C contents in different parts of drumstick and reported that higher levels of vitamin C was observed in matured leaves (51.226 to 150.157 mg/100 g) than tender leaves (62.66 to 143.587 mg/100 g). Vitamin C content in flower recorded 77.502 to 224.672 mg/100 g and pods with 3.96 to 8.27 mg/100 g of vitamin C. Gopalakrishnan *et al.* (2016) reported vitamin C of 220 mg per 100 g in drumstick leaves.

2.2.2.2 Protein

Gopalan *et al.* (1989) reported the presence of important amino acids arginine and histidine in drumstick leaf protein. Gardener and Ellen (2002) observed drumstick leaves contain high amount of protein with quality comparable with that of milk and eggs.

Vijayakumar (2001) reported the change in leaf protein with the months of sowing. Highest protein content of 8.96 g /100 g was observed in May sown plants and lowest in the months of January and March (6.85 and 6.75 g /100 g).

Kakengi *et al.* (2003) reported crude protein content ranged from 265-308 g/kg in drumstick leaves. Abdulkarim *et al.* (2005) observed that protein content in drumstick leaves is in higher levels (383.0 g/kg) compared to other leguminous seeds.

Owusu *et al.* (2008) compared the biochemical aspects of drumstick with seven varieties of sweet potato leaves. Results shows that the drumstick leaves contain crude protein, crude fibre, iron and calcium higher that of sweet potato.

Sánchez-Machado *et al.* (2010) found that all parts of drumstick is a rich source of protein like leaves contain 42 ± 1.4 per cent, immature pods with 19.34 ± 0.2 per cent and flowers with 18.92 ± 1.3 per cent and reported that, drumstick leaves had the richest amount of protein source with an adequate profile of amino acids and ash.

Jongrungruangchok *et al.* (2010) conducted a study to compare the proximate composition and mineral constituents in drumstick leaves from 11 different agro climatic regions of Thailand and observed a range of 19.15 -28.80 per cent for protein in leaves. Joshi and Mehta (2010) recorded 6.7 g and 23.66 g protein in fresh and dried leaves of drumstick that supports the present findings.

Kwenin *et al.* (2011) compared the protein status of drumstick with some African indigenous green leafy vegetables such as *Xanthosoma sagittifolia* and *Talinum triangulare* and reported that drumstick leaves can be a rich source of dietary nutrients with high protein content (6.60%) compared to *Xanthosoma sagittifolia* (4.65%) and *Talinum triangulare* (5.10%).

Selvakumari (2013) reported that drumstick can provide 27.1 g of protein which containing all of the essential amino acids. Wangcharoen and Gomolmanee (2013) recorded 29± 6 g of protein in 100 g dry matter of drumstick leaves. Teixeira *et al.* (2014) recorded 28.65 mg/100 g of protein in leaves.

2.2.2.3 Beta carotene

Beta carotene is one of the most important carotene in plants that act as precursor of vitamin A Vitamin A plays a vital role in many biological processes like vision, reproduction, immune competence, cell division *etc.*

Nambiar and Seshadri (2001) evaluated beta carotene in sixteen green leafy vegetables by HPLC method and drumstick leaves exhibited highest level of beta carotene (19210 μg/100 g). Rajyalakshmi *et al.* (2001) observed 6.23 mg/100 g of beta carotene in fresh leaves. Subadra *et al.* (2003) carried out an analysis on fresh drumstick leaves and found that leaves contain 27.1 mg of total carotene and 17.4 mg of beta-carotene.

Resmi *et al.* (2006) evaluated twenty eight accessions of drumstick from central and southern Kerala and biochemical evaluation of accessions reported high range of vitamin A in leaf and fruit as 8108 I.U to 13216 I.U and 95 to 185 I.U respectively.

Yang *et al.* (2006) observed higher levels of vitamin A during the hot-wet season.

Price (2007) reported dried drumstick leaves contain more beta carotene (17.6 to 39.6 mg/100 g) when compared to fresh leaves (6.6–6.8 mg/100 g). Ferreira *et al.* (2008) stated that fresh leaves of drumstick are an abundant source of vitamin A (11,300–23,000 IU).

Mustapha and Babura (2009) examined beta carotene content of some local vegetables (sorrel, carrot and drumstick) and result revealed the superiority of drumstick leaves regarding vitamin A (2.33×10^{2} μg/l) compared to the other vegetables. Radovich (2010) reported that drumstick leaves contain 75641U of vitamin A.

Selvakumari (2013) evaluated the beta carotene content in genetic variability study of drumstick accessions and found that accession MO 25 ranked highest for carotene content (13.76 mg/ 100 g) and MO 12 recorded lowest carotene content (9.36 mg/ 100 g). Tesfaye *et al.* (2013) recorded 15.25 mg/100 g of beta-carotene. Wangcharoen and Gomolmanee (2013) observed about 15,620±6,475 IU of vitamin A in 100 g dry leaf sample.

2.2.2.4 Calcium

Vijayakumar (2001) assessed the calcium content of leaves at different sowing time and observed that the calcium was higher in trees sown during the months of May and September (436 and 435 mg/100 g) and least calcium content was recorded in the leaves of the trees sown during July (427 mg/100 g).

Aslam *et al.* (2005) assessed variability in mineral composition of drumstick leaves and pods in different agro climate of Punjab and recorded calcium content range from 18950- 22931 mg/kg in leaves and 1292- 1837 mg/kg in pods.

Jongrungruangchok *et al.* (2010) conducted a study to examine mineral constituents in drumstick leaves from 11 different agro climatic regions distributed in Thailand and the value of calcium ranged from 1510.41 to 2951.13 mg/ 100 g.

Mahmood *et al.* (2010) reported calcium content as 440 mg and Radovich (2010) recorded the 185.0 mg of calcium content in drumstick leaves.

Ogbe and Affiku (2011) found that calcium accounts 1.91 per cent in the leaves of drumstick. Oluduro (2012) observed 98.67 ppm of calcium. Wangcharoen and Gomolmanee (2013) found 1,924±288 mg of calcium. Yaméogo *et al.* (2011) observed variation in calcium content in fresh and dry leaves of drumstick and reported calcium in fresh (847.1± 430.6) mg and dry leaves (2098.1± 1414.8) mg.

Melesse *et al.* (2012) stated that concentration of calcium in leaves was generally higher in the dry season than in the rainy season and lower elevation may favour the concentration of calcium. Sharma *et al.* (2012) evaluated calcium content of drumstick and amaranthus and found higher levels of calcium (2007.67 mg/100 g) in drumstick compared to amaranthus.

Madukwe *et al.* (2013) found dry drumstick leaf extract contain 33.35mg (% per 100 ml) of calcium. Selvakumari (2013) recorded the thirty four genotypes calcium content ranged from 0.85 per cent (MO 33) to 3.96 per cent (MO 14). Genotypes ranked for higher calcium content includes MO 1 (3.07 %), MO 10 (3.04 %), MO 12 (3.84 %), MO 14 (3.96 %) and MO 26 (3.87 %). Sodamade *et al.* (2013) recorded the value of calcium is 723.00±0.14 mg/100 g in drumstick.

Leone *et al.* (2015) performed a nutritional characterization of drumstick leaves grown in Chad, Sahrawi, and Haiti and observed higher range of calcium in Sahrawi drumstick (2743.38 ± 39.6) mg/100 g.

2.2.2.5 Iron

Vijayakumar (2001) observed highest iron content in leaves of trees sown in the month of May (8.57 mg/100 g) followed by March sown trees (8.46 mg/l00 g). The lowest iron content was recorded in leaves of trees sown during the month of July (8.11 mg/100 g).

Aslam *et al.* (2005) recorded iron content in leaves (205- 573 mg/kg) and pod (155.2-435.9 mg/kg) of drumstick. Yang *et al.* (2006) reported that iron were highest during the cool-dry season in a range of 26 mg/100 g.

Jongrungruangchok *et al.* (2010) reported iron content ranged from 20.31 to 37.60 mg in drumstick leaves collected from 11 different agro climatic regions distributed in Thailand. Joshi and Mehta (2010) reported 24 mg/100 g of iron in dried drumstick leaves.

Ogbe and Affiku (2011) recorded iron content in leaves as 107.48 ppm. Yaméogo *et al.* (2011) observed dry leaves of drumstick contain more iron (28.3 mg/100 g) than fresh leaves (17.2 mg/100 g).

Melesse *et al.* (2012) observed iron concentration was inconsistent across dry and rainy seasons.

Sharma *et al.* (2012) compared mineral composition of drumstick with amaranthus and recorded 26.34 mg/100 g of iron in drumstick leaves.

Selvakumari (2013) recorded the iron content among thirty four accessions ranged from 109.82 μg/ 100 g (MO 1) to 132.48 μg/ 100 g (MO 5). The genotypes MO 5 (132.48 μg/100 g), MO 10 (128.53 μg /100 g), MO 11 (131.96 μg /100 g), MO 16 (125.91 μg), MO 22 (132.05 μg /100 g), and MO 32 (128.70 μg /100 g) recorded high iron content. Wangcharoen and Gomolmanee (2013) found that 100 g dry matter of drumstick leaves contain 28± 6 mg of iron.

Leone *et al.* (2015) performed a comparative study on mineral composition from different area and recorded iron content in Chad (17.03 ± 0.79) mg/100 g Sahrawi (41.68 ± 1.08) mg/100 g, and Haiti (11.91 ± 0.82) mg/100 g varies according to agro climatic condition.

2.2.2.6 Total Phenol

Phenols exhibit antioxidant property and possess free radical scavenging activity. Principal polyphenol compounds in drumstick leaves are flavonoids and phenolic acids. Makkar and Becker (1996) assessed total phenols of drumstick leaves and reported 16 g/kg in extracted and 34 g/kg in unextracted sample.

Sidduraju and Becker (2003) reported the total phenolic content of leaf extract from India, Niacaragua, and Niger ranged from 2940 to 4250 mg GAE/100 g dry weight.

Sreelatha and Padma (2009) observed total phenol content in mature (45.81 mg/g) and tender leaves (36.02 mg/g). Polyphenol present in leaves range from 2090 to 12,200 mg GAE/100 g of DW (Sultana *et al.,* 2009).

Mukunzi *et al.* (2011) evaluated the total phenols and total flavonoid content of drumstick leaves collected from different agro climatic regions and observed significant difference in total phenolic content and flavonoid content among samples. Sample collected from Rwanda recorded higher total phenolic content (30.01 mg GAE/g dry weight basis) and total flavonoid content and (52.78 mg rutin/g dry weight basis). The sample collected from China reported total phenolic content of 24.65 mg GAE/g dry weight basis and 39.08 mg Rutin Eq/g dry weight basis amount of total flavonoid content. Ramakrishnan and

Venkataraman (2011) reported that drumstick leaves are rich source of total polyphenolics (gallic acid equivalents) and quercetin and kaempferol.

Oluduro (2012) reported that phenol accounts for 0.29 per cent composition of drumstick leaves. Singh *et al.* (2013) carried out the phenolic profiling of drumstick extract and found that free and bound phenolic extract includes gallic acid, catechin, epicatechin, p-coumaric acid and quercetin. Moyo *et al.* (2012) found that acetone extract of drumstick leaf contain higher total phenol (120.33 TE/g) than aqueous extract (40.27 TE/g).

Jaiswal *et al.* (2013) recorded the total phenolic content of the leaf extract powder was found to be 120 mg GAE/g and total flavonoid and total flavonol contents were found to be 40.50 mg QE /g and 12.25 mg QE /g. Vongsak *et al.* (2013) observed the reduction in total phenolics level of drumstick leaf extracts stored under accelerated condition to 6 months like 37.78 (0 month), 36.4 (3 month), 32.91 (6 month).

Leone *et al.* (2015) performed a nutritional characterization and a phenolic profiling of drumstick leaves and reported the total phenols from Chad (2813 mg/100 g), Sahrawi (3552 mg/100 g), and Haiti (2545 mg/100 g).

Drumstick has a lot of vitamins and minerals that are essential for growth and development. Vitamins like vitamin A, vitamin B such as folic acid, pyridoxine and nicotinic acid, vitamin C, D and E are present in drumstick. Phytochemicals such as alkaloids, tannins, sterols, terpenoids, flavonoids, saponins, athraquinones and reducing sugar present along with anti-cancerous agents like glucosinolates, isothiocyanates, glycoside compounds and glycerol-1-9-octadeconate (Kasolo *et al.,* 2010).

Oluduro (2012) reported the presence of sodium (11.86), potassium (25.83), magnesium (107.56), zinc (148.54), iron (103.75) and manganese (13.55) among others in parts per million and nutrients such as carbohydrate (45.43%), fat (9.68%), crude fibre (9.68%), moisture (11.76%) and ash (10.64%) in drumstick leaves. In addition, drumstick was found to have a group of unique compounds containing sugar and rhamnose, which are uncommon sugar-modified glucosinolates (Amaglo *et al.,* 2010). Another important point is that drumstick leaves contain all of the essential amino acids, which are the building blocks of proteins. It is very rare for a vegetable to contain all of these amino acids.

Beside the above mentioned nutritional content, *M. oleifera* has been found to contain a relatively low amount of anti-nutrients such as phytates, saponins, tannins and oxalates (Shih *et al.*, 2011). These anti-nutrients, though not necessarily toxic or deleterious, may interfere with digestion and absorption of other nutrients such as zinc, iron, calcium and magnesium when consumed in high quantities.

2.2.3 Organoleptic evaluation

An organoleptic evaluation was conducted to estimate the acceptance of three recipes made of *Phaseolus aureus*, *Cicer arietinum* - desi and kabuli channa were incorporated with freshly blanched drumstick leaves (20 g). All the three recipes were acceptable with a scoring of 3.06-3.53 out of 5 (Nambiar and Parnami, 2008).

Dachana *et al.* (2010) reported the overall acceptance of cookies incorporated with 10 per cent drumstick leaf powder. Madukwe *et al.* (2013) conducted an organoleptic evaluation of beverage made from dry drumstick leaf powder and found to be acceptable.

Kumar *et al.* (2014) conducted a study on 12 populations of drumstick and found that all accessions were palatable except that of MO 4 having bitterness.

Mouminah (2015) carried out a sensory evaluation of cookies incorporated with dry drumstick leaf powder and acceptable quality and typical flavor was obtained by incorporating 10 per cent of drumstick leaf powder.

2.2.4 Pest and diseases

Drumstick is a tree crop that is resistant to most of the pest and diseases. But studies show that there are different insect and non insect pests associated with this crop from different parts of world and became major threat to drumstick. Martin and Ruperté (1979) reported a termite attacking drumstick in Puerto Rico.

Ramachandran *et al.* (1980) reported a minor disease in trees growing in southern India, root rot caused by *Diplodia* sp.

Butani and Verma (1981) reported the incidence of leaf eating caterpillar (*Noorda blitealis*) during March to April and December to January. David and Kumarswamy (1982) pointed out that *Noorda blitealis* is a serious pest of annual drumstick as it causes serious damage to crop that occurs throughout the year.

Ullasa and Rawal (1984) found that drumstick tree is the collateral host of *Leveillu lataurica*, a powdery mildew that causes serious damage in papaya (*Carica papaya* L.) nurseries in south India. Anjaneyamurthy (1985) observed the incidence of leaf caterpillar, *N. blitealis* during January to April in Periyakulam, Tamil Nadu.

Olsen (1987) reported *Aphis craccibora*, the borer *Diaxenopsis apomecynoides* and the fruit fly Gitonia sp can seriously damage the crop.

Another disease affecting fruit is fruit rot caused by *Cochliobolus hawaiiensis* (Kshirsagar and D'Souza, 1989).

Some of the devastating pests in drumstick are bud worm *Noordia moringae* and the scale insects *Diaspidotus* sp. and *Ceroplastodes cajani* (Fuglie, 1999).

Sauveur and Broin (2010) reported the incidence of termites (*Macrotermes* and *Microtermes* spp.) that destroy trees and can cause serious damage to the roots, shoot, twigs, etc.

Usharani *et al.* (2010) observed bark-eating caterpillar *(Indarbela tetraonis)* on hatching feed below bark superficially making galleries and later feed internally causing severe damage to bark.

Anon (2011) observed the damage caused by bud worm (*N. moringae*) as the larva bores into flower buds and causes shedding.

Math and Kotikal (2014) examined 31 insect pests occurring in drumstick at different stages and reported four insect species as major pests causing serious damage to tree viz., *Noordia moringae, Noorda blitealis, Gitonia distigma* and *Myllocerus* spp. Math and Kotikal (2014) reported the incidence of *Noorda moringae* causing 17.08 per cent average bud damage with maximum at second fortnight of February (54 %). No incidence was reported in month of December.

Kumar *et al*. (2014) conducted a study on morphological diversity on 300 genotypes of drumstick trees to 12 populations located at Tamil Nadu and Himachal Pradesh and observed an accession MO 7 showing resistance to hairy caterpillar.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study entitled "Characterization and evaluation of drumstick (*Moringa oleifera* Lam.) accessions for yield and quality'' was conducted during January to December 2018 at College of Horticulture, Kerala Agricultural University, Vellanikkara. The experimental site was located at an altitude of 22.5m above MSL, between 70^0 32' N latitude and 76^0 16' E longitudes. The area has a warm humid tropical climate and soil type was laterite.

3.1 Experimental materials

Twenty-five accessions of drumstick trees collected from the farmer's field and planted in AICVIP experimental field of Department of Vegetable Science, College of Horticulture, Vellanikkara, which are in 5^{th} year of planting were used as the experimental material for study (Table 1). The accessions selected for the present study were given the same agronomic and cultural practices.

Table 1. Source of drumstick accessions

S.No.	Accession No.	Place of collection	Tree type
1	VKMo 2	Vellanikkara	Perennial
2	VKMo 3	Vellanikkara	Perennial
3	VKMo 5	Vellanikkara	Perennial
4	VKMo 6	Vellanikkara	Perennial
5	VKMo 7	Vellanikkara	Perennial
6	VKMo 8	Nenmara	Perennial
7	VKMo 9	Vellanikkara	Perennial
8	VKMo 10	Vellanikkara	Perennial
9	VKMo 11	Elanad	Perennial
10	VKMo 12	Elanad	Perennial
11	VKMo 13	Thrissur	Perennial
12	VKMo 15	Vellanikkara	Perennial
13	VKMo 16	Elanad	Perennial
14	VKMo 17	Elanad	Perennial
15	VKMo 19	Elanad	Perennial
16	VKMo 20	Vellanikkara	Perennial
17	VKMo 21	Elanad	Perennial
18	VKMo 22	Elanad	Perennial
19	VKMo 29	Periyakulam	Annual

20	VKMo 30	Periyakulam	Annual
21	VKMo 32	Vellanikkara	Perennial
22	VKMo 35	Vellanikkara	Perennial
23	VKMo 36	Vellanikkara	Perennial
24	VKMo 37	Vellanikkara	Perennial
25	VKMo 38	Vellanikkara	Perennial

3.2 Cataloguing of drumstick accessions

Twenty five accessions of drumstick were catalogued based on IPGRI minimal descriptor (2013) as shown in the Table 2.

Table 2. Cataloguing of drumstick accessions

1	**Morphological characters**	
1.1	Tree shape/ habit	Upright/ Spreading/ drooping
1.2	Bark colour	Grey/ White
1.3	Young shoot colour	Pale green/ Dark green
1.4	Foliage density	Sparse/ Medium/ Dense
2	**Leaf characters**	
2.1	Leaflet shape	Ovate/ Oblong/ Oblong oval/ Oval/ Elliptical
2.2	Leaflet apex	Obtuse/ Acute
3	**Floral characters**	
3.1	Nature of flowering branchlets	Secondary/ Tertiary
3.2	Shape of calyx	Triangular/ Others
3.3	Nature of calyx	Polysepalous/ Gamosepalous
3.4	Colour of calyx	Dark green/ Pale green
3.5	Shape of corolla	Triangular/ Others
3.6	Nature of corolla	Polypetalous/ Gamopetalous
3.7	Colour of corolla	Cream/ white/ yellow
4	**Fruit characters**	
4.1	Pulp colour	White/ Yellow/ Green
4.2	Taste of pulp	Bitter /Palatable

3.3 Collection of experimental data

Data on morphological and biochemical characters of drumstick accessions were recorded for further analysis.

Plate 1. General view of experimental field

3.3.1 Morphological characters

1. Tree shape

Tree shapes were recorded based on the visual appearance and recorded as per the minimal descriptor for drumstick.

2. Bark colour

Bark colour of the matured trees was observed and recorded based on RHS colour chart as grey/white.

3. Young shoot colour

The colour of the tender shoot at the region of leaf emergence was observed and recorded as pale green/dark green.

4. Foliage density

Foliage density at time of flowering was observed and recorded as sparse/medium/dense.

5. Leaflet shape

Fully matured leaflets were selected to record the shape asovate/ oblong/ oblong oval/oval/ elliptical.

6. Leaflet apex

Nature of leaflet apex was observed on matured leaves and recorded as acute/obtuse.

7. Date of start of flowering

First emerged panicle was tagged. Opening of 50 per cent flower buds in this panicle was observed and corresponding date was recorded.

8. Date of end of flowering

Last emerged panicle was tagged. Date after closure of 50 per cent flowers in this panicle was observed and corresponding date was recorded.

9. Nature of flowering branchlets

First emerged panicle was tagged, nature of flowering branchlets were observed, recorded as secondary/tertiary branches.

10. Shape of calyx

Calyx shape was observed from first emerged panicle and recorded as triangular/others.

11. Nature of calyx

Nature of calyx was observed at flower opening stage and recorded as polysepalous/ gamosepalous.

12. Colour of calyx

Calyx colour was observed based on RHS colour chart and categorized as dark green/ pale green

13. Shape of corolla

Shape of corolla was observed flower opening stage and recorded as triangular/others.

14. Nature of corolla

Nature of corollawas observed at flower opening stage and recorded as polypetalous/ gamopetalous.

15. Colour of corolla

Colour of the corolla was observed at flower opening stage and recorded as white/yellow/creambased on RHS colour chart.

16. Pulp colour

Colour of fresh fruit pulp was observed and categorized as white/yellow/green fruits based on RHS colour chart.

17. Taste of pulp

Freshly harvested fruit pulp was tasted, and taste of pulp was recorded as palatable/bitter.

3.3.2 Quantitative characters

1. Tree height

The height of the trees was measured from base to the tip of the highest shoot and expressed in metres (m).

2. Trunk girth

Girth of the trees was recorded by measuring diameter of main trunk from 25 cm above the ground level and expressed in centimetres (cm).

3. Fruit length

Length of five randomly selected fruits was measured with the help of an ordinary scale and average fruit length was calculated and expressed in centimetres (cm).

4. Fruit girth

Girth of five randomly selected fruits was measured; average was calculated and expressed in millimetres (mm).

5. Fruit weight

Five randomly selected fruits were weighed; average fruit weight was calculated and presented in grams (g).

6. Number of seeds per fruit

Number of seeds in five randomly selected fruits was counted and average was calculated.

7. Number of longitudinal ridges per fruit

Longitudinal ridges of five randomly selected fruits were counted, average value was recorded.

8. Number of fruits per tree

Number of fruits harvested from each accession were counted in each harvest and total number of fruits per tree was recorded.

9. Yield per tree

Yield from each harvest was recorded; total yield was computed for each accession.

3.3.3 Biochemical characters

Biochemical characters *viz.,* vitamin C, protein, beta-carotene, calcium, iron and total phenol, were estimated in leaves, flowers and fruits as detailed by Sadasivam and Manickam (1996); Srivastava and Sanjeev (1998). For measuring vitamin C content, fresh sample was taken and for all other parameters dried and powdered sample was taken.

1. Vitamin C

Vitamin C content of fresh leaves, flowers and fruits was estimated by 2, 6-dichlorophenol-indo-phenol dye method, as described by Sadasivam and Manickam (1996).

Reagents required: Oxalic acid (4%), Ascorbic acid standard and 2, 6-dichlorophenol-indo-phenol dye.

Preparation of dye solution: Sodium carbonate (42mg) was dissolved in some quantity of distilled water and later 2, 6-dichlorophenol (52 mg) was dissolved in same solution and made up to 200ml.

Preparation of standard ascorbic acid solution: Ascorbic acid standard was prepared by dissolving 100 mg pure ascorbic acid in 100ml of 4% oxalic acid. From this, 10 ml ascorbic acid solution was diluted to 100ml in 4% oxalic acid which is the working standard. Five ml of working standard solution was pipetted out into a conical flask and 10ml of 4% oxalic acid was added and titrated against dye taken in burette. End point was the appearance of faint pink colour which persisted for five seconds. Volume of the dye used up was recorded (V_1 ml).

