EVALUATION OF CURRY LEAF (*Murraya koenigii* L.) ACCESSIONS FOR YIELD AND QUALITY

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by

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

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DEPARTMENT OF PLANTATION CROPS AND SPICES

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KERALA, INDIA

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DECLARATION

I, hereby declare that this thesis entitled **"Evaluation of curry leaf (*Murraya koenigii* L.) 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: — 2016-12-006

CERTIFICATE

Certified that this thesis entitled **"Evaluation of curry leaf (*Murraya koenigii* L.) accessions for yield and quality"** is a record of research work done independently by **Ms. Anila Peter** 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. Anila Peter** (2016-12-006), a candidate for the degree of **Master of Science in Horticulture**, with major field in **Plantation Crops and Spices**, agree that this thesis entitled **"Evaluation of curry leaf (*Murraya koenigii* L.) accessions for yield and quality)"**may be submitted by **Ms. Anila Peter**, in partial fulfillment of the requirement for the degree.

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EXTERNAL EXAMINER

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"The rod of Aaron for the house of Levi had sprouted and put forth buds and produced blossoms, and it bore ripe almonds"

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Anila Peter

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LIST OF ABBREVIATIONS

AAE	Ascorbic Acid Equivalence
@	at the rate of
cm	centimetre
CD	Critical Difference
et al	and coworkers
Fig.	Figure
g	Gram
HCl	Hydrochloric acid
m	Metre
M	Molar
ppm	Parts per million
%	Percent
<	Less than
>	Greater than
µ	micro
RHS	Royal Horticulture Society
SE	Standard Error
viz	namely
mg	milligram
IU	International Unit

Introduction

1. INTRODUCTION

Among the herbal spices, Curry leaf (*Murraya koenigii* L.) belongs to the family Rutaceae which represents more than 150 genera and 1600 species. It is widely used in Indian culinary for centuries. It is a semi evergreen aromatic tree occurring in wild and cultivated state. It is a native of India growing to a height of about 6 metre and is valued for its aromatic leaves.

Curry leaves are fragrant, spicy and good source of beta carotene (Philip, 1981). *Murraya koenigii* possess medicinal and neutraceutical properties and have a versatile role to play in traditional medicine. Traditionally fresh leaves, dried leaf powder and essential oil are widely used for flavouring food preparations. The essential oil is also utilized in soap, cosmetic industry and aromatherapy. Pharmacological importance of crop is due to its antidiarroheal, hypoglycemic, antifungal, anti inflamatory and hypotensive properties.

Though it is classified as minor spice crop, India is the largest producer and consumer of curry leaf. It is grown on commercial scale in some states of India. Curry leaf has a huge demand in India and abroad which has made the commodity of immense trade value. It is an important export commodity from India fetching good foreign revenue. The fresh leaves are exported to Gulf, European and African countries etc. The country exported 600 tons of curry leaves valued at 37 lakhs during 2016-17, and the European Union accounts for 20 per cent of the total value of curry leaves exports (Aju *et al*., 2018).

Curry leaves are marketed both in fresh and dried forms and leaves retain their original flavour even after drying. *M. koenigii* leaves are used in traditional medicine both in ayurvedic and unani medicine. The plant is credited with tonic, stomachic and carminative properties. The green leaves are used to treat piles, inflammation, itching, fresh cuts, dysentery, vomiting, burses and dropsy.

In addition to leaves, bark and roots are also used in indigenous medicine as stomachic, antihelmintic, analgesic and as a carminative agent for treating variety of diseases. Leaves are reported to contain good amount of protein (6.1

%), carbohydrate (16 %) and fibre (6.2 %). It is a fairly good source of calcium (810 mg $100g^{-1}$), phosphorous (600mg $100g^{-1}$) and carotene (12600 IU).

In Kerala, curry leaf is not commercially cultivated at present and our requirements are met from nearby states of Karnataka, Andhra Pradesh and Tamil nadu. The presence of large quantities of residues of pesticides are detected when curry leaf, marketed in Kerala were analyzed in the NABL at College of Agriculture, Vellayani and reports indicates, highest pesticide residue of Profenophos (0.072 to 9.83 ppm) followed by Ethion (0.07 to 4.46 ppm) in leaf samples (NABL, 2019).

In Kerala it is grown as a homestead crop and a considerable variability is noticed in curry leaf plants grown in home gardens in morphological and biochemical traits. In Kerala, most of the farmers are growing landraces which may or may not have aroma and flavour.

Essential oil is the prime parameter influencing quality especially aroma and flavour due to the presence of certain versatile components. Leaves contain carbazole alkaloids and the major constituents for authentic aroma and flavour are caryophyllene and phellandrene. Variation in essential oil and volatile elements were reported in curry leaf from different geographical locations.

Department of Vegetable Science, KAU is maintaining a curry leaf germplasm in the field which has not been evaluated extensively till now. The chemical differences in leaf essential oils that influence the flavour value of spice have not been investigated so far. Hence a detailed study was taken up to identify the morphological and chemical diversity in curry leaf germplasm maintained in KAU, which will finally result in identification of superior genotypes with respect to yield and quality.