Standardization of dye solution: Standardization of the dye 2, 6-dichorophenol-indo-phenol solution was done by titrating it against standard ascorbic acid solution.

Estimation of vitamin C: A known quantity of fresh sample (0.5g) was weighed andwas grinded into fine paste using five ml 4% oxalic acid. Using 100ml volumetric flask, the extract was made up and filtered using Whatman no. 41filter paper. Five ml of the filtrate was pipetted out into a conical flask and 10ml of 4% oxalic acid was added and titrated against the dye. Appearance of faint pink color in solution is the end point of the titration. Volume of dye used was recorded (V_2 ml).

$$\text{Amount of vitamin C in the sample (mg/100 g)} = \frac{0.5\text{mg} \times V_2\ \text{ml} \times 100\text{ml} \times 100}{V_1\ \text{ml} \times 5\text{ml} \times \text{wt. of the sample}}$$

The results were expressed as vitamin C in mg/100 g of edible portion.

2. Protein

Protein in the leaf, flower and fruit sample was estimated by Lowry's method described by Sadasivam and Manickam (1996).

Reagents required:

Reagent A: Sodium carbonate (2%) in Sodium hydroxide (0.1 N)

Reagent B: Copper sulphate (0.5%) in potassium sodium tartarate (1%)

Reagent C: Alkaline copper solution (50ml of Reagent A in 1ml of Reagent B)

Reagent D: Folin- Ciocalteau reagent

Preparation of stock standard: 50mg of bovine serum albumin in 50ml of distilled water

Preparation of working standard: 10ml of stock solution diluted in 50ml of distilled water

Estimation of Protein: Protein extraction from sample was done using phosphate buffer. 0.5 g of sample was grinded using 5-10ml of buffer solution and centrifuged at 5000 rpm for 10 minutes and supernatant was collected.

0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1ml of working standards and 0.2ml of sample extract was taken to a series of test tubes and made up to 1ml using distilled water. Freshly prepared reagent C (5ml) was added to all test tubes and after 10 minutes 0.5 ml of Folin- Ciocalteau reagent (Reagent D) was added. All test tubes were stored in dark for 30 minutes and later absorbance was measured at 660 nm. A standard graph was drawn by plotting sample volume on X axis and absorbance on Y axis and amount of protein was calculated in sample.

$$\text{Amount of protein (g/100 g)} = \frac{\text{Absorbance of sample x concentration of standard}}{\text{Absorbance of standard x volume of sample x 100}}$$

3. Beta-carotene

Beta-carotene in leaves, flowers and fruits were estimated using n butanol (AOAC, 1970).

Preparation of stock solution: Stock solution of beta-carotene was prepared by dissolving 10mg of beta- carotene in 100ml of n butanol.

Preparation of working standard: 10ml of stock solution was diluted to 100ml.

Estimation of Beta-carotene: Five grams of dried and powdered sample was taken in an Erlenmeyer flask (150ml) and 50ml of water saturated butanol (n butanol: distilled water, 8:2) was added to this. Flask was closed with a stopper and was shaken. Later the flask was stored in dark and kept overnight. Next day the content was shaken again and filtered into a 100ml volumetric flask using Whatman no.1 filter paper.

Working standards of 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, 1 ml and 0.5 ml sample supernatant was pipetted out into a series of test tubes and diluted with 10 ml of water saturated butanol. Colour intensity of the solution in all test tubes was read in a spectrophotometer at 435.8 nm. A standard graph was drawn by plotting concentration of standards on X axis and absorbance on Y axis.

$$\text{Amount of beta-carotene (mg/100 g)} = \frac{\text{Absorbance of sample x concentration of standard}}{\text{Absorbance of standard x volume of sample x 100}}$$

4. Calcium and Iron

Dried and powdered sample (0.2 g) was digested to analyze the calcium and iron content in samples. Digestion of samples was done with di-acid mixture of concentrated HNO3: HClO4 (9:4) and were estimated by Atomic Absorption Spectrometer. Di-acid mixture (10ml) was taken into digestion tubes containing 0.2g of powdered sample. The digestion is deemed to be completed when contents of tubes become colourless. After cooling the content of the tubes, the extract was diluted with 50ml of distilled water and absorbance was measured in ICP- OES. Standard graph was plotted with concentration on X-axis and readings on Y-axis and prepared the standard curve.

$$\text{Calcium/Iron content (mg/100 g)} = \frac{\text{Absorbance of sample}}{\text{Weight of sample (g) x 100}}$$

5. Total Phenol

Total phenol was estimated by method described by Sadasivam and Manickam (1996).

Reagents required: Ethanol (80%)

Folin- Ciocalteau reagent

Sodium carbonate (20%)

Preparation of stock standard: 100mg Catechol in 100ml distilled water

Preparation of working standard: 10ml of stock solution diluted to 100ml

Estimation of total phenol: 0.5 g of powdered sample was grinded well in 10 times volume of 80% ethanol and centrifuged at 10,000 rpm for 20 minutes. Collected supernatant was again re-extracted with 80% ethanol and supernatants were pooled and evaporated to dryness. Residue was dissolved in a known volume of distilled water (5ml).

Working standards of 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, 1ml and 1ml of sample was pipetted out into a series of test tubes and made up to 3 ml with distilled water. Later Folin- Ciocalteau reagent (0.5ml) was added to the test tubes and waited for 3 minutes and added 2ml of 20% sodium carbonate to all test tubes. Then the test tubes were placed in a boiling water bath for 1 minute and cooled before taking absorbance at 650 nm. A standard graph was drawn by plotting concentration of standards on X axis and absorbance on Y axis.

$$\text{Amount of total phenol (mg/100 g)} = \frac{\text{Absorbance of sample x concentration of standard}}{\text{Absorbance of standard x volume of sample x 100}}$$

3.4 Organoleptic evaluation

The organoleptic quality and acceptability levels were assessed in leaves using a scoring method suggested by Jijiamma and Prema (1994). Appearance, colour, flavor, doneness, taste and bitterness were the quality traits included in the evaluation.

A panel of 15 judges was selected using triangle test (Jellinek, 1985) and organoleptic qualities were evaluated using nine point Hedonics' scale.

3.5 Pests and diseases

All the accessions were monitored for the incidence of pest and diseases. The major insect pest found in the trees was leaf eating caterpillar (*Noorda* *blitealis*) and the damage was categorized with respect to the presence or absence of damage by the insect pest in drumstick accessions.

3.6 Ranking of drumstick accessions

Twenty five drumstick accessions were ranked (Rajamony *et al.* 1994), based on important quantitative and biochemical characters. Quantitative fruit characters and biochemical leaf characters were considered for the scoring and ranking of accessions.

3.7 Statistical analysis

The data pertaining to the quantitative and biochemical characters were analyzed using statistical tools such as correlations studies, path coefficient analysis and principal component analysis. In case of biochemical characters, amount of vitamin C, protein, beta-carotene, calcium, iron and phenol were estimated in leaves, flowers and fruits as per the availability of the same, from month of January to December. Mean value of each parameter from January to December, for all accessions were calculated and this served as the data for statistical analysis. The data on organoleptic evaluation were analyzed using statistical software SPSS-K related (non parametric).

3.7.1 Correlation studies

The relationship between quantitative characters was performed by using Pearson coefficient (Goulden, 1952). This enabled to understand the association among different quantitative characters of drumstick accessions and can be utilized in further improvement programmes. Correlation studies among various qualitative parameters were also carried out which provided information on the nature and relationship among these characters. Correlation between weather parameters and the qualitative characters revealed the trend in quality characters with changing weather conditions.

3.7.2 Path coefficient analysis

Path coefficient analysis for the 25 drumstick accessions was done to understand the correlation between yield and yield contributing characters in drumstick. Here, association among a particular cause and effect is partitioned into direct and indirect effect of the different causal factors on effect factors. The scale follows the range 0.00-0.09, 0.10-0.19, 0.20-0.29, 0.30-1.00 and more than 1.00; with negligible, low, moderate, high and very high effects, respectively (Dewey and Lu, 1959). Association between the yield and yield attributing characters were studied and both positive and negative direct and indirect effects were identified.

3.7.3 Principal component analysis

Twenty five drumstick accessions were analyzed using principal component analysis (Kaiser, 1958), using the software Minitab 17.1. Based on first two principal components, the score plot was obtained and clustering of 25 accessions based on this score plot was done. Clustering based on quantitative and biochemical characters was carried out and accessions with similar performance was grouped and studied.

RESULTS

4. RESULTS

The present study entitled 'Characterization and evaluation of drumstick (*Moringa oleifera* Lam.) accessions for yield and quality' was done in twenty five accessions of drumstick by studying different morphological, quantitative and biochemical characters. The experimental data were subjected to statistical analysis and grouping of accessions was done to identify superior accessions. The results obtained in the present study are presented below.

4.1 Morphological characters

Morphological characters *viz.* tree shape, bark colour, young shoot colour, foliage density, leaflet shape, leaflet apex, nature of flowering branchlets, shape of calyx, nature of calyx, colour of calyx, shape of corolla, nature of corolla, colour of corolla, pulp colour and taste of pulp were recorded and tabulated in the Table 3.

Tree shape varied from upright to spreading among the twenty five accessions. Grey coloured barks were recorded in majority of accessions except in VKMo 3, VKMo 4 and VKMo 8 which had white bark colour. All accessions produced pale green coloured young shoots with purple tinge. Foliage density at flowering period varied from sparse, medium to dense. Leaflet shape varied from ovate to elliptical and leaf apex from obtuse to acute. Both secondary and tertiary flowering branchlets were observed among accessions. Flowers produced in the accessions had triangular shaped, polysepalous, pale green coloured calyx; corolla having triangular shape, polypetalous and cream colour. Fresh fruit pulp colour was white in all accessions. Taste of fresh fruit pulp was palatable in all flowering types except VKMo 3, VKMo 6, VKMo 11, VKMo 13 and VKMo 29, which recorded bitter taste for fresh fruit pulp.

Flowering behavior of all drumstick accessions was studied for one calendar year from January 2018 to December 2018 and presented in the Table 4 and Table 5. Out of twenty five accessions, three were leafy types *viz.* VKMo 32, VKMo 35 and VKMo 38. Remaining 22 accessions were flowering types. Period of flowering varied among accessions. It was observed that commencement of flowering occurred from January in all the flowering accessions except VKMo 19 and VKMo 21, which flowered from March to April. It was observed that these two accessions were late in flowering and with only one flowering peak from March to April. Accessions *viz*., VKMo 3, VKMo 6, VKMo 7, VKMo 36 and VKMo 37 continued flowering from January to March. In accessions *viz*., VKMo 5, VKMo 20, VKMo 22, VKMo 29 and VKMo 30, flowering was observed from January to February, these accessions recorded shortest flowering period of two months. Two peaks of flowering *viz.,* January- March and September-November were observed in VKMo 2, VKMo7, VKMo12, VKMo15, VKMo16 and VKMo17. Among these accessions VKMo 2 and VKMo 15 recorded longest flowering period. In these accessions, flowering was observed for six months in total in two flowering peaks. Accessions *viz*., VKMo 2 and VKMo 7 started second flowering from September to October. Accessions *viz*., VKMo 12, VKMo 15, VKMo 16 and VKMo 17 started second flowering from October to November.

Table 3. Morphological characters of drumstick accessions

Accession	Tree shape	Bark colour	Young shoot colour	Foliage density	Leaflet shape	Leaf apex	Leafy/Flowering type	Nature of flowering branchlets
VKMo 2	Upright	Grey	Pale green	Sparse	Ovate	Obtuse	Flowering	Tertiary
VKMo 3	Spreading	White	Pale green	Medium	Ovate	Obtuse	Flowering	Tertiary
VKMo 5	Spreading	White	Pale green	Dense	Ovate	Obtuse	Flowering	Secondary
VKMo 6	Upright	Grey	Pale green	Medium	Ovate	Obtuse	Flowering	Secondary
VKMo 7	Spreading	Grey	Pale green	Medium	Ovate	Acute	Flowering	Tertiary
VKMo 8	Spreading	White	Pale green	Medium	Ovate	Obtuse	Flowering	Tertiary
VKMo 9	Spreading	Grey	Pale green	Dense	Elliptical	Acute	Flowering	Secondary
VKMo 10	Spreading	Grey	Pale green	Medium	Ovate	Obtuse	Flowering	Secondary
VKMo 11	Spreading	Grey	Pale green	Dense	Ovate	Obtuse	Flowering	Secondary
VKMo 12	Spreading	Grey	Pale green	Dense	Elliptical	Obtuse	Flowering	Secondary
VKMo 13	Upright	Grey	Pale green	Sparse	Ovate	Obtuse	Flowering	Tertiary
VKMo 15	Spreading	Grey	Pale green	Dense	Ovate	Obtuse	Flowering	Tertiary
VKMo 16	Upright	Grey	Pale green	Medium	Ovate	Obtuse	Flowering	Tertiary
VKMo 17	Spreading	Grey	Pale green	Dense	Elliptical	Obtuse	Flowering	Secondary
VKMo 19	Spreading	Grey	Pale green	Medium	Ovate	Obtuse	Flowering	Secondary
VKMo 20	Spreading	Grey	Pale green	Dense	Ovate	Obtuse	Flowering	Tertiary
VKMo 21	Spreading	Grey	Pale green	Dense	Oblong	Obtuse	Flowering	Secondary
VKMo 22	Upright	Grey	Pale green	Medium	Ovate	Obtuse	Flowering	Secondary
VKMo 29	Spreading	Grey	Pale green	Medium	Oblong	Obtuse	Flowering	Tertiary
VKMo 30	Spreading	Grey	Pale green	Sparse	Ovate	Obtuse	Flowering	Secondary
VKMo 32	Upright	Grey	Pale green	Medium	Oblong	Obtuse	Leafy	-
VKMo 35	Spreading	Grey	Pale green	Medium	Ovate	Acute	Leafy	-
VKMo 36	Spreading	Grey	Pale green	Medium	Elliptical	Obtuse	Flowering	Secondary
VKMo 37	Spreading	Grey	Pale green	Medium	Ovate	Obtuse	Flowering	Tertiary
VKMo 38	Upright	Grey	Pale green	Sparse	Ovate	Acute	Leafy	-

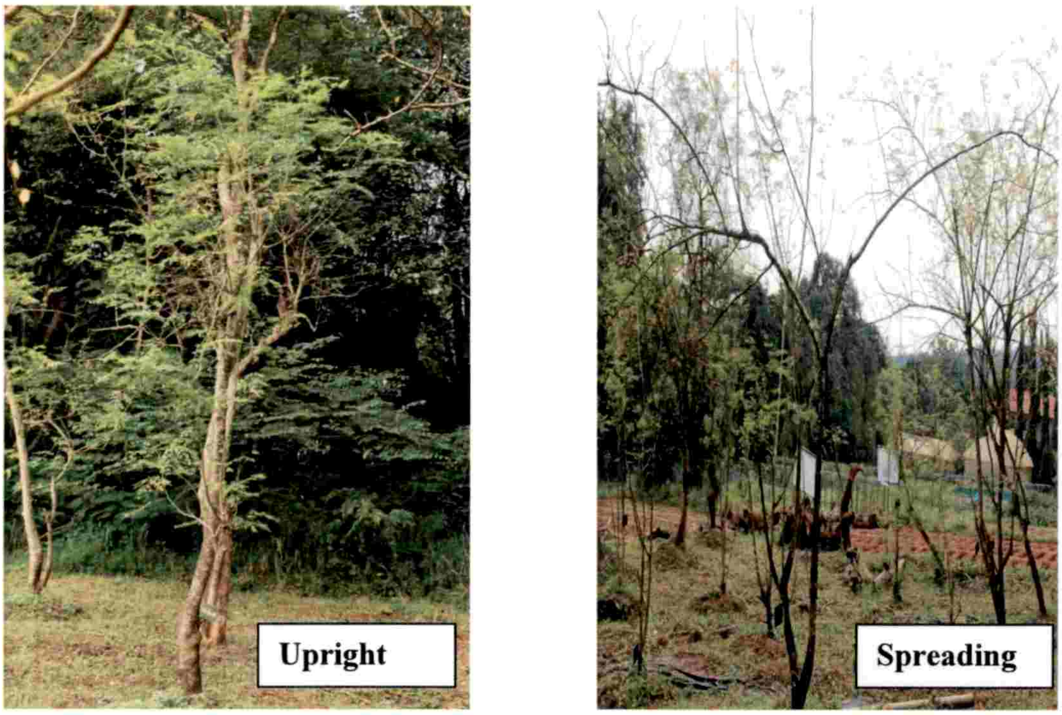

Plate 2. Variability in tree shape

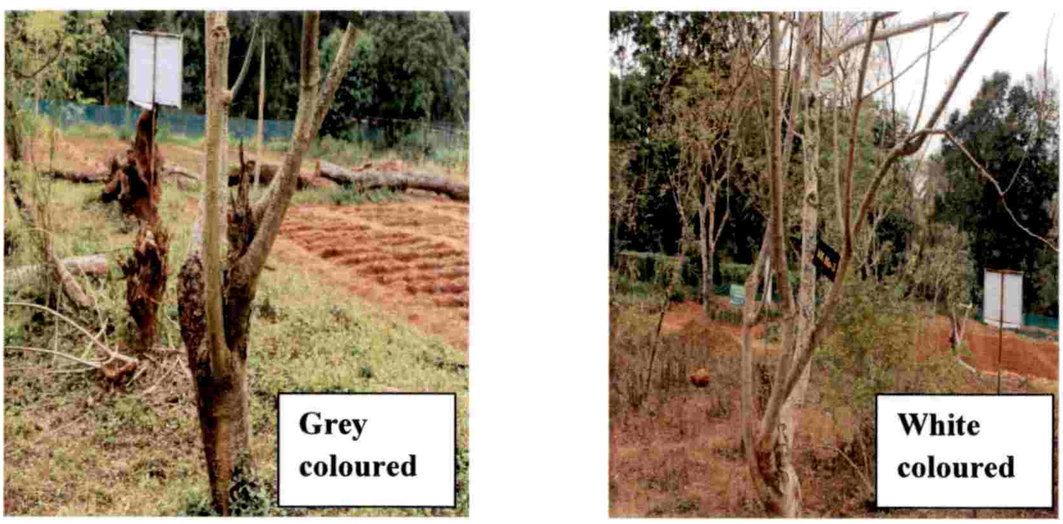

Plate 3. Variability in bark colour

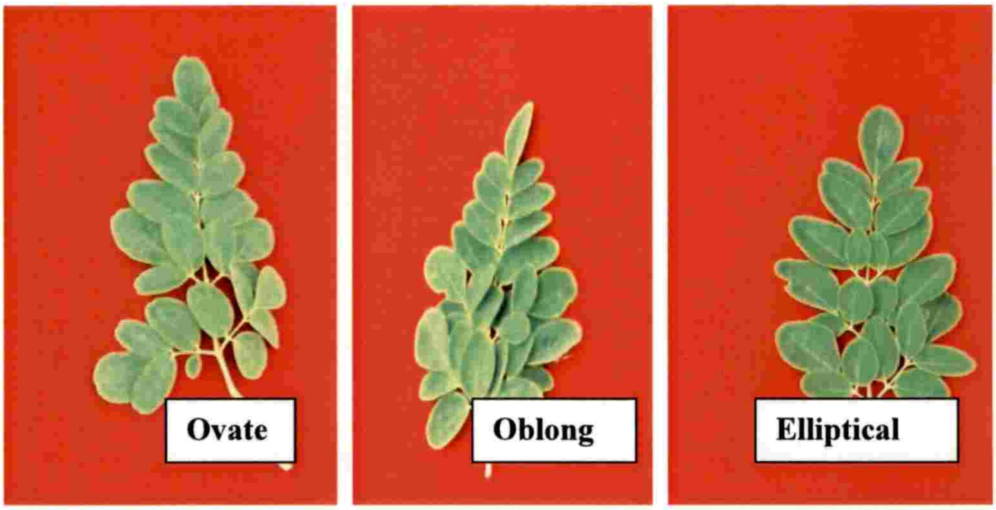

Plate 4. Variability in leaflet shape

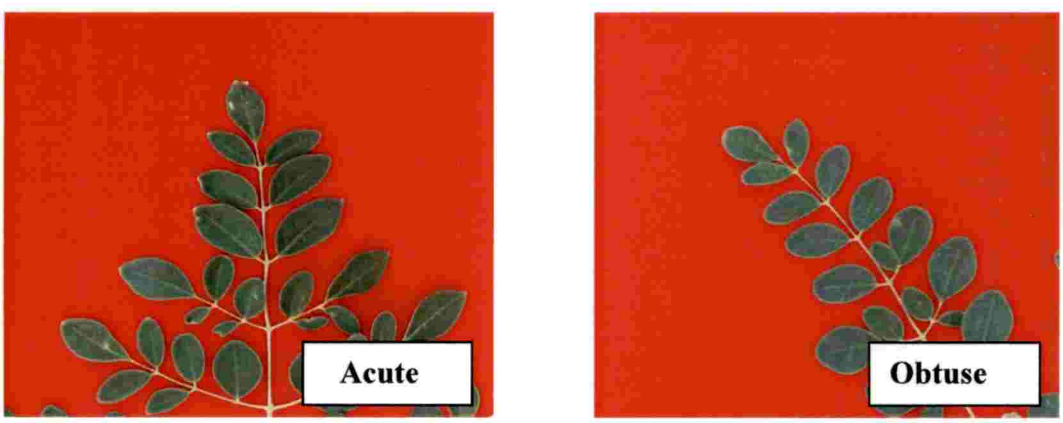

Plate 5. Variability in leaflet apex

Table 3. Contd...

Accession	Calyx shape	Nature of calyx	Calyx colour	Corolla shape	Nature of corolla	Corolla colour	Pulp colour	Pulp taste
VKMo 2	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 3	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Bitter
VKMo 5	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 6	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Bitter
VKMo 7	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 8	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 9	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 10	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 11	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Bitter
VKMo 12	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 13	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Bitter
VKMo 15	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 16	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 17	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 19	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 20	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 21	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 22	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 29	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Bitter
VKMo 30	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 32*	-	-	-	-	-	-	-	-
VKMo 35*	-	-	-	-	-	-	-	-
VKMo 36	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 37	Triangular	Polysepalous	Pale green	Triangular	Polypetalous	Cream	White	Palatable
VKMo 38*	-	-	-	-	-	-	-	-

*Leafy types

57

Table 4. Flowering pattern of drumstick accessions for one calendar year

Accession	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VKMo 2	+	+	+	+	-	-	-	-	+	+	-	-
VKMo 3	+	+	+	-	-		-	-	-	-	-	-
VKMo 5	+	+	-	-	-	-	-	-	-	-	-	-
VKMo 6	+	+	+	-	-	-	-	-	-	-	-	-
VKMo 7	+	+	+	-	-	-	-	-	+	+	-	-
VKMo 8	+	-	-	-	-	-	-	-	-	-	-	-
VKMo 9	+	-	-	-	-	-	-	-	-	-	-	-
VKMo 10	+	-	-	-	-	-	-	-	-	-	-	-
VKMo 11	+	-	-	-	-	-	-	-	-	-	-	-
VKMo 12	+	-	-	-	-	-	-	-	-	+	+	-
VKMo 13	+	+	+	+	-	-	-	-	-	-	-	-
VKMo 15	+	+	+	+	-	-	-	-	-	+	+	-
VKMo 16	+	-	-	-	-	-	-	-	-	+	+	-
VKMo 17	+	-	-	-	-	-	-	-	-	+	+	-
VKMo 19	-	-	+	+	-	-	-	-	-	-	-	-
VKMo 20	+	+	-	-	-	-	-	-	-	-	-	-
VKMo 21	-	-	+	+	-	-	-	-	-	-	-	-
VKMo 22	+	+	-	-	-	-	-	-	-	-	-	-
VKMo 29	+	+	-	-	-	-	-	-	-	-	-	-
VKMo 30	+	+	-	-	-	-	-	-	-	-	-	-
VKMo 36	+	+	+	-	-	-	-	-	-	-	-	-
VKMo 37	+	+	+	-	-	-	-	-	-	-	-	-

Plate 6. Fruit pulp colour - white

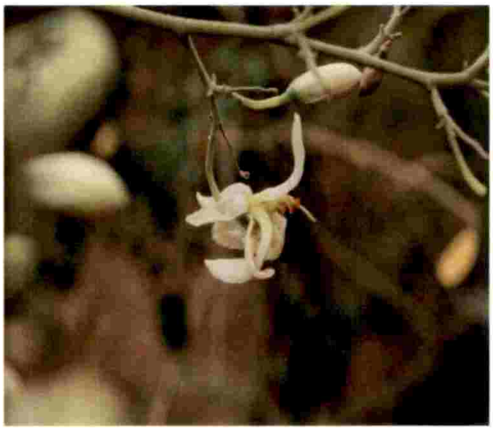

Plate 7. Drumstick flower

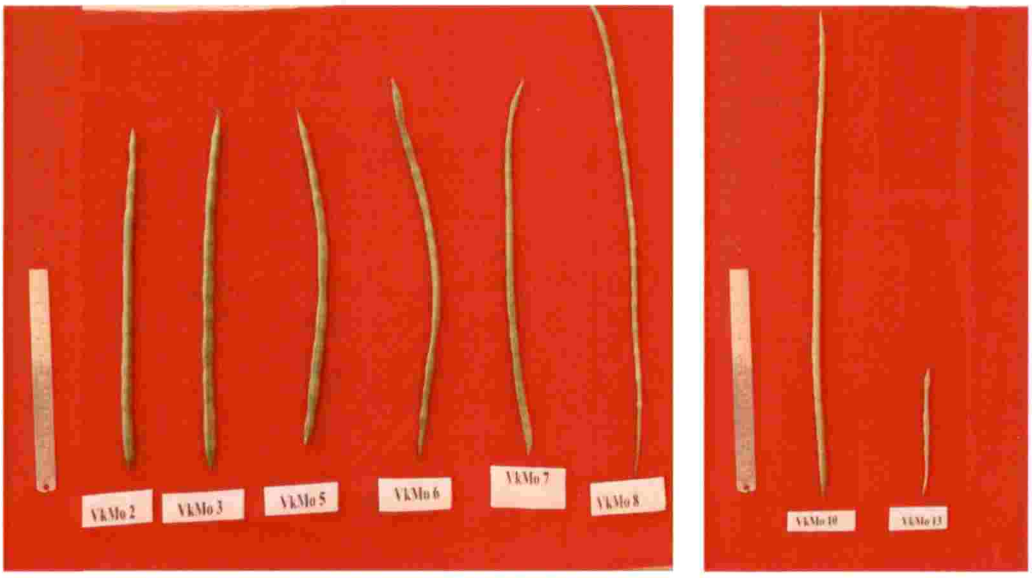

Plate 8. Variability in fruit characters

Table 5. Flowering behaviour of drumstick accessions

Accession	First flowering		Second flowering	
	Start of flowering	End of flowering	Start of flowering	End of flowering
VKMo 2	20-Jan	16-Apr	20-Sep	30-Oct
VKMo 3	18-Jan	20-Mar	-	-
VKMo 5	02-Jan	27-Feb	-	-
VKMo 6	20-Jan	12-Mar	-	-
VKMo 7	26-Jan	21-Mar	15-Sep	21-Oct
VKMo 8	18- Jan	23-Feb	-	-
VKMo 9	22- Jan	14- Feb	-	-
VKMo 10	24- Jan	21- Feb	-	-
VKMo 11	16- Jan	21- Feb	-	-
VKMo 12	21- Jan	10- Feb	05-Oct	27-Nov
VKMo 13	25-Jan	16-Apr	-	-
VKMo 15	26-Jan	25-Apr	06-Oct	27-Nov
VKMo 16	23-Jan	23-Feb	05-Oct	24-Nov
VKMo 17	19-Jan	23-Feb	05-Oct	19-Nov
VKMo 19	07-Mar	25-Apr	-	-
VKMo 20	24-Jan	21-Feb	-	-
VKMo 21	23-Mar	20-Apr	-	-
VKMo 22	13-Jan	02-Feb	-	-
VKMo 29	17-Jan	16-Feb	-	-
VKMo 30	25-Jan	22-Feb	-	-
VKMo 32*	-	-	-	-
VKMo 35*	-	-	-	-
VKMo 36	19-Jan	15-Mar	-	-
VKMo 37	15-Jan	20-Mar	-	-
VKMo 38*	-	-	-	-

*Leafy types

60

4.2 Quantitative characters

Quantitative characters such as, tree height, trunk girth, fruit length, fruit girth, fruit weight, number of ridges per fruit, number of seeds per fruit, number of fruit per tree and fruit yield per tree were recorded in 25 drumstick accessions and presented in the Table 6.

4.2.1 Tree height

Tree height ranged from 2.75 m (VKMo 38) to 7.68 m (VKMo 3). The general mean for tree height was 5.49 m. Nine accessions recorded lower value than the general mean. Accessions *viz*. VKMo 6 (7.13 m), VKMo 11 (7.15 m) and VKMo 3 (7.68 m) recorded higher tree height in that order.

4.2.2 Trunk girth

The trunk girth ranged from 30.50 cm (VKMo 16) to 65.8 cm (VKMo 3). The general mean for trunk girth was 50.59 cm. Thirteen accessions recorded lower value than the general mean. Accessions *viz.* VKMo 15 (61.70 cm), VKMo 5 (64.50 cm) and VKMo 3 (65.8 cm) recorded higher trunk girth in that order.

4.2.3 Fruit length

Length of the fruit ranged from 41.75 cm (VKMo 15) to 89.50cm (VKMo 10). The general mean for fruit length was 63.51 cm. Seventeen accessions recorded lower values than the general mean. Accessions *viz.* VKMo 9 (72.27 cm), VKMo 22 (85.30 cm) and VKMo 10 (89.50 cm) recorded higher fruit length in that order.

4.2.4 Fruit girth

Fruit girth ranged from 4.57 cm (VKMo 29) to 6.72 cm (VKMo 10). General mean for fruit girth was 6.15 cm. Fifteen accessions recorded lower values than the general mean. Accession *viz.* VKMo 11 (6.52 cm), VKMo 9 (6.57 cm), VKMo 6 (6.65 cm) and VKMo 10 (6.72 cm) recorded higher fruit girth in that order.

4.2.5 Fruit weight

Fruit weight ranged from 48.35 g (VKMo 20) to 160.00 g (VKMo 9). The general mean value for fruit weight was 82.53 g. Fifteen accessions recorded lower values than the general mean. Accession *viz.* VKMo 11 (109.37 g), VKMo

10 (100.50 g), VKMo 3 (117.12 g) and VKMo 9 (160.00 g) recorded higher fruit weight in that order.

4.2.6 Number of ridges/fruit

Number of ridges/fruit ranged from 7.20 (VKMo 13) to 10.50 (VKMo 10). General mean for number of ridges of fruit was 8.89. Thirteen accessions recorded lower values than the general mean. Accession *viz.* VKMo 37 (9.50), VKMo 17 (9.60), VKMo 30 (9.60) and VKMo 11 (9.80) recorded higher number of ridges/fruit in that order.

4.2.7 Number of seeds/fruit

Number of seeds per fruit ranged from 13.50 (VKMo 15) to 21.20 (VKMo 6). The general mean value for number of seeds per fruit was 18.45. Nineteen accessions recorded lower values than the general mean value. Accessions *viz.* VKMo 17(20.10), VKMo 7 (20.20), VKMo 10 (20.20), VKMo 3(20.40) and VKMo 6 (21.20) recorded higher number of seeds per fruit in that order.

4.2.8 Number of fruits per tree

Number of fruits ranged from 3.41 (VKMo 10) to 22.21 (VKMo 2). The general mean number for fruits/tree was 10.09. Fourteen accessions recorded lower values than the general mean. Accessions *viz.* VKMo 17 (12.17), VKMo 13 (12.21), VKMo 5 (12.32), VKMo 3 (15.16), VKMo 19 (17.58) and VKMo 2 (22.21) recorded higher number of fruits per tree in that order.

4.2.9 Yield per tree

Total fruit yield/tree ranged from 342.71 g/tree (VKMo 10) to 1775.54 g/tree (VKMo 3). The general mean for yield was 728.47 g/tree. Eleven accessions recorded lower value than general mean. Accessions *viz.* VKMo15 (1006.26 g/tree), VKMo 5 (1063.34 g/tree), VKMo 19 (1309.36 g/tree), VKMo 2 (1685.74 g/tree) and VKMo 3 (1775.54 g/tree) recorded high fruit yield/tree in that order.

Table 6. Mean performance of quantitative characters in drumstick accessions

Accession	Tree height (m)	Trunk girth (cm)	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Number of ridges/fruit	Number of seeds/fruit	Number of fruits/tree	Yield/tree (g/tree)
VKMo 2	4.40	35.80	43.25	6.05	75.90	8.50	15.70	**22.21**	1685.74
VKMo 3	**7.68**	**65.80**	58.33	6.30	117.12	8.80	20.40	15.16	**1775.54**
VKMo 5	6.90	64.50	53.74	6.27	86.31	9.40	15.30	12.32	1063.34
VKMo 6	7.13	47.70	61.50	6.65	106.66	9.50	**21.20**	6.17	658.09
VKMo 7	5.28	53.40	62.25	6.47	97.20	9.20	20.20	10.25	996.30
VKMo 8	3.97	51.20	69.88	5.34	65.00	9.60	16.20	5.14	334.10
VKMo 9	6.37	57.10	72.27	6.57	**160.00**	8.30	18.30	5.32	851.20
VKMo 10	5.10	54.50	**89.50**	**6.72**	100.50	**10.50**	20.20	3.41	342.71
VKMo 11	7.15	59.40	68.27	6.52	109.37	9.80	18.10	6.67	729.50
VKMo 12	5.30	50.00	41.88	5.57	65.27	9.40	17.70	6.55	427.52
VKMo 13	2.82	55.00	50.40	5.15	65.40	7.20	17.60	12.21	798.53
VKMo 15	6.67	61.70	41.75	4.90	95.20	9.00	13.50	10.57	1006.26
VKMo 16	3.90	**30.50**	49.50	5.66	98.80	8.50	18.20	9.23	911.92
VKMo 17	5.74	59.70	46.84	6.12	54.47	9.60	20.10	12.17	662.90
VKMo 19	4.83	55.50	61.32	5.89	74.48	8.70	17.50	17.58	1309.36
VKMo 20	5.40	47.00	51.32	5.87	48.35	8.80	17.10	11.74	567.63
VKMo 21	5.68	48.70	72.14	6.21	58.21	7.90	16.40	6.89	401.07
VKMo 22	6.20	50.40	85.30	6.14	74.61	8.00	18.10	11.2	835.63
VKMo 29	4.80	34.50	51.57	4.57	75.00	9.30	17.20	5.27	395.25
VKMo 30	5.80	49.50	48.07	6.26	92.10	9.60	18.30	8.31	765.35
VKMo 32*	5.52	34.80	-	-	-	-	-	-	-
VKMo 35*	6.21	57.62	-	-	-	-	-	-	-
VKMo 36	6.43	50.70	65.21	6.50	75.29	8.20	18.37	11.87	893.69
VKMo 37	5.20	50.50	66.37	6.00	86.31	9.50	19.14	9.27	800.09
VKMo 38*	**2.75**	39.30	-	-	-	-	-	-	-
Mean	**5.49**	**50.59**	**63.51**	**6.15**	**82.53**	**8.89**	**18.45**	**10.09**	**728.47**
CV	23.04	18.71	20.89	9.42	30.28	8.55	10.05	44.27	46.72
SE	0.25	1.89	2.65	0.12	5.00	0.15	0.37	0.89	77.35

*Leafy types

4.3 Biochemical characters

Biochemical characters *viz.* vitamin C, protein, beta-carotene, calcium, iron and total phenol were recorded for one calendar year in leaves, flowers and fruits of 25 drumstick accessions. Mean performance of biochemical characters in leaves, flowers and fruits of individual accessions for a period of twelve months from January to December is presented in the Table 7.

4.3.1 Vitamin C

Vitamin C content in leaves ranged from 179.58 mg/100 g (VKMo 10) to 260.63 mg/100 g (VKMo 38), which is a leafy type. General mean for the vitamin C content in leaves was 211.60 mg/100 g. Eleven accessions recorded higher value than the general mean. Accessions *viz*. VKMo 17 (243.07 mg/100 g), VKMo 5 (247.41 mg/100 g) and VKMo 38 (260.63 mg/100 g) recorded higher vitamin C content in leaves in that order.

In flowers, vitamin C ranged from 74.06 mg/100 g (VKMo 2) to 153.20 mg/100 g (VKMo 7). General mean for the vitamin C content in flowers was 116.5 mg/100 g. Twelve accessions recorded higher value than the general mean.Accessions *viz*. VKMo 19 (150.00 mg/100 g), VKMo 5 (151.42 mg/100 g) and VKMo 38 (153.20 mg/100 g) recorded higher vitamin C content in flowers in that order.

In fruits, vitamin C ranged from 47.06 mg/100 g (VKMo 8) to 106.66 mg/100 g (VKMo 17). General mean for the vitamin C content in fruits was 73.24 mg/100 g. Fourteen accessions recorded higher value than the general mean. Accessions *viz*. VKMo 12 (93.33 mg/100 g), VKMo 29 (93.33 mg/100 g) and VKMo 17 (106.66 mg/100 g) recorded higher vitamin C content in fruits in that order.

4.3.2 Protein

Protein content in leaves ranged from 15.31 g/100 g (VKMo 10) to 21.07 g/100 g (VKMo 30). The general mean for protein content in leaves was 18.84 g/100 g. Fifteen accessions recorded higher value than the general mean. Leaf type accession VKMo 32, recorded more protein (19.08g/100 g) than the general mean. Accessions *viz.* VKMo 19 (20.73 g/100 g), VKMo 7 (21.00 g/100 g) and VKMo 30 (21.07 g/100 g) recorded higher protein content in leaves in that order.

In flowers, protein ranged from 2.62g/100 g (VKMo 20) to 9.84 g/100 g (VKMo 16). The general mean for protein content in flowers was 5.95 g/100 g. Eleven accessions recorded higher value than the general mean. Accessions *viz.* VKMo 37 (8.48 g/100 g), VKMo 15 (9.33 g/100 g) and VKMo 16 (9.84 g/100 g) recorded higher protein content in flowers in that order.

In fruits, protein ranged from 2.82 g/100 g (VKMo 3) to 8.74 g/100 g (VKMo 21).The general mean for protein content in fruits was 5.74g/100 g. Nine accessions recorded higher value than the general mean. Accessions *viz.*, VKMo 37 (8.34 g/100 g), VKMo 16 (8.37 g/100 g) and VKMo 21 (8.74 g/100 g) recorded higher protein content in fruits in that order.

4.3.3 Beta carotene

Beta- carotene content in leaves ranged from 12.71 mg/100 g (VKMo 5) to 16.95 mg/100 g (VKMo 16). General mean for beta- carotene content was 15.83mg/100 g. Fourteen accessions recorded higher value than the general mean. Leaf type accession VKMo 32, recorded more beta-carotene (16.89 mg/100 g) than the general mean. Accessions *viz.* VKMo 32 (16.89 mg/100 g),VKMo 22(16.93 mg/100 g) and VKMo 16 (16.95 mg/100 g) recorded higher beta-carotene content in leaves in that order.

In flowers, beta carotene ranged from 6.18 mg/100 g (VKMo 17) to 9.77 mg/100 g (VKMo 29). General mean for beta- carotene content was 8.06 mg/100 g. Twelve accessions recorded higher value than the general mean. Accessions *viz.* VKMo 8 (9.31 mg/100 g),VKMo 2 (9.68 mg/100 g) and VKMo 29 (9.77 mg/100 g) recorded higher beta-carotene content in flowers in that order.

In fruits, beta carotene ranged from 9.02 mg/100 g (VKMo 7) to 12.52 mg/100 g (VKMo 19). General mean for beta-carotene content was 10.81 mg/100 g. Eleven accessions recorded higher value than the general mean. Accessions *viz.* VKMo 15 (12.19 mg/100 g),VKMo 5(12.45 mg/100 g) and VKMo 19 (12.52 mg/100 g) recorded higher beta-carotene content in fruits in that order.

4.3.4 Calcium

Calcium content in leaves ranged from 937.68 mg/100 g (VKMo 20) to 1330.21 mg/100 g (VKMo 8). The general mean for calcium content in leaves was 1130.41 mg/100 g. Ten accessions recorded higher values than the general mean. Leaf type accession VKMo 35 (1184.02 mg/100 g) and VKMo 38 (1262.80 mg/100 g) recorded more calcium than the general mean. Accessions *viz*. VKMo 6 (1292.08 mg/100 g),VKMo 13 (1312.75 mg/100 g) and VKMo 8 (1330.21 mg/100 g) recorded higher calcium content in leaves in that order.

In flowers, calcium content ranged from 289.37 mg/100 g (VKMo 22) to 688.28 mg/100 g (VKMo 37).The general mean for calcium content was 505.60 mg/100 g. Twelve accessions recorded higher values than the general mean. Accessions *viz*. VKMo 11 (633.84mg/100 g),VKMo 19 (668.27mg/100 g) and VKMo 37 (688.28 mg/100 g) recorded higher calcium content in flowers in that order.

In fruits, calcium content ranged from 304.00 mg/100 g (VKMo 37) to 586.71 mg/100 g (VKMo 30). The general mean for calcium content was 436.17 mg/100 g. Eleven accessions recorded higher values than the general mean. Accessions *viz*. VKMo 19 (554.89 mg/100 g),VKMo 13 (557.23 mg/100 g) and VKMo 30 (586.71 mg/100 g) recorded higher calcium content in fruits in that order.

4.3.5 Iron

Iron content in leaves ranged from 14.89 mg/100 g (VKMo 10) to 22.55 mg/100 g (VKMo 22). General mean for iron content in leaves was 18.85 mg/100 g and fifteen accessions recorded higher values than the general mean. Leaf type accessions VKMo 35 recorded more iron (19.85 mg/100 g) than the general mean. Accessions *viz*. VKMo 6 (21.25 mg/100 g),VKMo 2 (22.09 mg/100 g) and VKMo 22 (22.55 mg/100 g) recorded higher iron content in leaves in that order.

In flowers, iron content ranged from 15.54mg/100 g (VKMo 29) to 25.55 mg/100 g (VKMo 36). The general mean for iron content was 18.85 mg/100 g. Fifteen accessions recorded higher values than the general mean. Accessions *viz*.

VKMo 2 (24.57 mg/100 g),VKMo 8 (25.40 mg/100 g) and VKMo 36 (25.55 mg/100 g) recorded higher iron content in flowers in that order.

In fruits, iron content ranged from 8.43mg/100 g (VKMo 36) to 17.68mg/100 g (VKMo 5). The general mean for calcium content was 12.17mg/100 g. Ten accessions recorded higher values than the general mean. Accessions *viz*. VKMo 2 (14.76 mg/100 g),VKMo 6 (17.46 mg/100 g) and VKMo 5 (17.68 mg/100 g) recorded higher iron content in fruits in that order.

4.3.6 Total phenol

Total phenol content in leaves ranged from 113.21/100 g (VKMo 29) to 123.17 mg/100 g (VKMo 5). The general mean for total phenol content in leaves was 118.31 mg/100 g. Twelve accessions recorded higher values than the general mean. All leaf type accessions recorded lower total phenol content than the general mean. Accessions *viz*. VKMo 6 (121.19 mg/100 g),VKMo 3 (122.73 mg/100 g) and VKMo 5 (123.17 mg/100 g) recorded higher total phenol content in leaves in that order.

In flowers, total phenol content ranged from 15.01 mg/100 g (VKMo 7) to 20.18 mg/100 g (VKMo 19). The general mean for total phenol content was 17.68 mg/100 g. Eleven accessions recorded higher values than the general mean. Accessions *viz*. VKMo 9 (19.58 mg/100 g),VKMo 15 (20.09 mg/100 g) and VKMo 19 (20.18 mg/100 g) recorded higher total phenol content in flowers in that order.

In fruits, total phenol content ranged from 13.23 mg/100 g (VKMo 13) to 23.19 mg/100 g (VKMo 17). The general mean for total phenol content was 18.14 mg/100 g. Nine accessions recorded higher values than the general mean. Accessions *viz*. VKMo 16 (21.34 mg/100 g), VKMo 37 (22.19 mg/100 g) and VKMo 17 (23.19 mg/100 g) recorded higher total phenol content in fruits in that order.

Table 7. Mean performance of biochemical characters in drumstick accessions

Accession	Vitamin C (mg/100 g)			Protein (g/100 g)			Beta carotene (mg/100 g)		
	Leaf	Flower	Fruit	Leaf	Flower	Fruit	Leaf	Flower	Fruit
VKMo 2	202.06	74.06	54.85	19.01	6.09	6.60	15.37	9.68	11.10
VKMo 3	205.16	117.69	67.48	18.68	5.93	2.82	14.31	8.50	10.96
VKMo 5	247.41	151.42	53.32	18.04	4.28	5.86	12.71	7.20	12.45
VKMo 6	219.23	141.22	80.81	17.45	5.95	3.74	14.18	6.90	10.70
VKMo 7	237.39	**153.20**	80.81	21.00	6.60	5.09	15.26	8.35	9.02
VKMo 8	227.11	102.04	47.06	19.17	5.07	5.30	15.43	9.31	10.82
VKMo 9	214.03	87.03	70.61	17.92	6.28	3.93	16.69	7.55	9.57
VKMo 10	179.58	127.14	53.32	15.31	4.19	4.28	16.43	6.30	10.51
VKMo 11	209.46	81.63	80.81	17.31	5.06	4.52	14.75	8.42	11.04
VKMo 12	231.11	130.18	93.33	19.17	6.55	3.88	15.83	7.87	10.93
VKMo 13	226.89	124.83	83.94	16.94	5.34	6.03	16.12	7.36	12.04
VKMo 15	197.21	108.15	54.85	19.44	9.33	7.82	16.30	8.99	12.19
VKMo 16	196.63	112.94	79.99	20.56	**9.84**	8.37	**16.95**	7.24	9.63
VKMo 17	243.07	140.39	**106.66**	19.13	8.20	4.78	16.10	6.18	9.54
VKMo 19	196.93	150.00	75.00	20.73	4.57	8.33	16.04	9.14	**12.52**
VKMo 20	215.64	119.04	61.22	19.55	2.62	3.86	15.70	8.42	11.18
VKMo 21	189.61	125.00	75.00	20.61	6.52	**8.74**	15.89	8.15	12.21
VKMo 22	183.39	134.14	81.63	19.14	7.41	5.37	16.93	7.06	9.88
VKMo 29	184.73	98.23	93.33	20.14	3.13	7.30	16.62	**9.77**	10.19
VKMo 30	209.08	102.05	57.27	**21.07**	4.37	5.89	16.75	8.90	11.44
VKMo 32*	210.70	-	-	19.08	-	-	16.89	-	-
VKMo 35*	190.06	-	-	17.95	-	-	15.16	-	-
VKMo 36	215.65	102.04	79.99	18.34	5.11	5.37	16.01	7.56	10.24
VKMo 37	197.25	81.63	79.99	18.49	8.48	8.34	16.56	8.47	9.76
VKMo 38*	**260.63**	-	-	16.87	-	-	15.73	-	-
Mean	**211.60**	**116.55**	**73.24**	**18.84**	**5.95**	**5.74**	**15.83**	**8.06**	**10.81**
CV	10.02	20.31	21.10	7.60	31.40	30.79	6.36	12.69	9.51
SE	4.23	5.04	3.29	0.28	0.39	0.37	0.20	0.21	0.21

*Leafy types

Table 7. Contd...