Curry leaf is conventionally and commercially propagated through seeds, which germinate under partial shade conditions. The seeds retain viability only for a short period (1 month) and the seedlings exhibit heterogeneity. One year old root suckers are also used as propagating material, but the number of root suckers produced is very low in most of the cases.

Considering the above facts a study entitled "Evaluation of curry leaf accessions for yield and quality" was taken up with the following objectives

1. Evaluation of curry leaf accessions for morphological and biochemical characters
2. Standardisation of vegetative propagation through stem cuttings

Review of literature

2. REVIEW OF LITERATURE

Curry leaf *Murraya koenigii* L. (Syn *Bergera koenign* Linn), a member of Rutaceae family, is a perennial herbal spice crop grown for its aromatic leaves. The name *Murraya koenigii* has been drawn from the names of two German botanists, Johann Andreas Murray (1740-1791) from Sweden and Johann Gerhard Konig (1728-1785) (Peter, 2003). The plant is largely cultivated for its fragrant leaves and is common in most parts of India (Sivarajan and Balachandran, 1994). Curry leaves has slightly pungent, bitter and feebly acidic taste and they retain their flavour and other qualities even after drying. Besides being a spice crop, curry leaf plays a major role in the Ayurveda and Unani systems of medicine due to its wide range of medicinal properties. The traditional system of medicine, it is utilized as blood purifier, anti-diarrhoeal, dysentery, tonic, stomachic, febrifuge, antiemetic and as a flavouring agent in curries and chutneys as a flavouring agent (Prajapati *et al.,* 2003).The available literature on *Murraya koenigii* has been reviewed in this chapter.

2.1. Morphological characterization

Morphological characters have been the main criteria by which plant genotypes have been identified and it is also employed to assess the variability between genotypes. Most of the crop plants are essentially classified into varieties on the basis of characters such as growth habit, leaf and floral morphology.

Reish *et al.* (1994) recognized different genotypes of curry leaf in Srilanka of which many are common in India and identified drought and heat tolerant genotype.

Lal *et al.* (2001) studied the genetic associations and diversity of 43 genetically diverse genotypes (Nineteen from Uttar Pradesh, eleven from Orissa, nine from Kerala, two from Tamilnadu and one each from Andhra Pradesh and Delhi) and among these accessions, No. 40 (CNBNS-31),41 (CNHL-32) and

1(CNPRZ) were found to be superior in terms of high yield and quality parameters like essential oil and spicy odour under northern Indian condition.

Lal *et al*. (2003) grouped curry leaf accessions into seven clusters and observed enormous diversity among accessions. The oil content, branches per plant at primary and secondary axis, leaflet width at the primary axis, leaflet length and leaf length at the secondary axis respectively were the largest contributors to genetic divergence. The least contributor to genetic divergence were leaflet length in leaf at the primary and secondary axis and days to flowering initiation.

Ranade *et al*. (2006) carried out molecular differentiation in 20 accessions of *Murraya collected* from different geographical regions of India through ITS, RAPD and DAMD analysis and found out higher heterogeneity in *Murraya koenigii.*

Sivakumar and Meera (2013) reported three morphotypes of curry leaf differing in the habitat of plant, intensity of flavour, colour and size of leaves. They were named as brown or guthi, regular and dwarf. The tall and fast growing regular types with long dark green leaves were available all over India.

2.1.1. Plant and leaf characters

The important morphological traits that influence the growth, development and productivity of a curry leaf tree were found to be plant height, number of branches and leaves per rachis. Remarkable difference in leaf area was recorded in wild and cultivated types by Hiremath *et al*. (1997). The leaf area of tender leaf ranged from 3.92 to 8.68 cm^2 and the wild variety exhibited higher leaf area (8.68 cm^2).

Lalitha *et al*. (1997) evaluated sixteen accessions of curry leaf collected from South Indian states for variation in quantitative and qualitative characters.

The results revealed that leaf colour was dark green in most of the accessions. All the accessions had lanceolate leaves except MK10, which had cordate leaves. The highest number of shoots per plant (15) and number of leaflets per shoot (53.41) were recorded in accession MK 11. It also exhibited highest number of leaflets per leaves (21.35) and leaf length (6.11 cm). The leaf breadth ranged from 0.97 cm to 2.55 cm while the highest leaf area was recorded in MK 7 (139.95 cm^2).

Subha *et al*. (2010) observed mean plant height of 94.51 cm, number of secondary branches as 27.03, number of leaves per rachis as 16.32 and specific leaf area of 54.77 cm^2g^{-1} during monsoon season. However in winter season mean plant height, number of secondary branches, numbers of leaves per rachis and leaf area were found to be 91.22 cm, 18.85, 16.l0 and 44.66 cm^2g^{-1} respectively.

The cultivar 'Suvasini' recorded mean plant height of 156.46 cm, number of primary and secondary branches as 6.84 and 8.40 respectively. The number of leaflets per compound leaf and leaf area in this cultivar were found to be 20.52 and 49.50 cm^2 (Siddappa and Hedge, 2011 and Hedge *et al.* 2012).

Aravind *et al*. (2012) recorded mean plant height, number of secondary branches and number of leaves per rachis 19.22 in curry leaf during off season with values of 61.41 cm, 24.61 and 19.22 respectively.