Accession	Calcium (mg/100 g)			Iron (mg/100 g)			Total phenol (mg/100 g)		
	Leaf	Flower	Fruit	Leaf	Flower	Fruit	Leaf	Flower	Fruit
VKMo 2	1105.51	438.86	541.15	22.09	24.57	14.76	120.85	17.48	16.67
VKMo 3	1121.50	422.66	458.41	19.59	17.44	14.13	122.73	18.30	16.63
VKMo 5	1223.57	554.25	479.69	19.88	15.27	**17.68**	**123.17**	18.74	19.93
VKMo 6	1292.08	568.25	461.91	21.25	18.31	17.46	121.19	17.88	16.55
VKMo 7	1106.82	511.05	349.88	20.77	19.19	10.40	118.82	15.01	17.69
VKMo 8	**1330.21**	314.84	402.55	16.49	25.40	10.73	120.69	15.37	17.98
VKMo 9	1167.67	512.29	353.80	19.52	15.23	11.50	119.55	19.58	14.63
VKMo 10	1093.36	478.27	377.18	14.89	20.48	14.27	120.16	16.45	15.27
VKMo 11	1043.70	633.84	482.52	16.48	19.64	11.39	117.91	17.99	17.00
VKMo 12	1226.60	633.81	377.38	16.90	18.76	8.61	114.61	15.58	14.68
VKMo 13	1312.75	498.88	557.23	18.81	18.62	10.81	117.02	16.67	13.23
VKMo 15	1056.84	293.84	543.07	17.60	21.56	11.14	118.88	20.09	17.51
VKMo 16	972.55	523.36	356.75	18.58	21.12	11.27	117.89	16.44	21.34
VKMo 17	1211.58	625.11	340.25	19.25	18.66	10.15	118.62	19.88	**23.19**
VKMo 19	1110.42	668.27	554.89	18.05	17.49	14.28	115.39	**20.18**	20.23
VKMo 20	937.68	471.09	494.53	20.23	23.50	12.03	116.65	18.91	16.40
VKMo 21	1109.01	384.17	341.75	20.22	16.32	9.80	118.46	19.00	20.74
VKMo 22	1019.41	289.37	447.82	**22.55**	17.34	14.22	117.30	17.22	17.38
VKMo 29	1072.92	457.24	364.50	19.38	15.54	13.28	113.21	16.25	19.86
VKMo 30	1145.60	571.08	**586.71**	18.37	18.37	12.36	115.51	17.62	20.19
VKMo 32*	1060.62	-	-	15.76	-	-	117.59	-	-
VKMo 35*	1184.02	-	-	19.85	-	-	114.74	-	-
VKMo 36	1108.15	584.38	419.75	17.03	**25.55**	8.43	114.30	15.40	19.73
VKMo 37	984.78	**688.28**	304.00	19.49	20.35	9.15	117.44	18.48	22.19
VKMo 38*	1262.80	-	-	18.24	-	-	118.11	-	-
Mean	**1130.41**	**505.60**	**436.17**	**18.85**	**19.49**	**12.17**	**118.31**	**17.68**	**18.14**
CV	9.32	22.94	19.51	10.14	15.89	21.10	2.18	9.12	14.50
SE	21.07	24.73	18.15	0.38	0.66	0.54	0.51	0.34	0.56

*Leafy types

69

4.4 Monthly trend of biochemical characters

Drumstick is a hardy crop which flushes and flowers during dry season. It was observed that unlike other crops, drumstick exhibited yellowing and falling of leaves in rainy season. In Kerala, drumstick shows extensive leaf falling in the monsoon which may have some physiological mechanism responsible for this. Therefore, biochemical characters *viz.* vitamin C, protein, beta-carotene, calcium, iron and total phenol contents were estimated over a period of one calendar year in the leaves of various accessions. Monthly mean of each character in the leaves of drumstick accessions was tabulated and presented in the Table 8 to Table 13.

In drumstick leaves, highest mean vitamin C content was recorded in December (307.84 mg/100 g) followed by November (270.00 mg/100 g). Lowest vitamin C content was recorded in May (154.50 mg/100 g) as shown in the Table.8

Highest mean protein content in drumstick leaves was recorded in December (20.84 g/100 g) followed by September (20.50 g/100 g). Lowest protein content was recorded in May (16.20 g/100 g) as shown in the Table.9.

Highest mean beta-carotene content in drumstick leaves was recorded in September (16.54 mg/100 g) followed by November (16.52 mg/100 g). Lowest beta-carotene content was recorded in May (15.10 mg/100 g) as shown in the Table.10.

Highest mean calcium content in drumstick leaves was recorded in April (1565.97 mg/100 g) followed by March (1304.69 mg/100 g). Lowest calcium content was recorded in August (658.39 mg/100 g) as shown in the Table.11.

Highest mean iron content in drumstick leaves was recorded in August (22.34 mg/100 g) followed by July (21.53 mg/100 g). Lowest iron content was recorded in May (13.31 mg/100 g) as shown in the Table.12.

Highest mean total phenol content in drumstick leaves was recorded in September (124.83 mg/100 g) followed by October (122.90 mg/100 g). Lowest total phenol content was recorded in May (111.19 mg/100 g) as shown in the Table.13.

Table 8. Monthly trend of vitamin C in the leaves of drumstick accessions

Accession	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VKMo 2	224.48	213.22	200.00	211.74	186.66	171.20	163.26	148.14	127.66	275.86	300.00	202.53
VKMo 3	204.08	186.66	175.00	188.24	164.71	142.85	163.26	185.18	297.87	275.86	225.00	253.16
VKMo 5	265.30	239.90	275.00	258.83	204.08	199.50	265.30	185.18	255.32	241.37	250.00	329.11
VKMo 6	163.26	186.66	175.00	64.71	142.85	171.20	224.48	359.25	297.87	241.37	275.00	329.11
VKMo 7	224.48	213.22	200.00	211.77	164.71	171.50	224.48	259.25	340.43	310.34	250.00	278.48
VKMo 8	265.30	186.66	225.00	235.30	186.66	171.20	183.67	185.18	297.87	310.34	225.00	253.16
VKMo 9	163.26	186.66	175.00	188.24	164.71	142.85	224.48	296.29	297.87	275.86	200.00	253.16
VKMo 10	102.04	133.33	150.00	164.71	133.33	114.00	102.04	111.11	340.43	275.86	275.00	253.16
VKMo 11	102.04	159.99	175.00	164.71	142.85	142.85	163.26	148.14	425.53	310.34	275.00	303.79
VKMo 12	183.67	213.22	225.00	211.77	204.08	171.20	224.48	222.22	297.87	241.37	300.00	278.48
VKMo 13	183.67	186.66	200.00	211.77	186.66	199.50	183.67	185.18	255.32	275.86	300.00	354.42
VKMo 15	163.26	159.99	175.00	164.71	133.33	114.00	224.48	333.33	212.77	206.89	175.00	303.79
VKMo 16	163.26	186.66	175.00	188.24	142.85	171.00	183.67	185.18	127.66	206.89	300.00	329.11
VKMo 17	204.08	239.90	200.00	211.77	204.08	199.50	183.67	296.29	297.87	275.86	300.00	303.79
VKMo 19	142.85	133.33	150.00	117.65	116.66	85.50	163.26	185.18	297.87	241.37	275.00	354.42
VKMo 20	163.26	186.66	175.00	164.71	142.85	114.00	204.08	481.48	170.21	206.89	300.00	278.48
VKMo 21	183.70	159.99	150.00	141.18	133.33	114.00	183.67	228.22	170.21	206.89	275.00	329.11
VKMo 22	163.26	186.66	150.00	164.71	106.66	85.50	142.85	222.22	127.66	172.41	275.00	303.79
VKMo 29	183.67	213.33	200.00	188.24	133.33	114.00	183.67	444.44	255.32	241.37	325.00	354.42
VKMo 30	142.85	186.66	175.00	164.71	133.33	142.85	225.48	259.25	255.32	310.34	300.00	253.16
VKMo 32	102.04	106.66	125.00	117.65	106.66	185.50	183.67	222.22	212.77	275.86	275.00	303.79
VKMo 35	224.48	239.90	200.00	188.24	142.85	164.71	204.08	222.22	127.66	241.37	275.00	278.48
VKMo 36	163.26	133.33	125.00	117.61	106.66	85.50	204.08	222.22	255.32	241.37	275.00	278.48
VKMo 37	204.08	213.32	225.00	235.30	204.08	171.00	183.67	111.11	170.21	206.89	300.00	303.79
VKMo 38	224.48	213.32	225.00	211.77	186.66	142.85	98.67	74.07	255.32	241.37	275.00	329.11
Mean	**181.22**	**184.50**	**183.00**	**178.55**	**154.50**	**161.22**	**185.04**	**223.49**	**251.91**	**257.93**	**270.00**	**307.84**
CV	24.40	19.07	19.21	25.54	22.30	18.15	19.84	44.19	31.57	15.49	12.82	15.51
SE	8.84	7.04	7.03	9.12	6.89	5.85	7.34	19.75	15.91	7.99	6.92	9.55

Table 9. Monthly trend of protein in the leaves of drumstick accessions

Accession	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VKMo 2	18.36	16.61	16.13	15.52	15.82	18.41	20.78	25.20	18.01	21.95	21.25	20.13
VKMo 3	18.80	18.37	15.70	12.65	15.26	19.72	18.90	22.11	21.42	22.41	20.01	18.78
VKMo 5	19.57	16.01	17.19	16.08	17.86	17.24	19.03	19.51	18.07	18.75	18.52	18.69
VKMo 6	17.34	14.91	16.44	16.40	16.70	18.76	18.08	18.31	17.38	17.61	16.19	17.33
VKMo 7	18.69	19.77	15.92	15.41	20.08	24.40	24.74	24.25	23.03	22.73	22.09	20.90
VKMo 8	19.53	19.69	18.43	16.45	16.68	18.45	18.97	20.42	21.51	20.02	20.31	19.62
VKMo 9	16.46	16.83	15.36	16.67	13.69	18.11	18.18	19.06	20.08	19.84	17.57	17.18
VKMo 10	15.41	12.62	13.17	13.31	12.47	13.74	16.43	17.08	17.54	17.56	15.58	15.87
VKMo 11	18.64	15.95	15.41	15.82	13.43	15.15	18.60	18.73	20.40	17.17	17.67	17.79
VKMo 12	19.23	19.51	16.46	15.45	16.28	19.35	20.78	20.18	21.15	20.20	20.64	20.75
VKMo 13	17.26	17.67	13.81	13.99	12.94	16.18	18.00	18.12	18.41	17.91	17.35	17.66
VKMo 15	18.41	16.38	16.22	15.35	15.91	18.26	22.05	22.94	22.67	21.62	22.90	20.51
VKMo 16	20.48	20.13	17.72	17.96	18.66	19.19	18.85	23.94	23.27	22.39	22.25	21.93
VKMo 17	19.39	20.91	17.14	17.75	15.21	18.19	19.52	19.30	19.50	19.96	20.82	21.84
VKMo 19	20.41	17.01	18.87	17.24	18.09	20.19	22.97	23.66	23.61	22.66	22.70	21.39
VKMo 20	20.89	18.88	18.60	17.29	17.43	18.74	20.73	21.20	20.28	21.41	19.66	19.44
VKMo 21	21.08	21.87	19.15	19.34	18.82	19.11	19.47	23.11	22.92	20.82	21.18	20.47
VKMo 22	20.48	17.39	16.48	16.14	14.99	17.17	20.85	22.68	22.49	21.48	21.10	20.40
VKMo 29	19.87	19.06	18.84	18.41	18.71	20.14	20.60	24.83	22.87	22.09	20.90	19.24
VKMo 30	19.32	18.17	18.76	17.01	17.38	19.13	22.26	25.15	23.69	23.55	24.21	20.01
VKMo 32	21.04	21.26	17.08	16.94	16.88	17.13	19.49	19.79	22.42	23.89	23.40	22.36
VKMo 35	23.65	23.50	19.41	19.61	18.12	16.81	22.74	21.01	22.53	22.75	21.34	21.32
VKMo 36	19.14	19.82	18.71	18.95	17.00	20.74	22.18	23.80	23.63	24.73	24.84	22.94
VKMo 37	21.72	19.38	18.78	18.54	17.51	17.16	19.60	22.75	19.86	18.74	19.36	19.57
VKMo 38	17.31	16.12	16.03	15.68	17.49	16.81	17.62	17.83	20.56	17.67	17.43	17.55
Mean	**18.97**	**18.17**	**16.90**	**16.35**	**16.20**	**17.98**	**19.64**	**20.41**	**20.50**	**19.99**	**20.04**	**20.84**
CV	10.93	13.20	9.52	10.03	11.75	11.60	10.71	11.79	10.02	10.34	11.08	6.60
SE	0.41	0.48	0.32	0.33	0.38	0.42	0.42	0.48	0.41	0.41	0.44	0.28

Table 10. Monthly trend of beta-carotene in the leaves of drumstick accessions

Accession	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VKMo 2	4.33	4.07	4.11	4.89	4.24	4.36	5.57	6.62	6.58	6.34	6.53	6.76
VKMo 3	2.71	3.87	3.14	3.78	2.90	2.84	2.67	5.90	5.62	6.32	5.35	6.67
VKMo 5	2.19	2.53	1.43	2.91	1.17	2.14	3.81	2.89	4.22	3.69	3.54	2.01
VKMo 6	3.91	4.03	3.98	4.16	3.23	4.21	5.17	3.68	4.49	4.61	4.81	3.91
VKMo 7	4.71	4.05	4.52	4.38	4.81	5.50	6.41	4.94	6.82	5.26	5.92	5.82
VKMo 8	5.35	4.42	4.54	4.71	4.52	5.17	5.98	5.98	6.19	6.00	6.17	6.15
VKMo 9	6.38	6.92	6.52	6.92	6.04	6.51	6.58	6.52	6.94	7.03	7.18	6.78
VKMo 10	6.48	5.11	5.72	5.26	5.32	6.50	6.59	7.83	6.05	7.09	7.53	7.67
VKMo 11	4.80	4.01	4.46	4.51	3.62	5.12	5.38	4.07	5.77	4.94	5.46	4.86
VKMo 12	5.39	5.71	5.36	5.67	5.49	5.98	5.93	5.11	6.49	6.41	6.38	5.98
VKMo 13	5.93	5.86	5.33	5.43	5.87	6.32	6.16	5.97	6.73	6.76	6.92	6.13
VKMo 15	6.32	5.17	5.18	5.17	5.63	6.55	7.12	6.78	7.62	6.99	6.68	6.37
VKMo 16	6.13	6.73	6.16	6.18	6.05	6.60	6.82	7.33	7.91	7.69	7.93	7.87
VKMo 17	5.16	5.27	5.03	5.23	5.12	6.39	7.07	6.58	7.37	6.91	6.30	6.73
VKMo 19	6.49	7.17	6.85	6.97	6.90	6.33	6.67	7.28	6.95	7.47	7.58	7.86
VKMo 20	5.11	5.00	5.19	5.27	5.12	5.18	5.17	5.78	6.88	6.72	6.79	6.13
VKMo 21	5.26	5.39	5.82	5.38	5.18	5.34	5.77	6.37	6.37	6.57	6.92	6.34
VKMo 22	6.37	6.28	6.09	6.32	6.25	6.78	7.03	7.43	7.16	7.89	8.15	7.44
VKMo 29	6.78	6.18	6.78	6.99	6.47	6.55	7.20	6.87	7.32	6.91	7.18	6.66
VKMo 30	5.18	5.43	5.54	5.66	5.12	6.57	6.72	5.84	6.83	5.84	6.19	5.91
VKMo 32	5.89	5.69	6.90	5.76	5.72	6.31	6.42	7.44	6.81	7.65	7.48	7.41
VKMo 35	6.34	6.44	6.28	6.46	6.16	6.72	7.41	6.77	7.38	6.66	7.46	6.91
VKMo 36	4.31	5.38	5.15	5.31	4.08	4.39	5.17	5.16	5.46	5.68	5.82	5.35
VKMo 37	6.23	6.78	6.39	6.72	6.13	6.71	7.12	6.95	7.37	7.57	7.31	7.45
VKMo 38	5.87	6.39	6.17	6.38	5.73	6.41	6.73	5.68	6.78	6.38	6.37	6.16
Mean	**15.33**	**15.37**	**15.28**	**15.46**	**15.10**	**15.60**	**16.03**	**16.01**	**16.54**	**16.42**	**16.52**	**16.27**
CV	8.12	8.13	6.54	6.59	5.49	6.67	7.62	7.27	8.35	8.06	6.62	7.68
SE	0.26	0.26	0.21	0.22	0.18	0.21	0.24	0.22	0.25	0.25	0.20	0.24

Table 11. Monthly trend of calcium in the leaves of drumstick accessions

Accession	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VKMo 2	718.75	1853.13	1543.50	1739.50	1005.25	1647.75	853.00	669.50	1071.25	645.00	753.50	766.00
VKMo 3	1743.75	1643.75	1196.25	1259.25	1369.50	783.50	1108.25	228.00	754.50	677.25	1701.75	992.25
VKMo 5	1993.75	1946.88	1734.00	998.50	1072.25	1192.25	849.25	327.50	857.75	1567.50	1448.00	695.25
VKMo 6	1918.75	1425.00	1110.00	2419.75	1189.25	983.00	1364.50	496.50	950.50	1054.75	1738.50	854.50
VKMo 7	1264.06	1093.75	1395.50	1214.75	1533.50	1143.00	591.75	499.50	1648.25	904.25	1388.50	605.00
VKMo 8	1476.56	1731.25	969.25	1520.50	1361.75	1188.00	2015.50	1488.00	1125.50	836.50	1234.00	1015.75
VKMo 9	1362.50	1412.50	897.00	2175.25	1248.50	1406.75	937.00	683.75	1272.50	778.50	1023.25	814.50
VKMo 10	1437.50	1371.88	1186.25	1205.25	1036.50	886.75	1530.50	658.75	1004.25	1057.50	931.75	813.50
VKMo 11	1190.63	887.50	1867.75	1724.25	1320.50	800.25	741.00	401.25	883.50	1059.00	911.25	737.50
VKMo 12	1384.38	1446.88	1302.75	1337.25	893.00	1017.25	908.50	718.00	1278.50	1307.50	2122.50	1002.75
VKMo 13	1353.13	1434.38	1665.00	2720.25	1225.25	1463.25	1255.25	829.00	1429.50	636.75	804.25	937.00
VKMo 15	1273.44	1259.38	1364.75	964.25	1123.25	1132.75	1288.50	262.00	1032.00	1025.00	1257.50	699.25
VKMo 16	1226.56	1306.25	1371.75	1395.25	1093.75	1248.50	735.25	483.50	801.50	679.75	726.00	602.50
VKMo 17	1342.19	1237.50	1267.75	1433.25	1238.50	1035.50	1955.50	799.50	1203.75	752.50	1274.50	998.50
VKMo 19	1193.75	1600.00	951.25	1059.00	1100.25	1363.00	1335.25	1022.50	870.00	1036.50	942.75	850.75
VKMo 20	1239.06	903.13	1134.25	1199.00	1097.25	531.25	936.25	457.00	719.75	718.00	1350.00	967.25
VKMo 21	1462.50	1009.38	748.25	1322.50	1706.25	1339.75	1306.50	830.50	1358.25	720.25	769.50	734.50
VKMo 22	1445.31	1065.63	951.50	1425.25	1264.50	899.00	1158.00	534.75	1053.25	603.25	1040.25	792.25
VKMo 29	1350.00	828.13	895.25	1642.50	1608.50	1131.25	1361.25	863.00	793.25	711.75	619.75	857.25
VKMo 30	1384.38	956.25	1034.25	1881.00	1450.25	966.75	1201.50	410.25	1219.00	1436.25	849.25	899.75
VKMo 32	1370.31	937.50	1196.25	2256.00	1161.00	1562.00	479.50	578.00	973.25	721.75	804.75	834.75
VKMo 35	1259.38	1121.88	905.75	1820.50	1245.25	1785.75	684.50	867.00	1142.75	944.50	967.00	1003.00
VKMo 36	1367.19	918.75	1941.75	1897.75	1173.75	1741.50	684.50	1077.50	1284.50	861.75	928.00	1002.00
VKMo 37	1407.81	803.13	1379.75	1944.00	1094.25	1661.00	878.50	297.50	965.25	613.75	862.25	820.25
VKMo 38	1282.81	853.13	1010.25	953.00	1425.50	1237.00	951.00	442.50	942.00	630.00	939.00	799.50
Mean	**1369.56**	**1265.41**	**1304.69**	**1565.97**	**1214.84**	**1255.64**	**1115.21**	**658.39**	**1079.78**	**864.63**	**1060.49**	**810.26**
CV	17.93	25.07	25.13	29.21	18.66	27.67	34.75	45.55	23.22	27.08	38.16	19.12
SE	49.12	63.44	65.57	91.50	45.33	69.48	77.51	59.98	50.15	46.83	80.93	30.99

Table 12. Monthly trend of iron in the leaves of drumstick accessions

Accession	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VKMo 2	31.95	35.65	27.63	28.20	14.53	20.50	19.03	14.28	28.75	12.53	11.88	31.95
VKMo 3	27.00	39.25	18.40	24.15	12.10	16.35	10.88	15.40	23.45	9.68	10.00	27.00
VKMo 5	26.63	18.40	19.45	19.08	11.53	31.38	11.38	16.98	21.70	10.75	9.70	26.63
VKMo 6	22.35	38.00	21.63	20.33	13.60	29.38	12.08	31.78	13.48	11.05	9.98	22.35
VKMo 7	28.63	38.93	18.03	20.38	11.65	11.00	12.65	20.28	13.95	9.05	8.10	28.63
VKMo 8	26.78	12.38	19.55	17.70	12.85	11.33	11.80	14.38	11.78	9.90	9.70	26.78
VKMo 9	28.43	18.60	17.23	18.73	12.53	12.70	11.78	14.78	13.45	12.35	8.43	28.43
VKMo 10	25.45	19.65	23.48	24.90	29.70	11.20	11.40	19.53	14.40	11.28	9.20	25.45
VKMo 11	23.40	17.23	20.25	21.08	13.55	11.98	10.40	18.68	15.45	13.00	8.00	23.40
VKMo 12	24.98	33.95	22.75	20.98	13.40	9.88	15.80	17.48	18.93	11.70	9.95	24.98
VKMo 13	26.53	39.58	25.15	22.75	15.08	12.83	21.80	19.53	22.80	10.05	8.28	26.53
VKMo 15	23.80	38.65	24.40	20.08	14.33	12.23	10.55	32.68	22.65	10.35	9.68	23.80
VKMo 16	27.68	22.68	25.58	22.38	14.18	12.03	10.83	16.75	18.03	9.93	9.30	27.68
VKMo 17	30.15	27.93	23.35	23.35	11.73	9.75	11.78	16.73	13.35	10.95	9.45	30.15
VKMo 19	24.20	37.63	17.45	28.23	12.50	11.23	18.75	19.20	11.18	9.80	9.28	24.20
VKMo 20	23.50	32.90	19.88	24.35	13.10	9.10	14.25	14.83	13.45	11.63	9.25	23.50
VKMo 21	23.68	24.80	21.70	12.36	12.28	10.73	14.53	17.50	18.32	10.08	8.20	23.68
VKMo 22	24.80	33.18	24.38	21.93	8.88	10.35	12.08	15.85	15.85	11.25	9.48	24.80
VKMo 29	25.65	26.60	26.55	19.08	12.63	10.95	12.30	18.61	18.60	9.78	9.78	25.65
VKMo 30	24.63	38.88	26.10	18.10	11.38	11.88	11.65	16.80	16.80	11.95	10.48	24.63
VKMo 32	24.28	38.28	17.08	19.23	14.43	12.88	16.43	15.38	15.38	9.88	9.10	24.28
VKMo 35	21.43	37.50	27.55	18.65	13.73	14.25	20.08	14.88	14.88	10.05	9.23	21.43
VKMo 36	23.70	22.95	26.93	19.45	12.18	10.30	14.13	16.48	16.48	9.90	10.48	23.70
VKMo 37	28.15	25.23	22.43	21.00	13.05	11.35	15.55	16.58	16.58	10.68	11.13	28.15
VKMo 38	27.38	24.38	16.13	22.55	14.00	11.10	15.05	13.18	13.18	10.13	9.38	27.38
Mean	**20.44**	**19.93**	**18.04**	**15.84**	**13.31**	**17.14**	**21.53**	**22.34**	**20.75**	**19.18**	**18.58**	**19.14**
CV	17.30	17.75	14.77	16.79	12.34	28.11	16.98	18.67	21.27	19.16	17.32	18.57
SE	0.71	0.71	0.53	0.53	0.33	0.96	0.73	0.83	0.88	0.73	0.64	0.71

Table 13. Monthly trend of total phenol in the leaves of drumstick accessions

Accession	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VKMo 2	121.80	128.59	113.51	110.07	110.70	117.13	122.18	123.23	125.08	124.22	125.13	128.62
VKMo 3	126.14	126.19	117.06	113.57	112.77	120.29	126.56	127.18	127.99	123.35	125.41	126.24
VKMo 5	129.77	129.62	116.35	117.30	114.01	115.82	119.18	125.60	128.10	124.26	128.99	129.06
VKMo 6	122.90	115.28	115.44	110.22	115.92	117.65	125.70	128.62	130.96	122.37	124.36	124.84
VKMo 7	123.46	121.34	111.99	111.97	110.51	115.58	118.74	119.82	121.97	122.96	126.37	121.08
VKMo 8	119.31	118.01	117.64	117.76	117.03	114.50	121.87	125.68	128.19	125.10	121.28	121.96
VKMo 9	119.27	121.07	118.47	116.50	114.90	114.93	115.42	124.60	126.62	124.10	119.31	119.45
VKMo 10	121.51	118.48	120.80	115.95	110.22	115.12	119.28	124.74	125.52	125.33	123.69	121.26
VKMo 11	118.26	118.28	117.74	115.26	109.98	116.32	118.70	121.10	122.36	120.67	118.09	118.12
VKMo 12	115.47	111.32	109.50	109.60	108.13	111.89	115.06	120.11	122.44	118.06	117.21	116.56
VKMo 13	116.98	112.30	111.75	113.29	107.91	112.99	119.20	120.24	122.20	123.80	122.60	120.97
VKMo 15	117.53	115.19	116.77	117.42	115.43	110.27	116.52	125.49	130.64	123.06	119.43	118.77
VKMo 16	118.80	119.31	111.75	109.26	108.04	117.92	116.88	123.84	122.85	122.59	121.02	122.45
VKMo 17	121.00	111.78	115.56	110.64	115.24	116.01	116.73	120.56	128.71	123.68	122.36	121.13
VKMo 19	118.80	113.05	117.44	116.56	108.83	111.53	118.51	121.93	126.73	126.36	122.89	118.02
VKMo 20	121.21	122.66	112.58	112.01	115.91	116.20	120.42	126.50	129.23	125.54	124.86	120.69
VKMo 21	117.13	120.35	117.02	116.52	114.10	112.88	115.61	121.86	117.03	124.18	125.40	119.45
VKMo 22	115.64	112.45	109.32	105.28	105.16	114.21	122.85	122.96	129.06	124.04	123.73	122.95
VKMo 29	111.82	111.37	113.56	114.08	107.60	112.53	112.68	112.48	119.98	114.23	114.40	113.84
VKMo 30	115.99	119.32	119.97	105.42	109.26	107.67	109.16	116.20	122.75	124.36	119.07	117.01
VKMo 32	122.95	112.70	110.54	105.90	108.26	110.62	113.15	129.54	128.04	120.30	122.39	126.67
VKMo 35	115.62	119.30	109.57	107.48	110.15	105.68	108.05	110.77	119.77	126.59	126.13	117.74
VKMo 36	111.48	108.87	108.45	108.00	110.87	114.41	118.53	117.24	116.20	117.67	119.78	120.06
VKMo 37	123.15	119.12	108.41	108.42	110.32	106.02	113.74	129.04	123.69	123.91	121.58	121.93
VKMo 38	124.24	118.85	114.91	109.94	108.54	110.75	112.30	123.05	124.67	121.79	125.46	122.77
Mean	**119.61**	**117.79**	**114.24**	**111.94**	**111.19**	**113.56**	**117.48**	**122.49**	**124.83**	**122.90**	**122.44**	**121.27**
CV	3.58	4.62	3.24	3.59	2.93	3.21	3.88	3.87	3.25	2.32	2.75	3.07
SE	0.86	1.09	0.74	0.80	0.65	0.73	0.91	0.95	0.81	0.57	0.67	0.74

76

4.5 Organoleptic Evaluation

Estimation of qualitative characters in drumstick leaves, flowers and fruits revealed that, leaves were rich in nutrients and minerals compared to flowers and fruits. Hence, organoleptic evaluation was carried out in drumstick leaves. All the accessions were scored for various attributes like appearance, flavour, doneness, taste, bitterness and overall acceptability in leaves based on sensory evaluation on a nine point Hedonics scale ranging from dislike extremely (1) to like extremely (9). The Hedonics scale ratings were then converted to rank scores and statistical analysis was done using Kendall's coefficient of concordance. Mean rank obtained for each accession with respect to all attributes was tabulated and listed in the Table 14.