Jagadeeshkanth and Sankaranarayanan (2014) reported, mean plant height of 79.36 cm in curry leaf after three month planting. The numbers of primary and secondary branches were found to be 3.63 and 17.11 respectively at third cutting stage and mean number of leaflets per leaf recorded at this stage was 20.37.

Jansirani and Suresh (2017) evaluated the effect of pruning techniques and foliar nutrition on growth characters of curry leaf and the results indicated highest growth characters *viz.*, plant height (127.84 cm and 124.78 cm and number of secondary branches 7.01 and 13.67) at first and second harvest respectively.

Agba and Adiaha (2018) studied the effects of plant row spacing on the growth characters of *Murraya koenigii* in South Nigeria in two cropping seasons 2015 and 2016. In 2015 cropping season, after 21 weeks of planting observations on mean plant height (65.42 cm), number of branches per plant (7.30), number of leaves per plant (56.10) and leaf area index of (1.02) were recorded. Whereas, mean plant height of 68.77 cm, number of branches per plant (7.20), number of leaves per plant (57.30) and leaf area index (1.123)were noticed in 2016 cropping season.

2.1.2 Yield

Madalageri *et al.* (1996) reported that four year old curry leaf cultivars DWD-1 and DWD-2 produced 12.85 kg and 9.00 kg fresh leaves per bush per year. The fresh leaf yield of DWD-1 was found to be 3.70 kg in summer and 3.56 kg in winter season. Average yield of 3.35 kg per plant was recorded in curry leaf accession MK 2 (Vellanikkara) for four harvests (Lalitha *et al*., 1997)

The seasonal influence on fresh leaf yield of curry leaf cultivars were examined by Madalageri *et al*. (1998) and results showed per plant mean leaf yield of 836.76 g in winter, 3031.25 g in summer and 1513.27 g in rainy season. From the study it was concluded that summer season favours maximum production of curry leaf followed by rainy season and winter. It was revealed that there is a linear relationship between leaf yield and the growing degree days.

The crop regulation studies on curry leaf during off season by Subha *et al.* (2010) revealed less production of fresh curry leaves during winter season due to unfavourable environmental conditions especially due to low temperature. In their study fresh leaf yield per plant during monsoon and winter season were 608.810 g and 376.79 g respectively.

Foliar spray of vermiwash gave the highest annual fresh leaf yield per plant (5.79kg) and per hectare (13.07 t) compared to control (5.05 kg per plant and 11.13 t per ha respectively) in curry leaf cultivar Suvasini (Siddappa and Hedge, 2011).The mean fresh yield of 550.71 g leaves per plant was recorded in curry leaf plant during off season by Aravind *et al*. (2012).

Hedge *et al*. (2012) recorded an annual fresh leaf yield of 5.05 kg per plant and 13.07 tons per hectare in Suvasini cultivar. The effect of fertigation on fresh leaf yield of curry leaves were studied and mean yield at third stage of cutting was observed as 691.92 g (Jagadesshkanth and Sankaranarayanan, 2014).

Agba and Adiaha (2018) recorded a fresh leaf yield of 79.11g per plant and 76.35 g per plant in twenty four week old curry leaf plants in two different cropping seasons 2015 and 2016 respectively.

In a study conducted by Jansirani and Suresh (2017), the fresh leaf yield per plant was found to be 643.50 g in first harvest and 714.21 g in second harvest in curry leaf. The leaf yields per hectare were noticed as 4468.80 kg and 4959.47 kg in first and second harvest.

2.2. Biochemical characterization

Lalitha *et al*. (1997) reported highest chlorophyll content of 0.17 mg g^{-1} in fresh leaves from curry leaf accession collected from Vellanikkara. The reversed phase gradient HPLC analysis of fresh curry leaves reported 183 ng of beta carotene per gram fresh weight (Palaniswamy *et al*., 2003).

Subha *et al*. (2010) reported total chlorophyll content of fresh curry leaves as 0.104 mg g^{-1} and 0.096 mg g^{-1} in monsoon and winter season respectively.

The antioxidant activity of aqueous extracts of curry leaves and salam leaves were studied by Safriani *et al.* (2011). The total polyphenol content obtained was 54.99 mg GAE g^{-1} and 40.59 mg GAE g^{-1} in curry leaf and salam leaves respectively. The extracts exhibited antioxidant activity of 84.02 % and 84.03 % for curry leaves and salam leaves respectively through DPPH assay.

Zhang *et al*. (2011), compared the phytochemicals and antioxidant activity of curry leaf and recorded protein content of 11.8 % and 0.11 mg g^{-1} beta carotene on dry weight basis. The ethanolic extract shown 79.90 mg g^{-1} total phenolic content whereas HPLC analysis recorded 14.547 mg g^{-1} on dry weight basis. The antiradical power value was found to be 0.63 mg DPPH/mg ethanolic extract.

Sasidharan and Menon (2011), studied the effects of temperature and solvent on antioxidant properties of different curry leaf extracts. The total phenolic content of extracts varied from 140 to 501.4 GAE mg g^{-1} and found maximum in ethanol water mixture at room temperature (501.4 GAE mg g^{-1}). The ethanol water extract also expressed highest radical scavenging activity of 82 %.