Among the twenty five accessions, the highest mean rank for appearance was recorded in accession VKMo 2 (19.50) followed by VKMo 37 (18.80) and VKMo 38 (18.70). Lowest mean rank for appearance was recorded in accession VKMo 3 (6.30) followed by VKMo 11 (10.75). With respect to flavour highest rank was recorded in VKMo 20 (21.00) followed by VKMo 17 (18.60) and VKMo 5 (18.55). Lowest mean rank for flavour was recorded in accession VKMo 6 (4.25) followed by VKMo 11 (4.90). Highest mean rank for doneness was recorded in accession VKMo 17 (19.90) followed by VKMo 32 (19.2) and VKMo 20 (18.65). Lowest mean rank for doneness was recorded in accession VKMo 29 (6.60) followed by VKMo 11 (6.65). Highest mean rank for taste was recorded in accession VKMo 20 (20.20) followed by VKMo 9 (20.15) and VKMo 17 (18.50). Lowest mean rank for taste was recorded in accession VKMo 11 (2.50) followed by VKMo 6 (3.45). Highest mean rank for bitterness was recorded in VKMo 29 (22.10) followed by VKMo 22 (21.35). Lowest mean rank for bitterness was recorded in accession VKMo 6 (2.30) followed by VKMo 5 (3.10). Highest mean rank for overall acceptability was recorded in accession VKMo 29 (22.25) followed by 20 (20.25), VKMo 19 (20.10) and VKMo 38 (19.58). Lowest mean rank for overall acceptability was recorded in accession VKMo 5 (3.45) followed by VKMo 6 (4.95) and VKMo 3 (5.00).

Table 14. Organoleptic evaluation of the leaves of drumstick accessions

Accession	Appearance (mean rank)	Flavour (mean rank)	Doneness (mean rank)	Taste (mean rank)	Bitterness (mean rank)	Overall acceptability (mean rank)
VKMo 2	**19.50**	17.40	17.35	18.40	10.95	12.15
VKMo 3	6.30	7.85	13.20	3.20	5.70	5.00
VKMo 5	12.55	18.55	17.00	16.45	3.10	3.45
VKMo 6	11.10	4.25	8.70	3.45	2.30	4.95
VKMo 7	14.95	7.40	14.20	7.30	7.95	13.60
VKMo 8	13.55	11.05	17.85	10.90	10.75	9.55
VKMo 9	13.20	18.50	7.70	20.15	13.50	16.95
VKMo 10	12.85	15.40	9.90	12.35	11.80	13.10
VKMo 11	10.75	4.90	6.65	2.50	6.25	12.80
VKMo 12	12.15	5.25	9.50	4.00	7.75	6.90
VKMo 13	13.30	16.05	12.95	12.20	10.10	9.55
VKMo 15	11.05	10.55	7.50	11.95	17.10	10.70
VKMo 16	13.25	10.60	17.10	12.50	16.20	13.55
VKMo 17	12.85	18.60	**19.90**	18.50	17.45	17.25
VKMo 19	11.95	16.00	17.90	16.90	18.75	20.10
VKMo 20	11.75	**21.00**	18.65	**20.20**	20.15	20.25
VKMo 21	12.05	12.30	14.05	13.00	7.50	9.45
VKMo 22	10.40	15.15	17.00	16.55	21.35	18.95
VKMo 29	18.10	15.30	16.60	19.55	**22.10**	**22.25**
VKMo 30	14.10	14.25	10.25	18.05	14.35	12.85
VKMo 32	14.00	14.05	19.20	15.45	12.40	16.50
VKMo 35	14.05	17.85	14.80	15.70	15.35	16.95
VKMo 36	13.75	13.35	14.35	13.50	19.00	16.30
VKMo 37	18.80	13.30	12.15	14.65	11.30	14.05
VKMo 38	18.70	16.10	10.55	16.90	17.20	19.85

78

4.5 Pests and diseases

There was incidence of leaf eating caterpillar (*Noorda blitealis*) on drumstick accessions during the period of study (January-December). Observations on leaf eating caterpillar were recorded and presented in the Table 15. Out of 25 accessions, seven accessions *viz.* VKMo 5, VKMo 11, VKMo 17, VKMo 30, VKMo 35, VKMo 36 and VKMo 38 were not infested with the leaf eating caterpillar. The larvae fed on the leaves of drumstick while hanging from the undersurface of leaflets in a thin silken web. Appearance of papery leaves was the symptom caused by leaf eating caterpillar.

Table 15. Incidence of leaf eating caterpillar in drumstick accessions

Accession	Incidence of leaf eating caterpillar
VKMo 2	Present
VKMo 3	Present
VKMo 5	**Absent**
VKMo 6	Present
VKMo 7	Present
VKMo 8	Present
VKMo 9	Present
VKMo 10	Present
VKMo 11	**Absent**
VKMo 12	Present
VKMo 13	Present
VKMo 15	Present
VKMo 16	Present
VKMo 17	**Absent**
VKMo 19	Present
VKMo 20	Present
VKMo 21	Present
VKMo 22	Present
VKMo 29	Present
VKMo 30	**Absent**
VKMo 32	Present
VKMo 35	**Absent**
VKMo 36	**Absent**
VKMo 37	Present
VKMo 38	**Absent**

Later the infested leaves get dried. Severe infestation was observed in January-April. Flubendiamide (Fame 480 SC) was sprayed @480g/L. This drastically decreased the buildup of insect population and thereby, reduced the infestation by the caterpillar.

4.6 Correlation studies

The relationship among various quantitative, biochemical characters and yield was studied using correlation analysis that provides knowledge on the linkage of various characters and thereby, helps in exploitation of a particular character on crop improvement.

4.6.1 Quantitative characters

The association among nine quantitative characters *viz.* tree height, trunk girth, fruit length, fruit girth, fruit weight, number of ridges per fruit, number of seeds per fruit, number of fruits per tree and yield per tree was measured at 0.05 and 0.01 level by Pearson correlation coefficient and presented in the Table. 16.

Correlation matrix of quantitative traits revealed significant, positive correlation between tree height and trunk girth (0.558) at 0.01 levels. Fruit weight showed positive, significant correlation with tree height (0.404), fruit length (0.742) and fruit girth (0.813). Fruit girth showed positive, significant correlation with fruit length (0.888). Number of ridges per fruit showed significant, positive correlation with fruit weight (0.727), fruit length (0.757) and fruit girth (0.916). Number of seeds per fruit showed significant, positive correlation with fruit weight (0.792), fruit length (0.864), number of ridges per fruit (0.932) and fruit girth (0.968). Number of fruits per tree showed significant, negative correlation with number of ridges per fruit (0.505), fruit weight (0.560) and fruit girth (0.598). Fruit yield per tree showed highly significant, positive correlation with fruit length (0.398), fruit girth (0.618) and number of fruits per tree (0.896).

4.6.2 Biochemical characters

Pearson correlation coefficient was used to analyze the relationship among the six biochemical characters in drumstick *viz.* vitamin C, protein, beta-carotene, calcium, iron and total phenol content and the result is presented in the Table 17. Mean values of all parameters in leaves, flowers and fruits from January to December were considered for the correlation studies.

Significant positive correlation was recorded between protein and beta-carotene (0.424); beta-carotene and phenol (0.462) and protein and total phenol (0.466). In addition, significant negative correlation was observed between beta-carotene and calcium (0.419) and total phenol and calcium (0.418).

4.6.3 Weather variables and biochemical characters

Correlation among weather variables like mean temperature (°C), mean relative humidity (%), rainfall (mm) and number of rainy days (days) with the monthly mean values of biochemical characters during the study period was done using Pearson correlation coefficient and the results are presented in the Table 18.

Significant, positive correlation was observed for beta-carotene content with rainfall (0.640) and number of rainy days (0.403). Mean temperature (0.602) exhibited significant, negative correlation with beta-carotene.

Calcium content showed a significant, positive correlation with mean temperature (0.585). Calcium content showed a negative correlation with mean relative humidity (0.356), rainfall (0.317) and number of rainy days (0.343).

Significant, negative correlation between mean temperature and protein content (0.614) was also observed from the analysis. Other weather parameters *viz.* rainfall (0.120), number of rainy days (0.126) and mean relative humidity (0.158) showed a positive correlation with protein.

Table 16. Correlation matrix of quantitative characters

Character	Tree height	Trunk girth	Fruit length	Fruit girth	Fruit weight	Number of ridges/fruit	Number of seeds/fruit	Number of fruits/tree	Yield/tree
Tree height	1								
Trunk girth	**0.558******								
Fruit length	0.242	0.307							
Fruit girth	0.310	0.326	**0.888****						
Fruit weight	**0.404***	0.340	**0.742****	**0.813****					
Number of ridges/fruit	0.162	0.292	**0.757****	**0.916****	**0.727****				
Number of seeds/fruit	0.232	0.270	**0.864****	**0.968****	**0.792****	**0.932****			
Number of fruits/tree	0.075	0.183	0.359	**-0.598****	**-0.560****	**-0.505****	0.350		
Yield/tree	0.273	0.288	**0.398***	0.318	**0.613****	0.279	0.070	**0.896****	1

*. Correlation is significant at 0.05 level

**. Correlation is significant at 0.01 level

Table 17.Correlation matrix of biochemical characters

Character	Vitamin C	Protein	Beta-carotene	Total phenol	Calcium	Iron
Vitamin C	1					
Protein	0.080					
Beta-carotene	-0.378	**0.424***				
Total phenol	-0.078	**0.466***	**0.462***			
Calcium	0.388	-0.392	**-0.419***	**-0.418***		
Iron	0.099	-0.322	0.331	-0.361	0.375	1

*. Correlation is significant at 0.05 level

Table 18. Correlation among weather variables and biochemical characters

Qualitative characters	Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Number of rainy days (days)
Vitamin C	-0.122	-0.068	-0.262	-0.233
Protein	**-0.614***	0.158	0.120	0.126
Beta-carotene	**-0.602***	0.330	**0.640***	**0.403***
Total phenol	-0.318	0.027	0.083	0.066
Calcium	**0.585***	-0.356	-0.317	-0.343
Iron	-0.300	-0.004	0.157	0.144

*. Correlation is significant at 0.05 level

4.7 Path co-efficient analysis

The Path coefficient analysis was done by partitioning the correlation of yield and its component characters into direct and indirect effects, which helps to get information on the contribution of each character to the yield. The result of path coefficient analysis is presented in the Table 19.

The following characters such as, trunk girth (0.0266), fruit length (0.029), tree height (0.074), number of seeds per fruit (0.195), fruit weight (0.639) and number of fruits per tree (0.977) exhibited direct positive effect on yield in the increasing order. Number of ridges per fruit (0.205) and fruit girth (0.492) exhibited direct negative effect on yield per tree.

Tree height showed direct positive effect on yield (0.074) and indirect positive effect on yield through fruit length (0.007), trunk girth (0.014), number of seeds/fruit (0.045), number of fruits/tree (0.073) and fruit weight (0.258).

Trunk girth showed direct positive effect on yield (0.026) and indirect positive effect on yield through fruit length (0.009), tree height (0.041), number of seeds per fruit (0.052), number of fruits per tree (0.179) and fruit weight (0.217).

Fruit length showed direct positive effect on yield (0.029) and indirect positive effect on yield through trunk girth (0.008), tree height (0.018), number of seeds per fruit (0.168), number of fruits per tree (0.350) and fruit weight (0.474).

Fruit girth showed direct negative effect on yield (0.492) and indirect positive effect on yield through trunk girth (0.008), tree height (0.023), fruit length (0.026), number of seeds per fruit (0.189), fruit weight (0.520) and number of fruits per tree (0.584).

Fruit weight showed direct positive effect on yield (0.639) and indirect positive effect on yield through trunk girth (0.009), fruit length (0.022), tree height (0.030) and number of seeds per fruit (0.154).

Number of ridges per fruit showed direct negative effect on yield (0.205) and indirect positive effect on yield through trunk girth (0.007), tree height (0.012), fruit length (0.022), number of seeds per fruit (0.182), fruit weight (0.464) and number of fruit per tree (0.591).

Number of seeds per fruit showed direct positive effect on yield (0.195) and indirect positive effect on yield through trunk girth (0.007), tree height (0.017), fruit length (0.025), fruit weight (0.506) and number of fruits per tree (0.537).

Number of fruits per tree had direct positive effect on yield (0.977) and indirect positive effect on yield through trunk girth (0.004), tree height (0.005), fruit length (0.010) and number of seeds (0.107) fruit weight (0.229).

4.8 Ranking of drumstick accessions

Twenty five drumstick accessions were ranked based on important quantitative and biochemical characters. Quantitative fruit characters and biochemical leaf characters were considered for the above ranking and scores are presented in the Table 20. Scoring was done in such a way that, accessions with the highest recorded value get a score of one, and the final ranking was done by adding up the individual scores of each character. Thus, accession with lowest rank is considered as superior. Ranking of drumstick accession showed that, accession VKMo 7 ranked first (87), followed by accession VKMo 9 (91).

Table 19. Path coefficient analysis of various characters on fruit yield of drumstick

Character	Tree height	Trunk girth	Fruit length	Fruit girth	Fruit weight	Number of ridges/fruit	Number of seeds/fruit	Number of fruits/tree
Tree height	**0.0748**	0.01486	0.00720	-0.15251	0.25830	-0.03342	0.04537	0.07321
Trunk girth	0.0417	**0.02665**	0.00915	-0.16063	0.21715	-0.06014	0.05286	0.17925
Fruit length	0.0181	0.00819	**0.02976**	-0.43728	0.47463	-0.15572	0.16883	0.35099
Fruit girth	0.0231	0.00869	0.02642	**-0.49260**	0.52002	-0.18836	0.18919	0.58417
Fruit weight	0.0302	0.00905	0.02209	-0.40063	**0.63940**	-0.14961	0.15483	-0.35148
Number of ridges/fruit	0.0121	0.00779	0.02252	-0.45098	0.46495	**-0.20575**	0.18208	0.59111
Number of seeds/fruit	0.0173	0.00721	0.02571	-0.47684	0.50656	-0.19168	**0.19544**	0.53776
Number of fruits/tree	0.0056	0.00489	0.01069	-0.29442	-0.22993	-0.12443	0.10753	**0.97738**

Residual effect, h = 0.0284

Table 20. Overall ranking of drumstick accessions for important quantitative and biochemical characters

Accession	Fruits				Leaves						Cumulative rank
	Length (cm)	Girth (cm)	Weight (g)	Fruits /tree	Vitamin C	Protein	Beta-carotene	Calcium	Iron	Phenol	
VKMo 2	20	13	12	1	16	14	19	16	2	4	117
VKMo 3	12	7	2	3	15	15	23	11	9	2	**99**
VKMo 5	13	8	10	4	2	18	25	6	7	1	**94**
VKMo 6	10	2	4	15	8	21	24	3	3	3	**93**
VKMo 7	9	6	7	10	4	2	20	15	4	10	**87**
VKMo 8	5	19	19	19	6	9	18	1	22	5	123
VKMo 9	3	3	1	20	11	20	6	9	10	8	**91**
VKMo 10	1	1	5	20	25	25	22	17	25	7	148
VKMo 11	6	4	3	9	13	22	9	21	23	15	125
VKMo 12	21	18	18	17	5	10	15	5	21	23	153
VKMo 13	16	20	17	5	7	23	11	2	14	20	135
VKMo 15	22	21	8	11	18	8	10	20	19	9	146
VKMo 16	17	17	6	12	20	5	2	24	15	16	134
VKMo 17	19	12	21	6	3	12	12	7	13	11	116
VKMo 19	11	15	16	2	19	3	1	12	18	13	110
VKMo 20	15	16	22	7	10	7	17	25	5	6	130
VKMo 21	4	10	20	18	22	4	14	13	6	12	123
VKMo 22	2	11	15	8	24	11	3	22	1	19	116
VKMo 29	14	22	14	21	23	6	7	18	12	25	162
VKMo 30	18	9	9	14	14	1	5	10	16	21	117
VKMo 32	23	23	23	23	12	13	4	19	24	17	181
VKMo 35	24	24	24	24	21	19	21	8	8	22	195
VKMo 36	8	5	13	9	9	17	13	14	20	24	132
VKMo 37	7	14	11	13	17	16	8	23	11	18	138
VKMo 38	25	25	25	25	1	24	16	4	17	14	176

4.9 Cluster analysis

Cluster analysis of twenty five accessions was performed using principal component analysis based on principal components, thereby grouping of similar accessions and identification of elite accession was done. Clustering was done based on principal component analysis (PCA). Principal component analysis is essentially a data reduction technique in which original variables are subjected to a linear transformation, resulting in principal components. The number of principal components to be retained are based on Kaiser's criterion (Eigenvalue >1). Principal component analysis was done separately for quantitative and biochemical characters.

4.9.1. PCA of quantitative characters

Principal component analysis was carried out for the quantitative characters and the result is presented in the Table 21. This resulted in grouping of nine quantitative characters to different principal components. The scree plot of principal component analysis showed that the first three components had eigenvalue > 1 and contributed to the maximum proportion of the total variation (Fig.1). The first three main principal components (PCs) extracted from other components accounted for 88.1 7 per cent of the total variation. The first component (PC1) accounted for 60.7 per cent of the total variance with an eigenvalue of 5.46. The PC1 was contributed by number of seeds per fruit (0.403) and fruit girth (0.414). The second component (PC2) accounted for 15.2 7 per cent of total variance with an eigenvalue of 1.36. The PC2 was contributed by trunk girth (0.613) and tree height (0.686). The third component (PC3) accounted for 12.27 per cent of total variance with an eigenvalue of 1.09. The PC3 was negatively contributed by yield per tree (0.573) and number of fruits per tree (0.592).

The loading plot (Fig. 2) explains the correlation between any two variables by estimating the angle between their vectors. If the angle between the vectors is acute, then there will be a positive correlation between variables. If the angle is obtuse, there will be a negative correlation. Right angle indicates zero correlation. The loading plot revealed the positive association between tree height and trunk girth as the angle between the vectors of these characters were acute in nature. Extreme acute angle among fruit weight, fruit length, fruit girth, number of ridges per fruit, number of seeds per fruit, number of fruits/tree and yield/tree infers a close association among these traits.

Table 21. Principal components of quantitative characters

Variables	**Components**		
	PC1	**PC2**	**PC3**
Tree height	0.164	**0.686**	-0.129
Trunk girth	0.186	**0.613**	-0.175
Fruit length	0.361	-0.011	0.389
Fruit girth	**0.414**	-0.065	0.162
Fruit weight	0.367	0.101	0.172
Number of ridges	0.389	-0.160	0.131
Number of seeds	**0.403**	-0.119	0.222
Number of fruits/tree	0.291	-0.294	**-0.592**
Yield/tree	0.322	-0.115	**-0.573**
Eigenvalue	5.4660	1.3686	1.0937
Proportion	0.607	0.152	0.122
Cumulative	0.607	0.759	0.881

Clustering of the accessions was done based on the principal component analysis (Fig. 3). From 25 accessions of drumstick, five clusters has been made and presented in the Table 22. Mean performance of each cluster was calculated and presented in the Table 23. Cluster I consisted of five accessions *viz.* VKMo 35, VKMo 5, VKMo 9, VKMo 11 and VKMo 15, which recorded highest mean value for number of ridges per fruit (9.12). Cluster II consisted of maximum number of accessions *viz.* VKMo 6, VKMo 7, VKMo 8, VKMo 10, VKMo 12, VKMo 17, VKMo 19, VKMo 21, VKMo 22, VKMo 30, VKMo 36, VKMo 37 and VKMo 38. Cluster III consisted of four accessions *viz.* VKMo 2, VKMo 13, VKMo 16 and VKMo 29 recorded highest mean value for fruit length (64.18cm). Cluster IV consisted of two accessions *viz.* VKMo 32 and VKMo 20. Cluster V consisted of single accession, VKMo, 3 recorded high mean values for almost all characters like tree height (7.68 m), trunk girth (65.8 cm), fruit girth (6.30 cm), fruit weight (117.12 g), number of seeds per fruit (20.4), number of fruits per tree (15.16) and yield per tree (1775.53 g/tree).

Table 22. Cluster wise distribution based on quantitative characters

Cluster	Cluster size	Accessions
I	5	VKMo 35, VKMo 5, VKMo 9, VKMo 11, VKMo 15
II	13	VKMo 6, VKMo 7, VKMo 8, VKMo 10, VKMo 12, VKMo 17, VKMo 19, VKMo 21, VKMo 22, VKMo 30, VKMo 36, VKMo 37, VKMo 38
III	4	VKMo 2, VKMo 13, VKMo 16, VKMo 29
IV	2	VKMo 32, VKMo 20
V	1	VKMo 3

Table 23. Mean performance of clusters based on quantitative characters

Cluster	Tree height (m)	Trunk girth (cm)	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Number of ridges per fruits	Number of Seeds per fruits	Number of fruits per tree	Yield (g/tree)
I	6.66	60.06	59.00	6.06	112.72	**9.12**	16.3	8.72	912.57
II	5.33	50.85	**64.18**	6.15	79.17	8.86	18.61	9.06	702.23
III	3.98	38.95	48.68	5.35	78.77	9.2	17.17	12.23	947.86
IV	5.46	40.9	51.32	5.87	48.35	8.8	17.10	11.74	567.62
V	**7.68**	**65.8**	58.33	**6.30**	**117.12**	8.8	**20.4**	**15.16**	**1775.53**

91

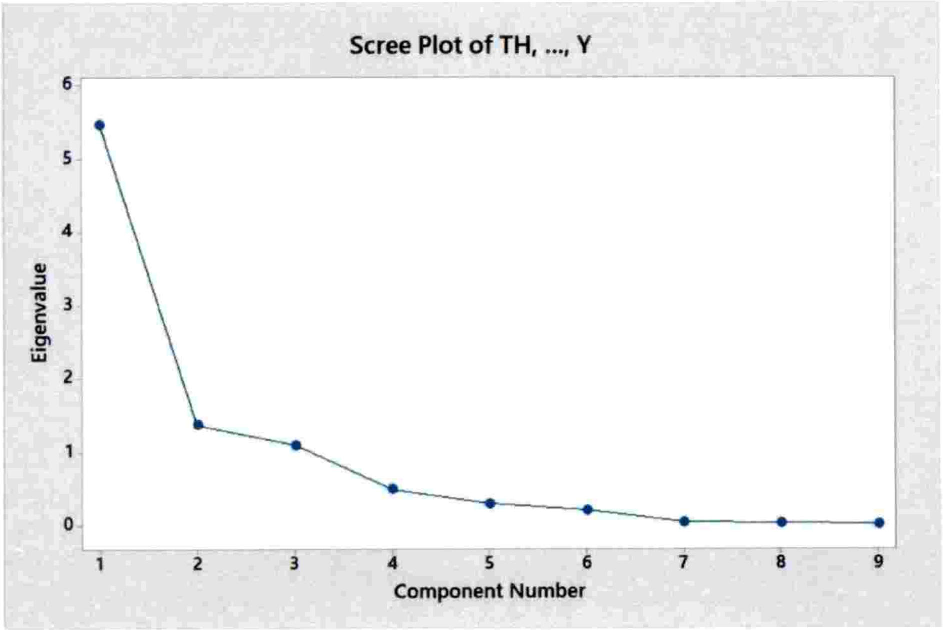

Fig 1. Scree plot showing eigenvalues of various quantitative characters

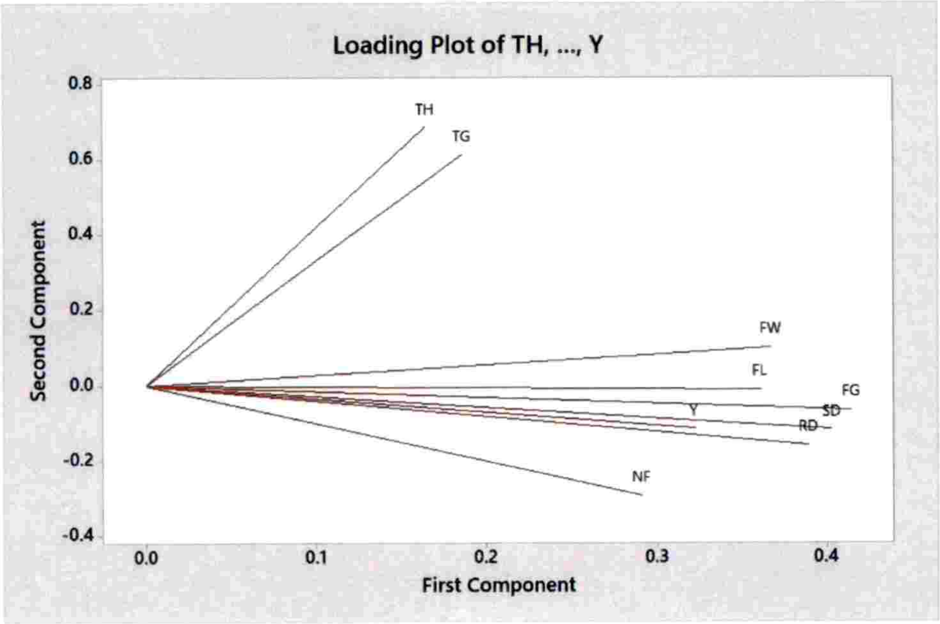

Fig. 2. Loading plot of first two PC's relation with various quantitative characters

TH- Tree height TG- Trunk girth FW- Fruit weight FL- Fruit length FG- Fruit girth SD- Number of seeds RD- Number of ridges Y- yield/tree NF- Number of fruits/tree

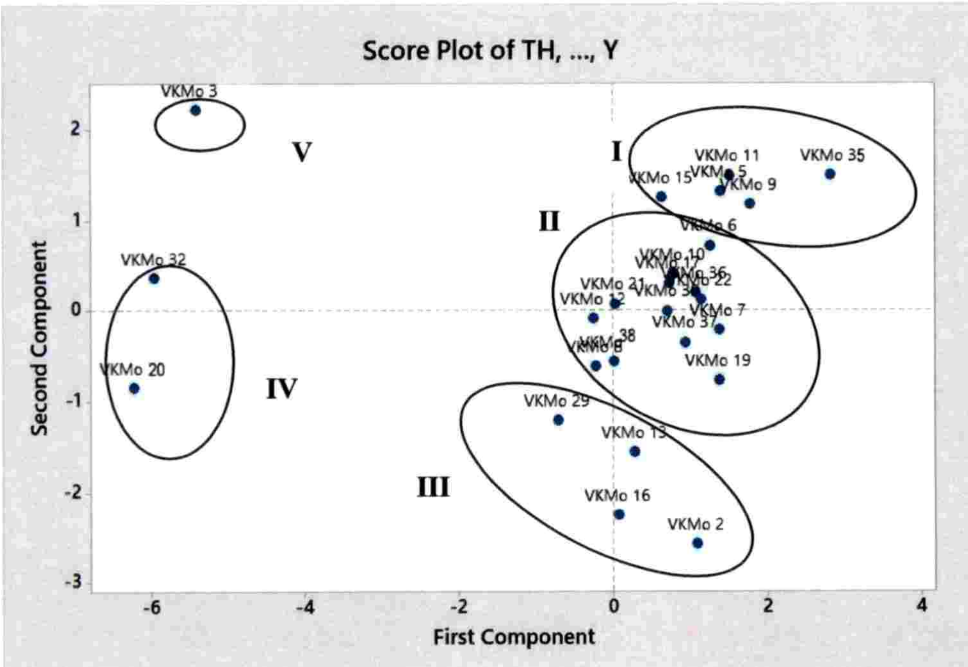

Fig. 3. Clustering based on quantitative characters by principal component analysis

4.9.2 PCA of biochemical characters

Principal component analysis (PCA) was carried out for the biochemical characters and is presented in the Table 24. This resulted in the grouping of six biochemical characters to different principal components. The scree plot of PCA of biochemical characters showed that the first two principal components with eigenvalues >1 contributed to the maximum proportion of the total variation (Fig. 4). The total cumulative variance of the first two principal components accounted 64 7 per cent variance and had an eigenvalue > 1. The first component (PC 1) accounted for 44.27 per cent of total variance with an eigenvalue of 2.65. The PC1 was positively contributed by iron content (0.452) and calcium content (0.503). The second component (PC 2) accounted for 19.8 7 per cent of total variance with an eigenvalue of 1.19. The PC 2 was positively contributed by protein content (0.467) and vitamin C content (0.773).

Table 24. Principal components of biochemical characters

Variable	**PC1**	**PC2**	**PC3**
Vitamin C	0.274	**0.773**	-0.057
Protein	-0.391	**0.467**	-0.356
Beta-carotene	-0.443	-0.152	-0.512
Total phenol	-0.345	0.242	0.751
Calcium	**0.503**	0.199	-0.208
Iron	**0.452**	-0.251	0.029
Eigenvalue	2.651	1.190	0.871
Proportion	0.442	0.198	0.145
Cumulative	0.442	0.640	0.786

The first two components showed major variance and were plotted to study the association among the biochemical parameters. From the PC loading plot (Fig. 5), it is clear that biochemical characters like protein and total phenol content have a strong association, since the angle between these two vectors were acute. Positive association was observed between vitamin C and calcium; calcium and iron; beta-carotene and total phenol. The association between vitamin C and iron showed perpendicular vectors that indicated zero association between these characters. Zero association was observed between vitamin C and total phenol content as inferred from the perpendicular vectors. A negative association of beta-carotene with calcium and vitamin C was observed as indicated by the angle between these factors.

Clustering of the accessions was done based on the first two components of the PC analysis of biochemical characters (Fig. 6). From 25 accessions, six clusters were made and presented in the Table 25. Mean performance on qualitative parameters of each cluster was estimated and presented in the Table 26. Cluster I consisted of two accession viz., VKMo 5 and VKMo 6 recorded high mean values for vitamin C (218.98 mg/100 g), calcium content (1419.58 mg/100 g) and iron content (19.75 mg/100 g). Cluster II consisted of three accessions *viz.* VKMo 2, VKMo 11, and VKMo 13. Cluster III consisted of single accession VKMo 10. Cluster VI consisted of maximum number of accessions *viz.* VKMo 3, VKMo 7, VKMo 8, VKMo 9, VKMo 12, VKMo 15, VKMo 17, VKMo 20, VKMo 29, VKMo 30, VKMo 38. Cluster V consisted of five accessions *viz.* VKMo 16, VKMo 19, VKMo 21, VKMo 22 and VKMo 32 recorded high mean values for protein (20.23 g/100 g), beta-carotene (16.72 mg/100 g) and total phenol content (111.52 mg/100 g).

95

Table 25. Cluster wise distribution based on biochemical characters

Clusters	Cluster size	Accessions
I	2	VKMo 5, VKMo 6
II	3	VKMo 2, VKMo 11, VKMo 13
III	1	VKMo 10
IV	3	VKMo 35, VKMo 36, VKMo 37
V	5	VKMo 16, VKMo 19, VKMo 21, VKMo 22, VKMo 32
VI	11	VKMo 3, VKMo 7, VKMo 8, VKMo 9, VKMo 12, VKMo 15, VKMo 17, VKMo 20, VKMo 29, VKMo 30, VKMo 38

Table 26. Mean performance of clusters based on biochemical characters

Clusters	Vitamin C (mg/100 g)	Protein (g/100 g)	Beta carotene (mg/100 g)	Total phenol (mg/100 g)	Calcium (mg/100 g)	Iron (mg/100 g)
I	**218.98**	17.28	14.76	109.06	**1419.58**	**19.75**
II	168.44	17.53	15.58	109.97	1222.17	16.01
III	115.12	15.13	16.41	108.59	1125.98	17.96
IV	120.37	17.88	16.61	109.56	1059.67	14.30
V	175.23	**20.23**	**16.72**	**111.52**	1044.13	13.91
VI	202.46	19.34	16.31	110.37	1188.89	14.06

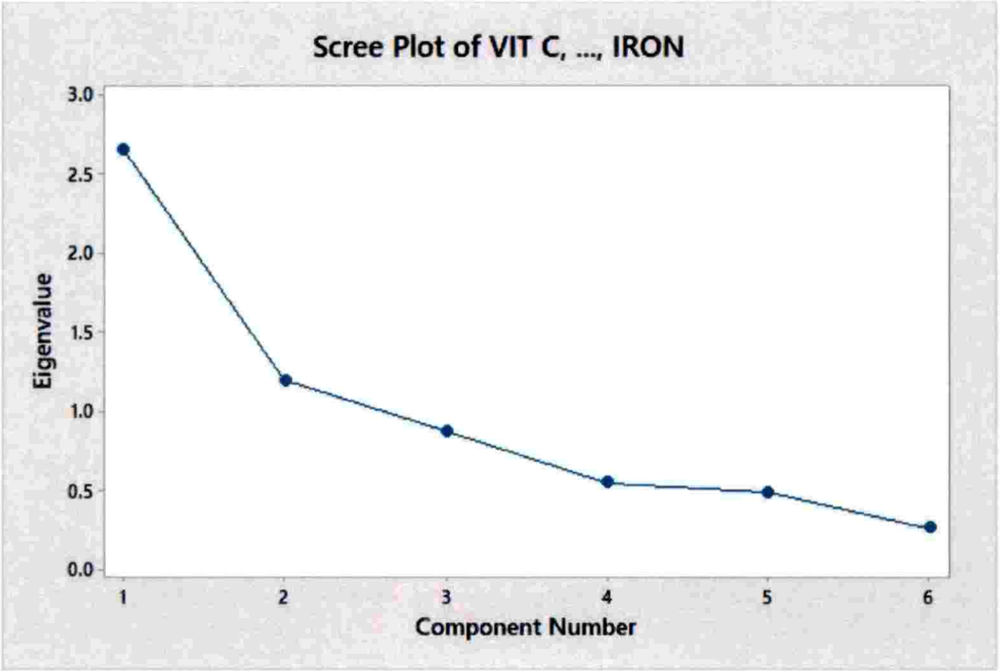

Fig. 4. Scree plot showing eigenvalues of various biochemical characters of drumstick

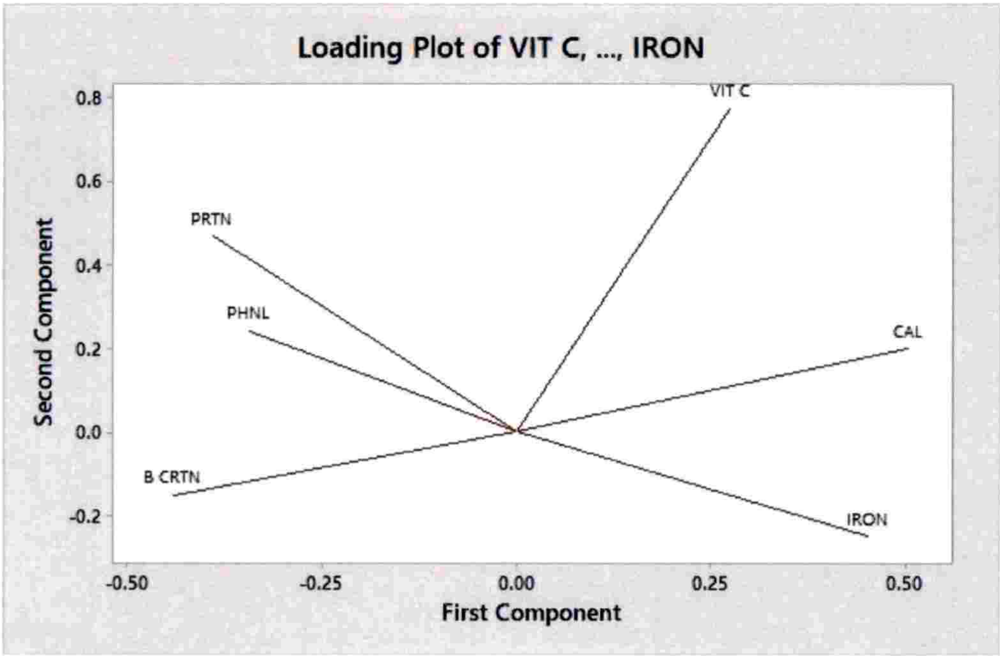

Fig.5. Loading plot of first two PC's relation with various biochemical characters of drumstick

B CRTN - Beta-carotene PHNL- Total phenol PRTN - Protein VIT C - Vitamin C CAL- Calcium

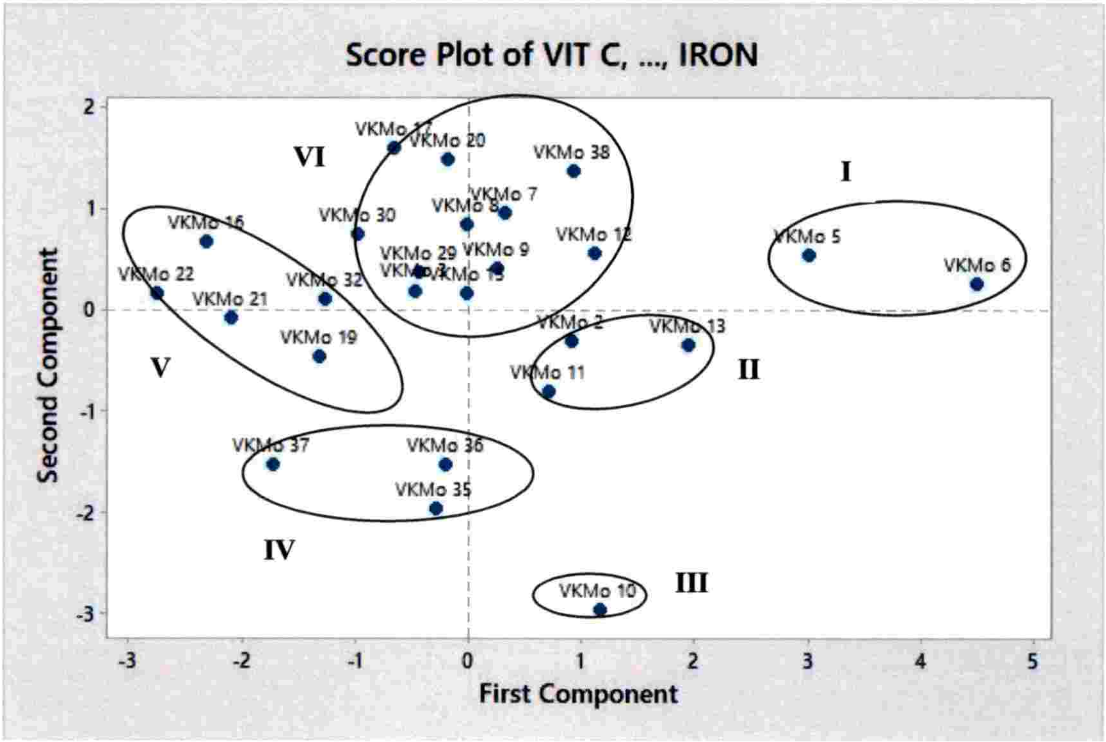

Fig. 6. Clustering based on biochemical characters by principal component analysis

DISCUSSION

5. DISCUSSON

Drumstick (*Moringa oleifera* Lam.) is a crop grown all over the country for its nutritious pods, leaves and flowers, which are rich sources of proteins, vitamins and minerals. Apart from the known nutritious value, the crop has got great potential as medicine, water purifier, and as a source for bio-energy.

Studying the variability allows to quantify the genetic variability, to estimate genetic linkage among characters, to identify duplicates, and to select suitable accessions for breeding programmes. Since drumstick is a cross-pollinated tree naturalized in diverse regions, high heterogeneity with respect to morphological characters and yield is reported. More the diversity, better are the chances of improving the economic traits under consideration in the resulting crosses (Singh and Singh, 1993).

In the present investigation, twenty five accessions of drumstick were evaluated for morphological characters, yield and quality. Data was subjected to statistical analysis to get the average performance of accessions with respect to yield and quality. Further, the data were subjected to correlation, path coefficient, and principal component analysis for assessing the nature of association among the characters and clustering the accessions to identify superior genotypes.

5.1 Morphological characters

In the present study, the morphological characters studied revealed that a considerable variation existed among the twenty five accessions. Tree shape varied from upright to spreading among the twenty five accessions and majority of accessions had spreading tree shape. This was in accordance with the findings of Kumar *et al.* (2014). Grey coloured barks were observed in majority of accessions except for VKMo 3, VKMo 4 and VKMo 8 which had white bark colour. Similar results were reported by Popoola *et al.* (2016) in stem bark color of drumstick.

Flowering in drumstick is dependent on genetic factors as well as climatic factors. In the present investigation, two peaks of flowering were observed in drumstick (January- April and September-November). Similar results were reported by Muthusamy, 1954; Ramachandran *et al.*, 1980; Pushpangathan *et al.*, 1996; Mathew and Rajamony, 2004. Accession VKMo 2 and VKMo 15 flowered for six months in total in two seasons. This is an important factor while determining the total yield of the tree. Accessions that flowered in September-November *viz.*, VKMo 2, VKMo 7, VKMo 12, VKMo 15, VKMo 16 and VKMo 17, might be the early types. This was in confirmation with the findings of Babu and Rajan (1996). Three accessions *viz.*, VKMo 32, VKMo 35 and VKMo 38 can be categorized as leafy types that rarely flower and can be cultivated exclusively for leaves. Similar results were reported by Ochse (1977).

Leaflet shape varied from ovate to elliptical and majority of accessions had ovate leaflet shape. Leaflet apex varied from obtuse to acute and majority of accessions had obtuse leaflet apex. Leafy tree types generally showed ovate leaflet and acute leaflet apex. Hameed (2015) reported similar results in drumstick.

Both secondary and tertiary flowering branchlets were observed among flowering accessions and majority of accessions had secondary flowering branchlets. Foliage density in flowering period varied from sparse, medium to dense and majority of accessions had medium foliage density. There was no variability with respect to flower characters. All the accessions produced flowers with triangular shaped, polysepalous, pale green coloured calyx; corolla having triangular shape, poly petalous and cream colour. Popoola *et al.* (2016) reported similar results with respect to flower morphology in drumstick.

The fruit colour was pale green in all 22 accessions that flowered. All the accessions produced pale green coloured young shoots with purple tinge. Fresh fruit pulp colour was white in all the accessions. Fresh fruit pulp taste was palatable in all the accessions except in VKMo 3, VKMo 6, VKMo 11, VKMo13 and VKMo 29, which had bitter taste. Similar findings were reported by Tak and Maurya (2015).

5.2 Quantitative characters

Plant height is considered as one of the important traits for better growth and vigour of the plants. Optimum plant height is a desirable character in drumstick. Tree height was highest in VKMo 3 (7.68 m) followed by VKMo 11 (7.15 m), VKMo 6 (7.13 m) and VKMo 5 (6.90 m). Similar trend of variation was reported by Resmi *et al.*, (2006). The accessions VKMo 38 (2.75 m) and VKMo 13 (2.82 m) were observed to be dwarf which is a desirable character for High Density Planting. Similar findings were reported by Selvakumari (2013).

With respect to trunk girth, VKMo 3 (65.8 cm) has high trunk girth followed by VKMo 5 (64.50 cm), VKMo 15 (61.70 cm) and VKMo 17 (59.70 cm) which was greater than the mean trunk girth (50.59 cm). Tall trees recorded more trunk girth compared to short trees. Similar results were reported by Karunakar *et al.* (2018).

Wide range of variability was observed in the length of the fruit. Highest fruit length was reported in accession VKMo 10 (89.50 cm) followed by VKMo 21 (72.14 cm), VKMo 9 (72.27 cm) and VKMo 22 (85.30 cm). Similar results were reported by Raja and Bagle (2008).

Fruit girth is an important trait that contributes to the yield. The drumstick accessions showed less variability with respect to this character. The fruit girth was highest in accession VKMo 10 (6.72 cm) followed by VKMo 6 (6.65 cm) and VKMo 9 (6.57 cm). The length and girth of fruit recorded highest in same accession VKMo 10, that shows a positive relation between fruit length and girth. Similar results were reported by Resmi *et al.* (2006).

Fruit weight is one of the key characters for selecting high yielding types. The fruit weight recorded highest in accession VKMo 9 (160.00 g) followed by VKMo 3 (117.12 g) with a mean of 82.53 g. Accession VKMo 9 recorded high fruit weight and a high fruit length of 72.27 cm. This shows a positive association between fruit length and fruit weight. It can be inferred that economic characters such as, high fruit weight and fruit length is found in a same accession. So this is a promising source for improving yield. Similar findings were reported by Selvakumari (2013).

Number of ridges per fruit varied from 7.20 (VKMo 13) to 10.50 (VKMo 10) with mean value of 8.89. Accession VKMo 10 recorded highest fruit length, girth and highest number of ridges per fruit. This shows a positive association between these characters which ultimately results in high fruit yield per tree. Similar results have not been reported so far.

Number of seeds per fruit ranged from 13.50 (VKMo 15) to 21.20 (VKMo 6) with a mean value of 18.45. The accessions viz. VKMo 17 (20.10), VKMo 7 (20.20), VKMo 10 (20.20), VKMo 3 (20.40) and VKMo 6 (21.20) recorded more number of seeds per fruit. From the present study it was found that accession VKMo 10 recorded highest fruit length (89.50 cm) and more number of seeds per fruit (20.20). Therefore, it can be inferred that these characters show close association. So selection simultaneously for these characters can improve the yield. Similar findings were reported by Selvakumari (2013).