Mitra *et al.* (2012) recorded total phenol content of 57.5 mg GAE g^{-1} in curry leaf aqueous extract. Gul *et al*. (2012) evaluated curry leaf extracts for their antioxidant activity and found that total polyphenol contents in the range of 2.7 to 28.84 GAE mg g^{-1}dry weight plant material while total antioxidant activity ranged from 6.04 to 25.54 AAE mg g^{-1} dry weight plant material.

The evaluation study on three morphotypes (brown, dwarf and regular) of *Murraya koenigii* for antioxidant activity was carried out by Sivakumar and Meera (2013). The total polyphenol content varied from 111.60 to 532.8 mg g^{-1} whereas antioxidant activity ranged from 621.10 to 1268.80 ascorbic acid equivalence mg g^{-1}. The study concluded that brown type possesses highest antioxidant activity followed by dwarf and regular type.

Ghasemzadeh *et al*. (2014) investigated bioactive compounds of curry leaf extracts from different locations in Malaysia. The total phenolic content varied from 12.02 to 14.371 mg g^{-1} dry weight. The DPPH scavenging activity ranged from 5.76 to 66.41 % among extracts.

Vyas *et al*. (2015) reported that higher total phenolic content of curry leaves is responsible for its higher antioxidant activity. The phytochemical characterization of curry leaves recorded 18.49 % protein, 68.66 % total carbohydrate and total phenolic content of 3.21mg g^{-1}.

Azeez *et al*. (2016) examined major Indian spices for its essential oil content, ethanol-water extract. The essential oil of curry leaf recorded total phenolic content of 0.019 mg GAE ml^{-1} and total antioxidant potential of 357.47 µmol AAE ml^{-1}. In case of solvent extracts, higher antioxidant potential was observed in ethanol extract (579 µmol AAE g^{-1} dry weight) than aqueous extract (68.55µmol AAE g^{-1} dry weight). The higher total phenolic content was found in aqueous extract (0.376 mg GAE g^{-1}) over ethanol extract 0.293 mg GAE g^{-1}.

The proximate composition and vitamin contents of *Murraya koenigii* leaves were investigated by Igara *et al*. (2016) using standard procedures. The results of the study indicated a phenolic content of 4.25 %, carbohydrate 39.44 %, crude fibre 6.30 % and protein content of 8.38 %. The beta carotene content was analyzed and was found to be 6.04 mg $100g^{-1}$.

The dehydration studies on curry leaves by Sakhale *et al*. (2017) revealed 44 % dehydration yield in shade dried curry leaves. The proximate composition study reported 5.9 % protein, 6.3 % crude fibre and 15.6 % carbohydrate in fresh curry leaf sample.

The biochemical investigation on *Murraya koenigii* conducted by Soundappan *et al*. (2018) revealed a total polyphenol content of 547 mg g^{-1} and TROLOX equivalent antioxidant capacity of 211 µgml^{-1} in leaf extract.

Pharmagcognostical evaluation of curry leaf powder and extract using standard procedures were performed by Aju *et al*. (2018). The results showed low values for moisture content (19.26 %) and crude fibre content (19.96 %). The leaves possessed strong aroma even though it contain low amount of volatile oil (1.5 %).

A higher polyphenol content (24.44 GAE mg g^{-1}) and free radical scavenging activity (81.13 %) were reported in Curry leaf over Euphorbia leaves where the values for polyphenol content and free radical scavenging activity were found to be 14.98 mg GAEg^{-1} and 17.41 % respectively (Lalwani *et al*., 2014).

2.2.1. Essential oil

Variation in essential oil and volatile elements were reported from different geographical locations. The yield of volatile oil was found to be greater in dried leaves than fresh leaves (Prakash and Natarajan, 1974). Philip (1981) reported that tender leaves contain more content of volatile oil and oleoresin than the mature leaves. Tender leaves upon steam distillation yield 2.6 % oil, consisting of caryophyllene (26.30 %), cadinene (18.20 %), cadinol (12.80 %), sabinene (9.2 %), dipentene (6.8 %), alpha pinene (5.5 %), alpha phellandrene (4.6 %), alpha terpene (3.2 %), lauric acid (2.7 %) and palmitic acid (3.4 %).

Curry leaf cultivar 'Suvasini' yielded 2.27 % oil by solvent extraction method whereas percentage oil yield of 0.49 % was noted in hydro-distillation method. Madalageri *et al*. (1996) reported that local cultivar yield low percentage oil in solvent extraction (2.13 %) and hydro distillation (0.35 %) method. The highest quantity of β-caryophyllene (36.30 %) was also observed in 'Suvasini' cultivar. The cultivar 'Suvasini' on hydro distillation yields pale yellow coloured oil of 0.44 %. Madalageri *et al.* (1997) identified seven major components covering 68.25 % of the total composition of oil from GC analysis. The major components identified were β-caryophyllene (36.30 %) followed by β- Gurjunene (24.51 %), which are responsible for the strong aroma of leaves.