The number of fruits per plant is the most important trait in deciding the yield potentiality of drumstick. The best performing accessions in number of fruits per plant were VKMo 17 (12.17), VKMo 13 (12.21), VKMo 5 (12.32), VKMo 3 (15.16), VKMo 19 (17.58) and VKMo 2 (22.21) and the mean for this character was 10.9.

Yield/tree is the ultimate character that decides the superiority of the accession from others. Accessions *viz*. VKMo 15 (1006.26 g/tree), VKMo 5 (1063.34 g/tree), VKMo 19 (1309.36 g/tree), VKMo 2 (1685.74 g/tree and VKMo 3 (1775.54 g/tree) recorded high yield. The mean for this character was 728.47 g/tree. Similar results were reported by Gopalakrishnan (1978); Peter (1979) and Selvakumari (2013). Accessions with more yield/tree such as VKMo 2, VKMo 3, VKMo 5 and VKMo 19 also recorded more number of fruits per tree. It can be inferred that more yield is contributed by more number of fruits per tree and selection for these characters will improve the yield. Similar results were reported by Raja and Bagle (2008).

5.3 Biochemical characters

In the present study biochemical parameters of the drumstick accessions were estimated in each month for one calendar year. Vitamin C, protein, beta-carotene, calcium, iron and total phenol contents were included in the study. Mean values of all these parameters for each month was calculated in leaves, flowers and fruits of drumstick accessions separately.

Vitamin C is a strong antioxidant that is important for skin, bones, and connective tissue. It provides immunity and may reduce the risk of chronic diseases. Drumstick leaves contain high amount of vitamin C. In leaves, highest vitamin C content was recorded in leaf type accession, VKMo 38 (260.63 mg/100 g), whereas the lowest vitamin C was recorded in VKMo 10 (179.58 mg/100 g). In flowers, highest vitamin C was recorded in VKMo 7 (153.20 mg/100 g) and in fruits, VKMo 17 (106.66 mg/100 g) recorded high vitamin C content. The present study revealed that drumstick leaves contain approximately 1.5 times more vitamin C than in flowers and 2 times more vitamin C than in fruits. This result was in agreement with the finding of Prabhakar *et al.* (2003); Rai *et al.* (2004) and Resmi *et al.* (2006). From the present study it was also found that a leaf type accession, VKMo 38 recorded the highest vitamin C content among all the accessions. Hence it can be exploited as an important leafy vegetable. Similar results have not been reported earlier.

Proteins are important to build and repair tissues. Protein is also essential to make enzymes, hormones, and other body chemicals. It's a key building block of bones, muscles, cartilage, skin, and blood that are required in plenty in routine life. In leaves, highest protein was recorded in accession VKMo 30 (21.07 g/100 g) and lowest protein content in VKMo 10 (15.31 g/100 g). In flowers, VKMo 16 (9.84 g/100 g) recorded highest protein and in fruits, VKMo 21 (8.74 g/100 g) recorded high protein content. The present study revealed that, drumstick leaves contain approximately 2 times more protein than in flowers and 2.5 times more protein than in fruits. These results were supported by the findings of Joshi and Mehta (2010). The present study also revealed that, leaf type accession VKMo 32 recorded more protein content (19.08 g/100 g), than the general mean recorded for all the accessions. Thus leaves of this accession can be utilized as a leafy vegetable which is an important source of protein. Similar results have not been reported earlier.

Beta -carotene is an antioxidant which acts as a precursor of vitamin A (retinol) – that is needed for the healthy skin, mucus membranes, immune system, good eye health and vision. In leaves, highest beta-carotene content was recorded in accession VKMo 16 (16.95 mg/100 g). In flowers, highest beta carotene was recorded in VKMo 29 (9.77 mg/100 g) and in fruits, VKMo 19 (12.52 mg/100 g) recorded high beta-carotene content. It was found that, drumstick leaves contain approximately 2 times more beta-carotene than in flowers and 1.5 times more beta-carotene than in fruits. This was in accordance with the reports of Price (2007) and Subadra *et al.* (2003). From the present study it was also observed that, leaf type accession VKMo 32, recorded more beta-carotene content (16.89 mg/100 g) than the general mean recorded for all accessions. Thus, this leaf type accession can be consumed as a leafy vegetable for providing good source of beta-carotene. Similar results have not been reported earlier.

Calcium is essential to build and maintain strong bones and proper functioning of heart, muscles and nerves. In leaves, highest calcium content was recorded in VKMo 8 (1330.21 mg/100 g). In flowers, highest calcium content was recorded in accession VKMo 37 (688.28 mg/100 g) and in fruits, VKMo 30 (586.71 mg/100 g) recorded high calcium content. It was found that, drumstick leaves contain approximately 2 times more calcium than flowers and fruits. This result was in confirmity with findings of Jongrungruangchok *et al.* (2010); Yaméogo *et al.* (2011) and Wangcharoen and Gomolmanee (2013). Leafy type accessions VKMo 35 (1184.02 mg/100 g) and VKMo 38 (1262.80 mg/100 g) recorded more calcium content than the general mean. Thus these two accessions can be utilized as an excellent source of calcium. Similar results have not been reported earlier.

Iron is one of the most vital minerals involved in eliminating fatigue and plays an important role in immune system function, treating anemia and boosting hemoglobin. In present study, accession VKMo 22 (22.55 mg/100 g) recorded highest iron content in leaves. Highest iron content in flowers was recorded in accession VKMo 36 (25.55 mg/100 g) and in fruits, accession VKMo 5 (17.68 mg/100 g) recorded high iron content. It was found that, drumstick flowers contain more iron content than that of leaves followed by fruits. This result was supported by the findings of Joshi and Mehta (2010). From the present study it was also found that, leaf type accession VKMo 35 recorded more iron content (19.85 mg/100 g) than the general mean. Thus, this accession can be utilized as a leaf vegetable with good amount of iron in leaves. Similar results have not been reported earlier.

Phenolic compounds are phytochemicals, with antioxidant and antimicrobial properties, thereby prevents inflammation, allergies and degenerative diseases. In leaves, highest total phenol content was recorded in accession VKMo 5 (123.17 mg/100 g) and lowest in accession VKMo 29 (113.21 mg/100 g). In flowers, highest total phenol content was recorded in accession VKMo 19 (20.18 mg/100 g) and in fruits, VKMo 17 (23.19 mg/100 g) recorded high total phenol content. Thus drumstick leaves contain approximately 6 times more total phenol than in flowers and 5 times more total phenol than in fruits. This result was in confirmation with the results of Jaiswal *et al.* (2013). The leaf type accession included in the present study, recorded low total phenol content than the general mean. Hence it was inferred that leaf type accession of drumstick may contain low levels of total phenol than the fruiting types. Similar results have not been reported so far.

The study on biochemical characters in drumstick accessions revealed that highest vitamin C content was recorded in leaves of VKMo 38 (260.63 mg/100 g), in flowers of VKMo 7 (153.20 mg/100 g) and in fruits of VKMo 17 (106.66 mg/100 g). Highest protein content was recorded in leaves of VKMo 30 (21.07g/100 g), in flowers VKMo 16 (8.74 g/100 g) and in fruits of VKMo 21 (8.74 g/100 g). Highest beta-carotene was recorded in leaves of VKMo 16 (16.95 mg/100 g), in flowers of VKMo 29 (9.77 mg/100 g) and in fruits of VKMo 19 (12.52 mg/100 g). Highest calcium content was recorded in leaves of VKMo 8 (1330.21 mg/100 g), in flowers of VKMo 37 (688.28 mg/100 g) and in fruits of

VKMo 30 (586.71 mg/100 g). Highest iron content was recorded in leaves of VKMo 22 (22.55 mg/100 g), in flowers of VKMo 36 (25.55 mg/100 g) and in fruits of VKMo 5 (17.68 mg/100 g). Highest phenol content was recorded in leaves of VKMo 5 (123.17 mg/100 g), in flowers of VKMo 19 (20.18 mg/100 g) and in fruits of VKMo 17 (23.19 mg/100 g).

Thus it can be inferred that, consumption of leaves from accession VKMo 38 (vitamin C), VKMo 30 (protein),VKMo 16 (beta-carotene), VKMo 8 (calcium), VKMo 22 (iron) and VKMo 5 (phenol) provide good amount of these nutrients in the diet. Consumption of flowers from accession VKMo 7 (vitamin C), VKMo 16 (protein),VKMo 29 (beta-carotene), VKMo 37 (calcium), VKMo 36 (iron) and VKMo 19 (phenol) provide good amount of these nutrients in the diet. Consumption of fruits from accession VKMo 17 (vitamin C), VKMo 21 (protein),VKMo 19 (beta-carotene), VKMo 30 (calcium), VKMo 5 (iron) and VKMo 17 (phenol) provide good amount of these nutrients in the diet.

5.3 Correlation studies

Correlation is a bivariate analysis that measures the strength of association between two variables and the direction of the relationships. Correlation studies will be useful in planning and evaluating breeding programmes. Greater the magnitude of correlation coefficient, stronger is the association.

5.3.1 Quantitative characters

The association among nine quantitative characters *viz.* tree height, trunk girth, fruit length, fruit girth, fruit weight, number of ridges per fruit, number of seeds per fruit, number of fruits per tree and yield per tree was studied using correlation analysis.

In the present study, significant, positive correlation between tree height and trunk girth (0.558) was observed. These two characters showed positive correlation with yield. Thus tall tree with thick trunk is an important character in contributing to high yield. Significantly, high positive correlation was observed between fruit length and fruit girth (0.888). Thus, it was inferred that increase in fruit length resulted in increase of fruit girth. Fruit weight showed positive, significant correlations with tree height (0.404), fruit length (0.742) and fruit girth (0.813).From this result, it can be concluded that tall trees produce fruits with good length, girth and weight. These characters contributed to high yield. This is in confirmation with the result of Kumar *et al.* (2014).

Number of ridges per fruits recorded significant, positive correlation with fruit weight (0.727), fruit length (0.757) and fruit girth (0.916). As fruit length and girth increases, fruit weight increases, it resulted in the increase of number of ridges per fruit, which ultimately resulted in high fruit yield. Thus, it was inferred that positive correlation of number of ridges per fruit with fruit length, fruit girth and fruit weight ultimately resulted in high yield. Similar results have not been reported so far.

Number of seeds per fruit showed significant, positive correlation with fruit weight (0.792), fruit length (0.864), number of ridges per fruit (0.932) and fruit girth (0.968). Thus long fruits contained more number of seeds and contributed to the total weight of the fruit. As fruit girth increases, number of ridges per fruit and number of seeds per fruit also increases, and results in increased fruit weight, which in turn contributed to high fruit yield per tree. These results confirm the findings of Popoola *et al.* (2016).

Yield/ tree exhibited high significant, positive correlations with fruit length (0.398), fruit weight (0.613) and number of fruits (0.896). Fruits with more length contributed to high fruit weight, which ultimately resulted in high fruit yield per tree. Thus it is clear that high fruit yield can be obtained from more number of fruits/tree rather than fruits with more length and weight. Similar results were reported by Raja and Bagle (2008) in drumstick.

Number of fruits per tree showed significant, negative correlation with number of ridges per fruit (0.505), fruit weight (0.560) and fruit girth (0.598). Increased fruit girth and number of ridges per fruit, resulted in increased fruit weight, which resulted in reduced number of fruits per tree and finally reduced fruit yield per tree. This was in accordance with the findings of Mohideen and Shanmugavelu (1982).

5.3.2 Biochemical characters

Biochemical parameters of the drumstick accessions were estimated in each month for one calendar year. Vitamin C, protein, beta-carotene, calcium, iron and total phenol contents were estimated. Mean values of these characters in drumstick leaves for each month was calculated and correlation was analyzed. Significant positive correlation was recorded between protein and beta-carotene (0.424), beta-carotene and phenol (0.462) and protein and phenol (0.466). In addition, significant negative correlation was observed between beta-carotene and calcium (0.419) and phenol and calcium (0.418).

Beta-carotene content in drumstick showed positive correlation with protein and total phenol. Protein content showed a positive correlation with total phenol. Calcium content showed a negative correlation with total phenol and beta-carotene. Present investigation revealed that increased content of both protein and total phenol leads to the accumulation of high beta-carotene in drumstick leaves, at the same time it may resulted in reduced amount of calcium in drumstick leaves.

5.3.3 Weather parameters and biochemical characters

Monthly variation of each biochemical character was graphically represented and their correlation with the weather parameters for one year was computed. The weather condition during the investigation period is given in Appendix II.

Correlation studies between weather characters and qualitative characters revealed a significant, positive correlation between mean temperature and calcium content. Significant, positive correlation was recorded among beta-carotene, rainfall and number of rainy days. Significant, negative correlation was recorded among mean temperature, protein content and beta-carotene.

Monthly variation of vitamin C content in drumstick leaves was graphically represented in Fig. 7. Negative association among vitamin C, temperature and rainfall revealed that, cool-dry weather condition favoured the synthesis of vitamin C in drumstick leaves. This might be the reason for high vitamin C content in December and low in May. Similar results were also reported by Yang *et al.* (2006).

Monthly variation of protein content in drumstick leaves was graphically represented in Fig. 8. Protein content in drumstick leaves showed a positive correlation with mean relative humidity, rainfall, number of rainy days and significant, negative correlation with mean temperature. High rainfall along with high relative humidity may result in accumulation of higher amount of protein in drumstick leaves. Thus, high protein content in September may be due to the heavy rainfall received in Kerala in August. Low protein content in May might be due to the elevated mean temperature.

Monthly variation of beta-carotene in drumstick leaves is graphically represented in Fig. 9. Significant positive correlation was observed among beta-carotene, rainfall and number of rainy days. Influence of temperature in the production of plant secondary compounds was reported by Lefsrud *et al.* (2005). Senescence and aging of the plant is characterized by the yellowing and falling of leaves. At time of senescence, chlorophyll degradation occurs and carotenoid production increases, that result in yellowing of leaves. In drumstick, yellowing and falling of leaves occurs in rainy months which may be due to the degradation of chlorophyll and increased production of carotenes in leaves. High content of beta-carotene was recorded along with high rainfall in September. Negative correlation between beta-carotene and mean temperature might be the reason for low beta-carotene in May. Similar results in drumstick have not been reported earlier.

Monthly variation of calcium content in drumstick leaves was graphically represented in Fig. 10. Calcium content showed a significant, positive correlation with mean temperature and a negative correlation with mean relative humidity, rainfall and number of rainy days. High temperature resulted in high calcium uptake whereas, high humidity and rainfall reduced it. Similar results were reported by Sud *et al.* (1995). Thus high calcium content was recorded in April and low in August. This result was supported by the findings of Melesse *et al.* (2012).

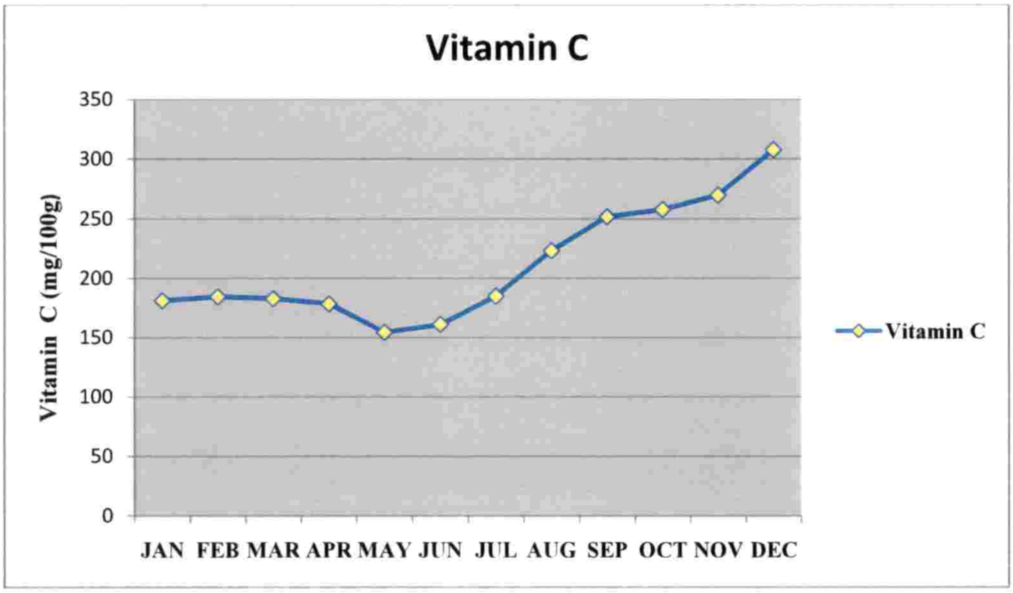

Fig 7. Monthly trend of vitamin C content in drumstick accessions

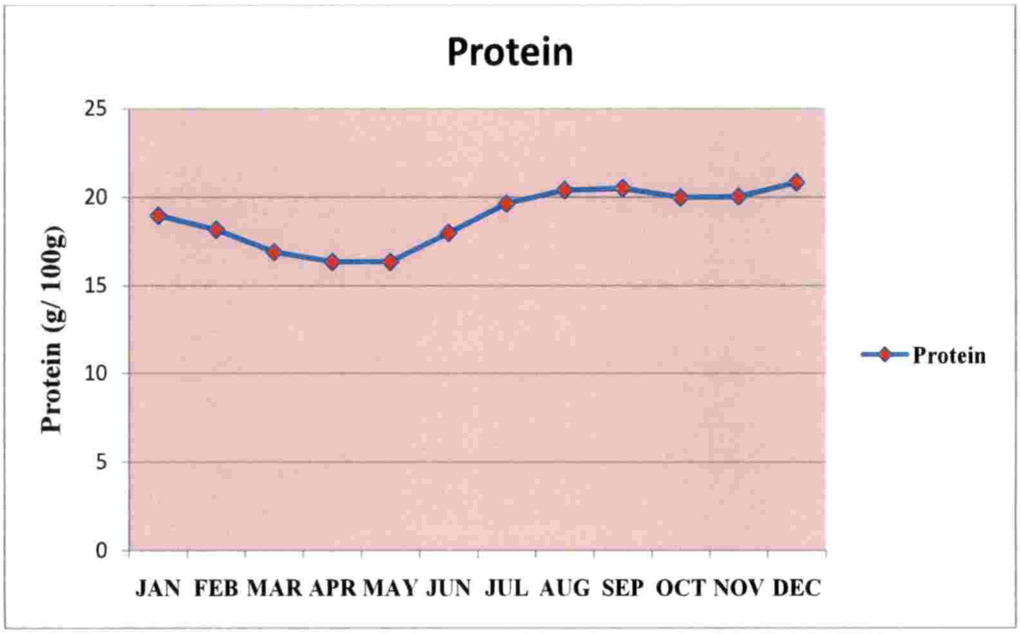

Fig 8. Monthly trend of protein content in drumstick accessions

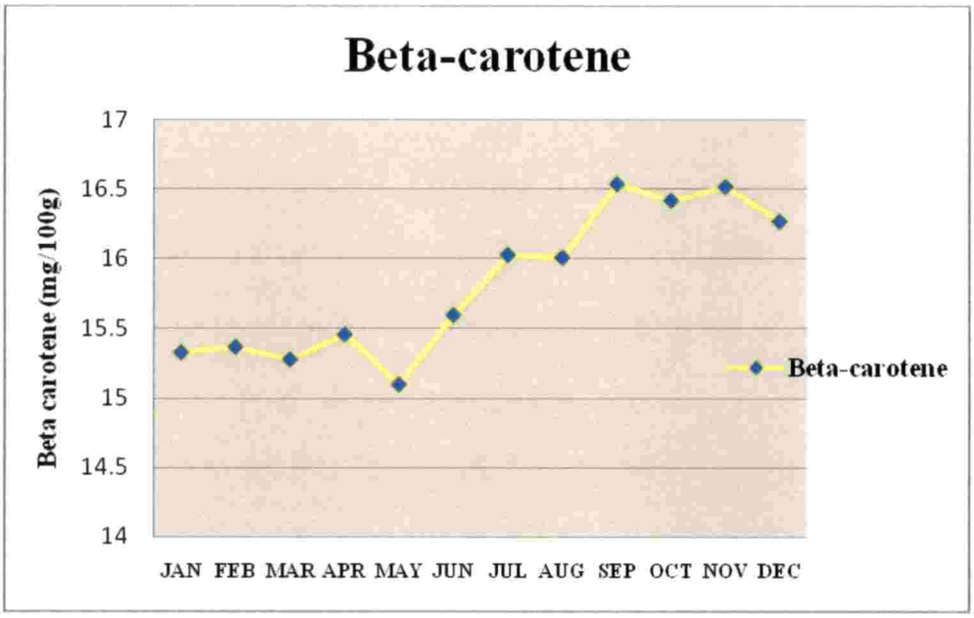

Fig 9. Monthly trend of beta-carotene content in drumstick accessions

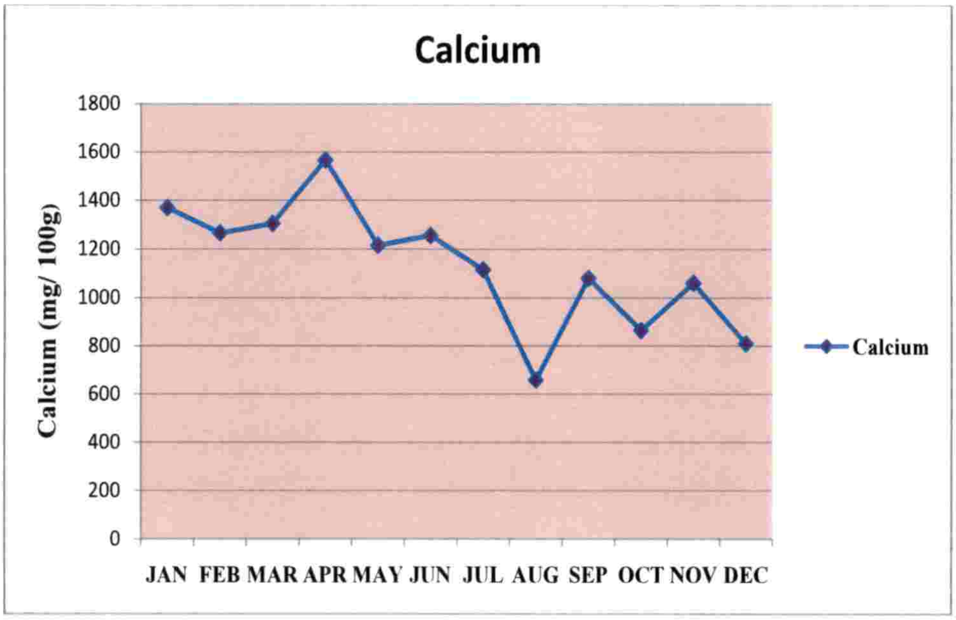

Fig 10. Monthly trend of calcium content in drumstick accessions

Monthly variation of iron content in drumstick leaves was graphically represented in Fig. 11. Iron content exhibited a positive correlation with rainfall, number of rainy days and negative correlation with mean temperature. High iron content was recorded in August and low in May, may be due to the high temperature in May, which resulted in decline of iron content.

Monthly variation of total phenol content in drumstick leaves was graphically represented in Fig. 12. Total phenols recorded a declining trend throughout the summer months (March, April and May) and it was the lowest in the month of May. However, with the onset of monsoon in the month of June, total phenols showed an increasing trend and the highest total phenols were recorded in the month of September. This may be due to the heavy pouring rains recorded in month of August which resulted in an accumulation of total phenols in drumstick. Thus consumption of drumstick leaves during rainy days may result in the high intake of phenol compared to other periods. Phenol, when ingested at high concentrations may exhibit roles in genotoxicity, inhibition of iron absorption, thyroid toxicity, and low estrogenic activity. Thus high accumulation of phenols during rainy period may be one of the reasons for avoiding the intake of drumstick leaves in rainy season. Similar results have not been reported earlier.