Hiremath *et al.* (1997) evaluated the oil content of curry leaf cultivars and recorded higher oil yield in cultivated variety 'Suvasini' (0.44 %) than the remaining cultivars (0.06 to 0.44 %). This study indicated the superiority of the cultivar 'Suvasini' in terms of aroma, flavour and oil content.

Chemical investigations carried out on aroma principle of curry leaf revealed the occurrence of several chemical races from different parts of India. In their study, occurence of four distinct chemotypes *viz.*, alpha-phellandrene, alpha-pinene, beta-pinene and beta caryophyllene were reported from Kerala, Tamilnadu, Andhra Pradesh, Orissa, Uttar Pradesh and Delhi (Raina *et al.*, 2002).

Walde *et al.* (2005) recorded essential oil yield of 0.833 % by steam distillation in curry leaves. Chowdhary *et al.* (2008), evaluated chemical composition of two Murraya species. The leaves of *Murraya paniculata* and *Murraya koenigii* extracted through hydro distillation yielded 0.5 % and 1 % of essential oil per weight of dried material respectively.

Verma and Rana (2011), assessed the variations in yield and composition of essential oil of two chemotypes A and B of curry leaf grown in Northern India in different seasons. The essential oil yield of chemotype A varied from 0.15 to 0.18 % whereas 0.12 to 0.14 % oil yields were recorded in chemotype B in different seasons. A higher oil content of 0.18 % was recorded by chemotype A in spring and autumn season while chemotype B, recorded 0.14 % oil in summer and rainy season. A total of fifty eight compounds (93.7 to 98.8 % of total composition) were reported from chemotype A while chemotype B composed of fifty six compounds (96.1 to 98.7 % of total composition).

The variation in essential oil yield of *Murraya koenigii* among different locations of India was investigated by Rao *et al.* (2011). The essential yield varied from 1.25 to 2.5 ml kg^{1} fresh leaves. The lowest yield was noted in curry leaves collected from Thrissur (1.2 ml per kg). The spicy aroma of curry leaves from Thrissur and Warangal were attributed by presence of sesquiterpenes, E-caryophyllene and α-selinene. The cultivated trees produced higher essential oil yield compared to the wild trees.

Syamasundar *et al.* (2012), examined wild curry leaf samples from Western Ghats for their differences in essential oil yield. The essential oil yield varied from 1.6-3.70 ml kg^{-1} fresh leaves on hydro distillation method. GC-MS analysis recorded significant chemical diversity in terms of major components (α-pinene, β-phellandrene, sabinene and β-caryophyllene) in essential oil.

Curry leaves grown in South Vietnam recorded 0.83 % and 0.39 % oil yield in conventional and microwave assisted hydro distillation method respectively. The analysis of essential oil identified 76 and 62 compounds for conventional and microwave assisted hydro distillation method respectively (Nguyen *et al.*, 2012).

A comparative study on extraction methods of curry leaf essential oil were carried out by Azeez *et al.* (2016). Hydro distillation method yielded 0.02 % yellow coloured oil after 5 hour of extraction whereas microwave assisted yielded 0.01 % pale yellow colour oil with one and half hour extraction. Highest numbers of chemical compounds were recorded in hydro distillation method (79.6 %) than microwave assisted hydro distillation (75.7 %).

Shivanna and Subban (2014) observed higher oil recovery on volatile oil extracted from shade dried curry leaf sample (1.34 %) compared to fresh leaves which yielded low oil recovery (0.66 %).

Jamil *et al*. (2016) compared the efficacy of two oil extraction methods, hydro distillation and steam distillation of fresh curry leaves. Higher oil yield (0.25 %) was recorded in steam distillation over hydro distillation (0.09 %) for the same extraction period.

Rani *et al*. (2017) examined essential oil yield of fresh and shade dried curry leaves Fresh leaves on hydro distillation yielded 0.6 % oil and shade dried curry leaves yielded 0.5 % oil after 5 hours of extraction. Forty two compounds representing 95.7 % of total volatile were identified from shade dried material of which α-pinene was the major compound (34.4 %).

2.3. Propagation of stem cuttings

Propagation by cuttings is probably the easiest, most efficient and cheapest method to produce true-to-type and uniform plant materials. However, cuttings from different species have different capacity to form roots. Woody plant stem cuttings are often difficult-to-root, and this difficulty is still one of the major obstacles for economical propagation. Application of synthetic auxins as root promoting substances such as indole-acetic acid (IAA), indole butyric acid (IBA), or naphthalene acetic acid (NAA) at the basal portions of the stem cuttings appeared to be an effective method to induce root formation. Mixtures of two types of auxins are sometimes more effective than either component alone (Hartmann *et al.*, 2010). In some difficult-to-propagate species, shoots might grow earlier, but roots did not form in months. The success of propagation by cuttings is indicated by high percentage of rooted cuttings and shoots growth.

2.3.1. Effect of Indole butyric acid (IBA) on cuttings

Devigire (1986) observed significant effect of IBA treatment with respect to rooting, survival and sprouting of sweet lime stem cuttings. The treatments 50 and 100 ppm IBA applied by the prolong dip method and 2000 ppm IBA used by the quick dip method recorded 100 percent rooting. The root and shoot parameters, percentage of callus forming cuttings and percentage of cuttings having secondary roots also showed improvement with the application of IBA in this experiment.

Mohanalakshmi *et al*. (2000) investigated the effect of maturity and season on rooting of semi hardwood cuttings of curry leaf. The cuttings from past season and current season shoot were treated with 1500 ppm IBA and the semi hardwood cuttings planted during May and July recorded 30 % and 20 % rooting. The cuttings from past season shoot planted in May month found to be best for rooting over current season shoot. The rooting percentage of cuttings increased with increase in concentration of IBA and the hardwood and semi hardwood cuttings showed higher rate of survival with increased rate.

Nath (2000), treated apical shoots of lemon (*C. limon*) cv. Assam, with IBA (1000, 2000, 3000 and 4000 ppm). Results showed that the highest percentage of rooting (98.5%) and survival (100%) were recorded for cuttings treated with 3000 IBA ppm under sand medium, whereas the lowest rooting and survival were obtained in untreated cuttings. Cuttings treated with 3000 ppm IBA also proved to be superior with regard to number of primary roots, root length, number of leaves, dry root weight and shoot length per cutting.

Patel (2001) concluded that among the various levels of IBA (1000, 2000, 3000, 4000 and 5000 ppm), 4000 ppm IBA was proved to be the best for sprouting, highest number of main roots, length and thickness of longest root, number of shoots per rooted cuttings as well as fresh and dry weight of roots in hardwood cutting of *Jasminum sambac* cv. Double Mogra. Gupta and Thakur (2001) studied the effect of IBA and NAA on rooting of air layers of Jackfruit and result revealed, maximum success (90 %) with combination of 5000 ppm IBA+ NAA.

Ranganathappa *et al*. (2002) studied the effect of IBA on rooting and survivability of curry leaf stem cuttings. Hardwood cuttings treated with 2000ppm IBA recorded highest rooting percentage (37.50 %) and survival percentage (91.67 %). Swetha (2005) reported that IBA at 2000 ppm was found to be better for induction of rooting (66.66%) as against the control (15.33%) in Indian lavender (*Bursera delpechiana*).

Rema *et al*. (2008) reported that all spice cuttings treated with IBA at1000 ppm during December month resulted in highest rooting of 48.8% compared to other treatments and growth regulator combinations. Study on vegetative propagation of pomegranate through cutting conducted by Sharma *et al*. (2009) showed maximum rooting, field survival, root number and root length in semi hardwood and hardwood cuttings of Pomegranate treated with 500 ppm IBA.

Air layer of waterapple treated with various concentrations of IBA and NAA revealed that, NAA and IBA at 1000 ppm found to be more effective in inducing roots with thicker roots in IBA treated cuttings (Paul and Aditi 2009).

The effect of different concentrations of Indole butyric acid (IBA) and different growing conditions on the adventitious root formation in stem cutting of Kagzi lime was evaluated by Butt and Tomar (2010). The cuttings treated with IBA at500 ppm, performed the best in all aspects *viz.*, on root formation, length of root, thickening of root and leaf sprouting in shoot in this study.

Singh *et al.* (2011) observed that the length of sprout (18.77 cm) and number of roots (21.22) were maximum in 3000 ppm IBA treatment whereas length of root was maximum (15.32 cm) in 5000 ppm of IBA in stem cuttings of *Bougainvillea glabra*. Treatment of 4000 ppm IBA was found to be the best for increasing rooting percentage, number of roots and root length in difficult to root H*ibiscus rosasinensis* var. yellow double hybrid (Shadparvar *et al.*, 2011)

Ganjure *et al.* (2012) evaluated the response of IBA on rooting of Chrysanthemum cuttings and results indicated that number of days to sprouting (8.60) and rooting (9.33) were minimum with IBA at 1000 ppm.

Mehraj *et al*. (2013) investigated the influence of IBA on sprouting and rooting potential of *Bougainvillea spectabilis* stem cuttings. Stem cuttings were soaked in 500, 1000 and 2000ppm of IBA and the cuttings treated with 1000ppm IBA gave maximum percentage of rooting and survival.

Sahariya and Abhishek (2013) reported that the IBA at 2000 ppm was found to be superior for getting high percentage of rooted cuttings (63.33%), number of roots (30.00), length of roots (12.85cm) and dry weight of roots (0.43g) after two months of planting in Bougainvillea var. Thimma cuttings.

Singh *et al*. (2013) reported IBA at 2000 ppm concentration as the best rooting treatment for *Citrus limon* cuttings. The treatment produced highest number of sprouted cuttings (6.29), number of sprouts (17.77), longest sprout (23.77 cm) and number of roots per cutting (52.42).

Singh *et al*. (2013) carried out a study on rooting of Night queen cuttings under subtropical valley conditions. The cuttings treated with 100ppm IBA showed higher number of sprouted cuttings, rooting percentage, length of roots while the maximum length of sprout was recorded in 300ppm IBA treatment.

Saumitro and Jha (2014) studied the effects of plant growth regulators IBA and NAA on root proliferation of *Taxus wallichiana* stem cuttings and found better rooting response in IBA treated cuttings.