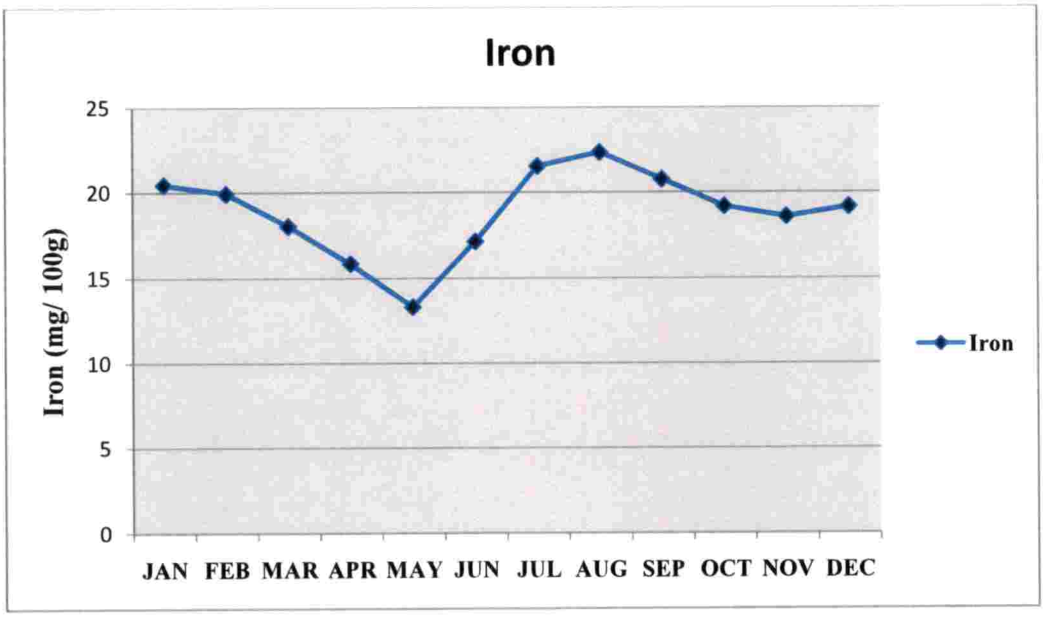

Fig 11. Monthly trend of iron content in drumstick accession

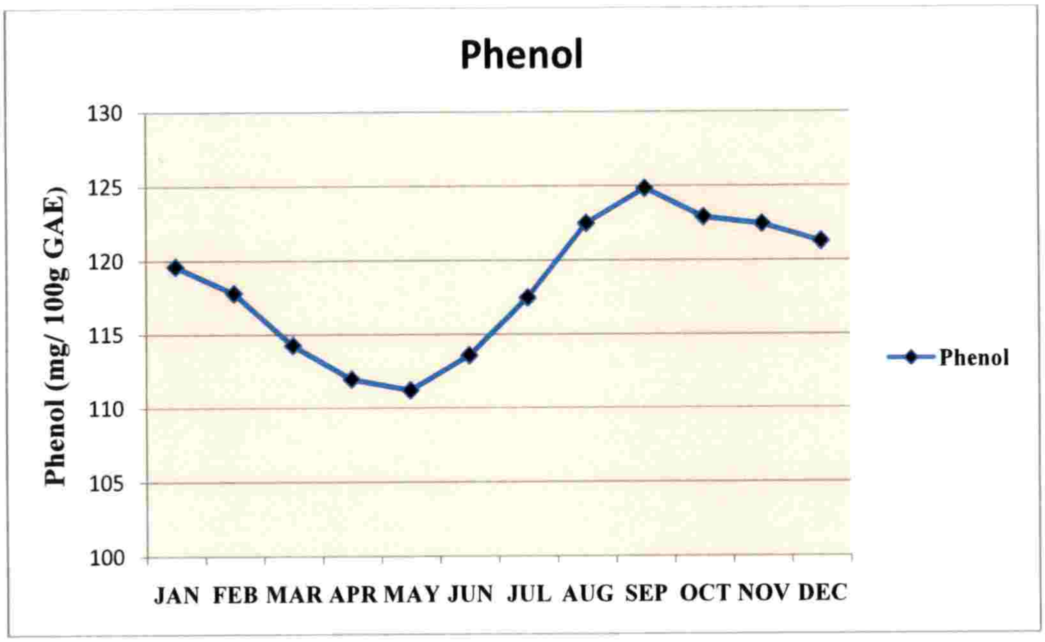

Fig 12. Monthly trend of total phenol content in drumstick accessions

5.4 Path coefficient analysis

A path coefficient analysis is simple standardized partial regression coefficient that divides the observed correlation coefficient into direct and indirect effects of yield components (Dewey and Lu, 1959). It differs from simple correlation in the sense, it points out the causes and their relative importance whereas; the latter measures simply the mutual association ignoring the causation.

Present study revealed the association among yield and yield contributing characters. Knowledge on the association of component characters with the yield may greatly help in making more precise and accurate selection (Seetharam and Ganesamurthy, 2013).

High direct positive effect on yield was exhibited by number of fruits per tree (0.977), fruit weight (0.639) number of seeds (0.195) and tree height (0.0748). Thus, increase in number of fruits/ tree, tree height and fruit weight may result in high fruit yield/tree. This finding was in confirmation with the results of Tak and Maurya (2015).

Yield per tree showed highest direct negative effect with fruit girth (0.492) and number of ridges (0.205). Thus increase in the fruit girth, increased the number of ridges per fruit, which resulted in reduction of number of fruits/tree, and influenced the yield negatively. These results were supported by the findings of Karunakar *et al.* (2018).

Tree height had direct positive effect on yield (0.074) and indirect positive effect on yield through fruit weight (0.258), number of fruits/tree (0.0732) and trunk girth (0.014).Thus tall drumstick tree yields more number of fruits with high girth and weight compared to short trees. Trunk girth showed direct positive effect on yield (0.026) and indirect positive effect on yield through fruit weight (0.217), number of fruits/tree (0.179), number of seeds per fruit (0.052) and tree height (0.041). Trees with high trunk girth resulted in increased fruit yield per tree. Similar results have been not reported so far.

Fruit length had direct positive effect on yield (0.029) and indirect positive effect on yield through fruit weight (0.474), number of fruits/tree (0.350), number of seeds (0.168), tree height (0.018) and trunk girth (0.008). Increased fruit length resulted in high fruit yield per tree directly. Indirectly fruit weight and number of seeds per fruit contributed to increased fruit yield per tree. Fruit girth had direct negative effect on yield (0.492) and indirect positive effect on yield through number of fruit/tree (0.584), fruit weight (0.520), number of seeds (0.189), fruit length (0.026), tree height (0.023) and trunk girth (0.008). Long thick fruits resulted in reduced number of fruits per tree and ultimately reduced the fruit yield per tree. While, fruit girth positively influenced the fruit weight and increased fruit yield per tree. Fruit weight had direct positive effect on yield (0.639) and indirect positive effect on yield through number of seeds (0.154), fruit length (0.022), tree height (0.030) and trunk girth (0.009). Thus increase in fruit weight resulted in increased fruit yield per tree. Similar results have not been reported earlier.

Number of ridges per fruit had direct negative effect on yield (0.205) and indirect positive effect on yield through number of fruit/tree (0.591), fruit weight (0.464), number of seeds (0.182), fruit length (0.022), tree height (0.012) and trunk girth (0.007). Since fruit length, girth and number of ridges per fruits were positively associated, increase in fruit length and girth results in increased number of ridges and ultimately results in reduced yield per tree. Number of seeds had direct positive effect on yield (0.195) and indirect positive effect on yield through number of fruit/tree (0.537), fruit weight (0.506), fruit length (0.025), tree height (0.017) and trunk girth (0.007). Increase in number of seeds per fruit results in high fruit weight and will increase the total fruit yield per tree. Number of fruits/tree had direct positive effect on yield (0.977) and indirect positive effect on yield through number of seeds (0.107), fruit length (0.010), tree height (0.005) and trunk girth (0.004). Production of more number of fruits with high fruit length results in increased yield per tree. Thus based on path analysis, the traits *viz.*, number of fruits per tree, fruit weight, number of seeds per fruit and tree height may be considered as selection indices for yield improvement. Similar result was also given by Raja and Bagle (2008).

5.5 Principal component analysis

To identify the contribution of each variable to the total variation, principal component analysis was performed for the quantitative characters *viz.*, tree height, trunk girth, fruit weight, fruit length, fruit girth, number of ridges per fruit, number of seeds per fruit, number of fruits per tree and yield per tree. This resulted in the grouping of nine quantitative characters into different principal components. The first three main principal components (PCs) accounted for 88.1 per cent of the total variation. The first factor (PC1) accounted for 60.7 per cent of the total variance which was comprised of fruit girth and number of seeds. The second factor (PC2) contributed 15.2 per cent of total variance which was comprised of tree height and trunk girth. The third factor contributed 12.2 per cent of total variance and was comprised of number of fruits/tree and yield/tree. Thus, variation observed in the drumstick accessions for quantitative characters might be mostly due to the influence of fruit girth and number of seeds. Variation with respect to tree height, trunk girth, number of fruits/tree and yield/tree was also observed in less proportion. The loading plot of first three PCs exhibited a strong association between tree height and trunk girth. Same results were obtained in the correlation studies. Positive correlation among fruit weight, fruit length, fruit girth, number of ridges, number of seeds, number of fruits/tree and yield/tree were also revealed. Similar results in principal component analysis in quantitative characters of drumstick have not been reported earlier.

Clustering was done based on principal component analysis that resulted in formation of five clusters. Cluster I comprised of five accessions *viz.,* VKMo 35, VKMo 5, VKMo 9, VKMo 11 and VKMo 15 which recorded fruits with maximum number of ridges. While cluster II with accessions *viz.*, VKMo 6, VKMo 7, VKMo 8, VKMo 10, VKMo 12, VKMo 17, VKMo 19,VKMo 21, VKMo 22, VKMo 30, VKMo 36, VKMo 37 and VKMo 38 recorded highest mean value for fruit length. Cluster V consisted of a single accession, VKMo 3 which recorded maximum tree height, trunk girth, fruit girth, fruit weight, number of seeds, number of fruits/tree and yield. Thus for designing crop improvement programme accessions from cluster V (VKMo 3) and from cluster II having high mean value for fruit length may be selected. Similar results were reported by Popoola *et al.* (2016).

In the present investigation, six biochemical characters studied were subjected to principal component analysis. This resulted in the grouping of these six biochemical characters into different principal components. Among this, first two components explained 64 per cent of the variation. The first component (PC1) contributed 44.2 per cent of total variance while the second component (PC 2) contributed 19.8 per cent of total variance. The PC1 comprised of calcium and iron content. The PC 2 was comprised of vitamin C and protein. Thus, it can be concluded that qualitative characters like calcium and iron were mostly responsible for the variation exhibited by drumstick accessions for qualitative characters. The correlation among the biochemical characters in loading plot indicated the strong and positive association between protein and total phenol; vitamin C and calcium; calcium and iron; beta-carotene and total phenol. Zero correlation was recorded between vitamin C and iron; beta-carotene and total phenol. Beta-carotene exhibited negative correlation with calcium and vitamin C. Similar results were reported by Olson *et al*. (2016).

Clustering of the 25 drumstick accessions based on PCA grouped them into six clusters. Cluster I consisted of two accessions *viz.,* VKMo 5 and VKMo 6 which recorded high mean values for vitamin C, calcium and iron. Cluster V with five accessions *viz.*VKMo 16, VKMo 19, VKMo 21, VKMo 22 and VKMo 32 recorded high mean values for protein, beta-carotene and total phenol. Thus, for crop improvement programme, selection of accessions in cluster I and cluster V will help in production of elite genotypes with high nutritional quality.

Ranking of the 25 accessions detailed by Rajamony *et al.* (1994) was done based on important biochemical and quantitative characters. The result showed that, VKMo 7 ranked first with a score of 87, followed by accession VKMo 9 with a score of 91. Thus, while considering both biochemical and quantitative characters, the performance of the accession VKMo 7 and VKMo 9 were outstanding compared to other accessions, which can be further utilized in breeding programme.

5.6 Organoleptic evaluation

Sensory evaluation is an important factor while identifying a superior accession in breeding programmes. It is essential to regulate the marketability of a product by assessing the consumer's acceptability. Organoleptic evaluation of the drumstick accessions gave an index for overall acceptability with respect to appearance, colour, flavour, aroma, taste and overall acceptability of the leaves.

Among the twenty five accessions, the high mean rank for appearance was recorded in accessions VKMo 2, VKMo 37 and VKMo 38. High mean rank for flavour was recorded in accessions VKMo 20, VKMo 17 and VKMo 5. High mean rank for doneness was recorded in accessions VKMo 17, VKMo 32 and VKMo 20. With respect to taste, high rank was recorded in accessions VKMo 9, VKMo 17 and VKMo 20. High mean rank for bitterness was recorded in accessions VKMo 29 and VKMo 22. In the present investigation it was revealed that, accessions which were high in phenol such as, VKMo 3, VKMo 5 and VKMo 6, ranked low for bitterness in organoleptic evaluation. Thus, it can be inferred that phenols may impart bitterness to the leaves. Accessions such as VKMo 19, VKMo 20, VKMo 29 and VKMo 38 ranked highest for overall acceptability, having low bitterness. These accessions can be selected for further improvement programme to incorporate more qualitative traits.

5.7 Pests and diseases

Incidence of leaf eating caterpillar (*Noorda blitealis*) was observed on drumstick accessions causing maximum damage during the period of January to April. Thus it can be concluded that high temperature favoured the incidence of leaf eating caterpillar. The early instars fed on the leaves of drumstick, leading to papery appearance and leaves get dried up. Results showed that, seven accessions *viz.*, VKMo 5, VKMo 11, VKMo 17, VKMo 30, VKMo 35, VKMo 36 and VKMo 38 were not affected by the leaf eating caterpillar. Hence, there exists a possibility that, these accessions may possess tolerance to leaf eating caterpillar. The same has to be verified by further studies. Similar findings were reported by Anjaneyamurthy (1985).

SUMMARY

6. SUMMARY

The study entitled "Characterization and evaluation of drumstick (*Moringa oleifera* Lam.) accessions for yield and quality'' was carried out in the Department of Vegetable Science, College of Horticulture, Kerala Agricultural University, Vellanikkara during January to December 2018. The study was conducted with the main objective of characterizing drumstick accessions with respect to yield and quality and to identify the superior ones among the accessions under study. The salient findings and important conclusions drawn out from the study are summarized below.

Accessions of drumstick were catalogued based on IPGRI minimal descriptor (2013). These twenty five accessions exhibited considerable variability with respect to quantitative and qualitative characters. Tree shape varied from upright to spreading among the twenty five accessions. Grey coloured barks were observed in majority of accessions except for VKMo 3, VKMo 4 and VKMo 8 which had white bark colour. Leaflet shape varied from ovate to elliptical and leaf apex from obtuse to acute. Leafy tree types generally showed ovate leaf let and acute leaf apex. Both secondary and tertiary flowering branchlets were observed among flowering accessions. Foliage density during flowering period varied from sparse, medium to dense. There was no variability with respect to flower characters. All the accessions produced pale green coloured young shoots with purple tinge. The fruit colour was pale green in all 22 accessions that flowered. Fresh fruit pulp colour was white in all the accessions. Fresh fruit pulp taste was palatable in all the accessions except in VKMo 3, VKMo 6, VKMo 11, VKMo 13 and VKMo 29 which had bitter taste.

Variability in flowering was observed among accessions. Flowering in drumstick were observed in two peaks in January-April and September-November in accessions *viz.* VKMo 2, VKMo 7, VKMo 12, VKMo 15, VKMo 16 and VKMo 17. Accessions VKMo 2 and VKMo 15 flowered for six months in total in two seasons. There are leafy types (VKMo 32, VKMo 35 and VKMo 38) that rarely flower and cultivated exclusively for foliage.

Accession VKMo 3 recorded highest tree height (7.68 m) and trunk girth (65.8 cm). Accession VKMo 10 recorded highest fruit length (89.50 cm), fruit girth (6.72 cm) and number of ridges/fruit (10.50). Highest fruit weight was recorded in VKMo 9 (160.00 g). Accession VKMo 6 recorded highest number of seeds per fruit (21.20). Highest number of fruits/tree was recorded in VKMo 2 (22.21) and total fruit yield/tree in VKMo 3 (1775.54 g/tree). Estimation of biochemical characters in leaves, flowers and fruits revealed that, leaves are rich sources of these biochemical characters followed by flowers and fruits, except for iron. Highest iron content was recorded in flowers, followed by leaves and fruits. Highest vitamin C content was recorded in leaves of VKMo 38 (260.63 mg/100 g) which is a leafy type. Highest protein content was recorded in leaves of VKMo 30 (21.07 g/100 g). Highest beta-carotene content was recorded in leaves of VKMo 16 (16.95 mg/100 g). Highest calcium content was recorded in leaves of VKMo 8 (1330.21 mg/100 g). Highest iron content was recorded in leaves of VKMo 22 (22.55 mg/100 g) and in flowers of VKMo 36 (25.55 mg/100 g). Highest total phenol content was recorded in leaves of VKMo 5 (123.17 mg/100 g) followed by VKMo 6 (121.19 mg/100 g).

Fruit yield/ tree were positively correlated with fruit length, fruit weight and number of fruits per tree. Thus simultaneous selection for these characters would be helpful in improving the total fruit yield per tree. Significant positive correlation was recorded between biochemical characters such as, protein and beta-carotene; beta-carotene and total phenol; and protein and total phenol. Correlation studies between weather characters and biochemical characters revealed a significant, positive correlation between mean temperature and calcium content; beta-carotene with rainfall and number of rainy days.

Path coefficient analysis of yield and yield contributing characters revealed a high direct positive effect on yield by number of fruits per tree, fruit weight, number of seeds per fruit and tree height. Thus based on path analysis, the traits *viz.,* number of fruits per tree, fruit weight, number of seeds per fruit and tree height may be considered as selection indices for yield improvement.

Principal component analysis performed based on quantitative characters revealed that the first three main principal components accounted for 88.1 per cent of the total variation, which was comprised of fruit girth, number of seeds, tree height, trunk girth, number of fruits/tree and yield/tree. Clustering based on principal component analysis resulted in formation of five clusters. Cluster I consisted of a single accession, VKMo 3 recorded maximum tree height, trunk girth, fruit girth, fruit weight, number of seeds, number of fruits/tree and yield. Thus for designing crop improvement programme accession VKMo 3 can be selected.

Principal component analysis based on biochemical characters revealed that, first two components explained 64 per cent of the variation which was comprised of calcium, iron, vitamin C and protein. Clustering based on principal component analysis grouped the accessions into six clusters. Cluster I consisted of two accessions *viz.* VKMo 5 and VKMo 6 which recorded high mean values for vitamin C, calcium and iron. Cluster V with five accessions *viz.* VKMo 16, VKMo 19, VKMo 21, VKMo 22 and VKMo 32 recorded high mean values for protein, beta-carotene and phenol. Thus, for crop improvement programme, selection of accessions in cluster I and cluster V will helps in production of elite genotypes with high nutritional quality.

Ranking of the 25 accessions detailed by Rajamony *et al.* (1994) revealed that accession VKMo 7 and VKMo 9 were superior in terms of important quantitative and biochemical characters compared to other accessions and can be further utilized in breeding programme.

Accession VKMo 29 was most preferred by panelists in the organoleptic evaluation of leaves for overall acceptability and low bitterness. Oganoleptic evaluation also revealed that, accessions which were high in total phenol such as, VKMo 3, VKMo 5 and VKMo 6 recorded high bitterness in leaves.

Incidence of leaf eating caterpillar (*Noorda blitealis*) was observed on drumstick accessions causing maximum damage during the period of January to April and seven accessions *viz.* VKMo 5, VKMo 11, VKMo 17, VKMo 30, VKMo 35, VKMo 36 and VKMo 38 recorded tolerance to leaf eating caterpillar.

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CHARACTERIZATION AND EVALUATION OF DRUMSTICK (*MORINGA OLEIFERA LAM.*) ACCESSIONS FOR YIELD AND QUALITY

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ABSTRACT OF THE THESIS

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ABSTRACT

Drumstick (*Moringa oleifera* Lam.), belonging to the family Moringaceae is one of the most useful tree with a variety of potential uses. Large variability exists in drumstick since the crop is cross pollinated and naturalized in many areas. The study entitled "Characterization and evaluation of drumstick (*Moringa oleifera* Lam.) accessions for yield and quality'' was conducted during January to December 2018. Twenty five accessions were catalogued based on IPGRI minimal descriptors (2013). Data on morphological, quantitative and biochemical characters were recorded for one calendar year (2018) for further analysis.

Tree shape varied from upright to spreading. Grey coloured barks were recorded in majority of accessions except in VKMo 3, VKMo 4 and VKMo 8 which had white bark colour. All accessions produced pale green coloured young shoots with purple tinge. Foliage density at flowering period varied from sparse, medium to dense. Leaflet shape varied from ovate, oblong to elliptical and leaf apex from obtuse to acute. Both secondary and tertiary flowering branchlets were observed. Flowers produced in all the accessions had triangular shaped, polysepalous nature, pale green coloured calyx; corolla having triangular shape, polypetalous nature and cream colour. Fresh fruit pulp colour was white in all accessions. Taste of fresh fruit pulp was palatable in all flowering types except VKMo 3, VKMo 6, VKMo 11, VKMo 13 and VKMo 29, which were bitter in taste. Out of twenty five accessions, three were leafy types *viz.* VKMo 32, VKMo 35 and VKMo 38. Two peaks of flowering *viz.* January- April and September-November were observed in VKMo 2, VKMo 7, VKMo 12, VKMo 15, VKMo 16 and VKMo 17.

Accession VKMo 3 recorded highest tree height (7.68 m) and trunk girth (65.8 cm). Accession VKMo 10 recorded highest fruit length (89.50 cm), fruit girth (6.72 cm) and number of ridges/fruit (10.50). Highest fruit weight was recorded in VKMo 9 (160.00 g). Accession VKMo 6 recorded highest number of seeds per fruit (21.20). Highest number of fruits/tree was recorded in VKMo 2 (22.21) and total fruit yield/tree in VKMo 3 (1775.54 g/tree). Estimation of

biochemical characters in leaves, flowers and fruits revealed that leaves are rich sources of these biochemical characters followed by flowers and fruits, except for iron. Highest iron content was recorded in flowers, followed by leaves and fruits.

Significant, positive correlation was observed between fruit yield per tree and fruit weight (0.613); fruit yield per tree and number of fruits per tree (0.896). Significant positive correlation was recorded between protein and beta-carotene (0.424); beta-carotene and phenol (0.462); protein and phenol (0.466). Significant, positive correlation was observed for beta-carotene content with rainfall (0.640) and number of rainy days (0.603). Calcium content showed a significant, positive correlation with mean temperature (0.585). Trunk girth (0.0266), fruit length (0.029), tree height (0.074), number of seeds per fruit (0.195), fruit weight (0.639) and number of fruits per tree (0.977) exhibited direct positive effect on yield.

Principal component analysis for the quantitative characters revealed that, first three principal components accounted for 88.1 per cent of the total variation and was contributed by number of seeds per fruit, fruit girth, trunk girth and tree height. Clustering of the accessions resulted in formation of five clusters. Principal component analysis on biochemical characters revealed that, first two principal components accounted for 64 per cent variance and was contributed by iron, calcium, protein and vitamin C. Clustering of the accessions resulted in formation of six clusters.

Overall ranking of drumstick accessions for important quantitative and biochemical characters revealed that the performance of accession VKMo 7 (87) was superior followed by accession VKMo 9 (91). Organoleptic evaluation revealed that accession VKMo 29 ranked superior for overall acceptability. Incidence of leaf eating caterpillar (*Noorda blitealis*) on drumstick accessions showed that seven accessions *viz.* VKMo 5, VKMo 11, VKMo 17, VKMo 30, VKMo 35, VKMo 36 and VKMo 38 possess tolerance to leaf eating caterpillar.

APPENDICES

Appendix I

Abbreviations and units used

- IPGRI – International Plant Genetic Resources Institute
- APEDA – Agricultural and Processed Food Products Export Development Authority
- AVRDC - Asian Vegetable Research and Development Center
- RHS – Royal Horticultural Society
- AICVIP - All India Coordinated Vegetable Improvement Project
- PCA – Principal Component Analysis
- hrs – Hours

Units

- g : Grams
- kg : Kilo Grams
- % : Per cent
- cm : Centimetres
- m : Metres

Appendix II

Mean monthly weather data from January to December 2018

Month	Temperature (^0C)	Relative Humidity (%)	Rainfall (mm)	Rainy days
January	27.20	52.94	0.0	0
February	29.05	46.57	0.0	0
March	30.36	58.56	0.9	0
April	30.49	69.97	25.9	2
May	27.93	78.13	483.6	14
June	26.40	89.17	708.0	22
July	26.07	88.02	795.2	21
August	25.68	87.13	928.0	29
September	27.32	75.68	29.0	1
October	27.86	76.13	383.0	13
November	28.03	68.27	63.9	2
December	27.76	62.71	9.6	1