Singh *et al*. (2014) investigated the effect of IBA and NAA on the rooting of mulberry cuttings treated with 1000, 1500 and 2000ppm of IBA and NAA by quick dip method. The number of sprouted cuttings, length of roots and sprout length were found to be higher in 2000ppm IBA treated cuttings.

Among the different treatments tried, Singh *et al.*(2014) observed minimum days (20.66) taken to callus formation, highest number of sprouts per cuttings (4.34), number of roots per cutting (43.00), percentage of rooted cutting (88.00 %), length of roots per cutting (9.28 cm) and diameter of root per cutting (1.67 mm) in 1400 ppm IBA treated stem cuttings of Golden Duranta.

Al Zebari and Al Briffkany (2015) investigated the effect of IBA on rooting capacity of Citron stem cuttings and found that increase in IBA concentration resulted in increased rooting percentage, length of roots, shoot diameter, number of leaves and leaf chlorophyll content. Semihardwood cuttings treated with 500 and 1000 ppm of IBA performed better in terms of root percentage, length of shoot, number of leaves and length of roots.

Singh *et al*. (2015) evaluated the effect of hormonal treatments on rooting ability and survival of *Citrus limon* cuttings. Maximum number of sprouts (2.42) and highest survival percentage (81.68 %) were noticed in IBA 5000pm concentration. The combination of 5000 ppm IBA + NAA resulted in maximum number of primary and secondary roots (7.74 and 16.19 respectively) per cutting. Spring season was found superior in terms of survival percentage (77.37 %), number of sprouts (2.29), and number of primary and secondary roots per cutting (7.3 and 15.30 respectively). Among the different media observed, mixture of soil + sand+ cocopeat was concluded as the best medium for rooting.

Kumar *et al*. (2015) recorded maximum spouting (81.90 %) and survival percentage (88.70 %) of cuttings of Carnation with 8000ppm IBA as compared to control. Soni *et al.* (2015) noticed higher success percentage (36.63 %) in hardwood and semi hardwood cuttings of guava treated with 3000 ppm IBA as compared to control.

The stem cuttings of *Gmelina arborea* treated with NAA 1000ppm showed maximum sprouting (41.33 %), rooting (53.58 %) and number of roots per cutting (23.83) in a study conducted by Patil *et al*. (2017).

Semihardwood cuttings of Pomegranate cv Bhagwa were treated with a combination of different concentrations of IBA and NAA for 8 hours. The cuttings treated with 1500 ppm IBA+1500 ppm NAA recorded highest sprouting and rooting percentage, maximum number of sprouts, greatest diameter of sprout and roots as well as longest roots (Ahmad, 2017).

Kabir and Karim (2018) evaluated the rooting performance of *Aegle marmelos* (Bael) through clonal propagation by stem cuttings under three different doses of IBA (0.2 %, 0.4 % and 0.8 %). The highest rooting percentage (60 %) was recorded with 0.2 % and 0.4 % IBA followed by 0.8% IBA (40 %) whereas the longest root (3 cm) was recorded with 0.4 % IBA followed by 0.2 % IBA (1.2 cm). The maximum root number (2.25) and root diameter (2 mm) was obtained from cuttings treated with 0.8 % IBA followed by 0.4 % IBA (2 and 1.9 mm respectively). Survival percentages of the rooted cuttings were significantly enhanced and the highest survival percentage (73.5 %) was obtained for the cuttings treated with 0.4 % IBA followed by 0.8 % IBA (68.5 %).

Ahmad *et al*. (2018) studied the effect of IBA and GA_3 alone and in combination on rooting and shooting parameters of Rangpur lime cuttings. Among the various treatments used, IBA 1000 ppm gave the best response in all the parameters studied *viz.*, maximum number of roots per cutting (3.93), girth of the thickest root (1.38 mm), length of the longest root (4.47 cm), percentage of rooting per cutting (45.37 %), survival percentage (60.00 %), number of leaves per cutting (2.27), number of secondary branches per cutting (1.87) and number of leaves per secondary branch (4.60) and minimum was with control.

. Lower concentration of IBA (1000 ppm) for juvenile and higher concentration (2000ppm) for mature cuttings were proved to be the best for successful rooting in *Taxus baccata* stem cuttings by Das and Jha (2018).Tanya and Rana (2018) observed maximum percentage of sprouting and rooting with 8000ppm of IBA in stem cutting of karonda cv Pant manohar

Ibrahim *et al*. (2015) studied the effect of growth regulators in the propagation of difficult to root Limon verbena cuttings. The highest values for rooting percentage and root length were recorded with 250ppm of IBA in semihardwood cuttings followed by 1500 ppm IBA and 200ppm NAA.

In Pomegranate cuttings, highest number of sprouted cuttings, maximum number of leaves on new shoot, length of longest sprout and percentage of rooted cuttings were observed with 500ppm IBA (Mehta *et al.,* 2018).

2.3.2. Effect of Naphthalene Acetic Acid (NAA) on cutting

Chauhan *et al.* (1992) reported that NAA and IAA at 300 ppm under prolonged soaking method and NAA at 1500 ppm in quick dip method were found to be the best for initiation of early rooting, maximum root length and survival percentage under field condition in *Rosmarinus officinalis* L.

Sari and Qrunfleh (1995) noticed that the softwood cuttings of *Jasminum grandiflorum* rooted best in January with 500 ppm NAA.

Tripathy *et al*. (2003) observed that *Euphorbia pulcherrima* cuttings treated with NAA 2000 ppm and IAA 2000 ppm showed the maximum rooting percentage (97.78) followed by IAA 1000 ppm (95.56).

Maximum bud sprouting (78.76 %), bud spread (11.32 cm) and shoots length (13.68 cm) in Damask rose cuttings were recorded at 50 ppm of NAA while, the maximum days to bud sprouting (13.11) and number of leaves (7.37) were recorded at 75 ppm of NAA (Khan *et al.*, 2006).

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Abuzahra and Ahmad (2013) reported highest rooting percentage with 3000 ppm NAA in Hedera cuttings and with 4000 and 1000 ppm of NAA in Gardenia and Syngonium cuttings respectively.

Kumar *et al.* (2015) investigated the effect of different concentrations of auxins (IAA, NAA and IBA) and types of cuttings on the rooting traits of *Dianthus caryophyllus* L. Earliest rooting (18.69 days), highest rooting percentage (58.70 %), number of roots (13.18), root length (12.26 cm), highest fresh (4.93 g) and dry weight of roots (45.08 mg) were obtained in basal cuttings treated with NAA 500 ppm.

The stem cuttings treated with NAA 1000ppm showed maximum sprouting (41.33 %), rooting (53.58 %) and number of roots per cutting (23.83) in *Gmelina arborea* (Patil *et al.*, 2017).

2.3.3. Effect of combination of IBA and NAA on cutting

Gupta and Thakur (2001) studied the effect of IBA and NAA on rooting of air layers of Jackfruit and maximum success (90 %) was reported with combination of 5000 ppm IBA+ NAA.

Blythe *et al.* (2004) studied the rooting behaviour of stem cuttings of four tropical ornamentals treated with auxin by basal quick dip method with the concentration of 4920 µM IBA and 2685 µM NAA. The softwood cuttings of *Aglaonema modestum* S. produced 9.5 roots per cutting and highest root length of 38.6 cm while untreated cuttings produced only6.1 roots per cutting and root length of 27.0 cm. Two node cuttings of *Gardenia augusta* L. produced 9.1 roots per cutting and total root length of 31.1 cm while untreated cuttings produced lesser. Terminal cuttings of *Ficus benjamina* L. produced total root length of 40.0 cm while untreated cuttings produced total root length of 33.2 cm. Cuttings of *Hedera helix* L. produced 8.3 roots per cutting and total root length of 25.7 cm.

Rema *et al.* (2008) studied the different methods of vegetative propagation of Allspice (Jamaican pepper). The combinations of IBA + NAA at 2500 ppm were found to be ideal for rooting of air layers and combination of IBA 2500 ppm + NAA 2500 ppm with charcoal was found as the best treatment with 73 and 63 percent rooting during December and October month respectively.

Vinaykumar (2008) reported that the highest percentage of rooting with combination of 2000 ppm IBA and NAA (63.73%) followed by IBA and NAA at 1500 ppm in stem cuttings of *Thunbergia grandiflora.*

Air layer of waterapple treated with various concentrations of IBA and NAA revealed that combination of 1000 ppm IBA and NAA found to be the effective rooting hormone for inducing roots (Paul and Aditi 2009).

Bhatt and Chouhan (2012) studied the effect of different auxins and their levels with combinations on rooting of African Marigold (*Tagetes erecta* L.) and results recorded maximum number of roots per cutting after 20 and 30 days (40.53 and 58.79 respectively) in IBA + NAA 150 ppm treatment. The length of stem per cutting was maximum (6.1 and 15.33 cm respectively) under IBA + NAA 150 ppm after 20 and 30 days respectively whereas the length of root per cutting was found maximum under NAA 200 ppm after 20 days (4.6cm) and under IBA + NAA 150 ppm after 30 days of planting (5.51cm).

Sharma (2014) reported maximum root lengths (9.14 cm) as well as root spread (4.53 cm) in 200 ppm of IBA in stem cuttings of marigold. The maximum number of roots (44.43), fresh weight (0.71 gm) and dry weight of roots (0.079 gm) was found in 400 ppm of IBA and the rooting percentage was maximum (92.80 %) in combination of IBA+NAA at 200 ppm in this study.

Singh *et al*. (2015) reported the effect of different hormonal treatments on rooting ability and survival of *Citrus limon* cuttings and the combination of 5000 ppm of IBA + NAA resulted in maximum number of primary (7.74) and secondary roots (16.19) per cutting.

Juvenile (2 year old trees) and mature hardwood (15 year old trees) cuttings of *Robinia pseudoacacia* and *Grewia optiva* were treated with IBA and NAA for evaluating rooting capacity. The highest rooting in juvenile (83.3%) and mature (66.6%) cuttings was observed with the NAA (500 ppm) treatment in *R. pseudoacacia* during the spring season. In *G. optiva*, IBA (250 ppm) in the monsoon season was found most effective and recorded maximum of 80 % and 70 % rooting in juvenile and mature cuttings respectively (Swamy *et al.*,2006).

Semihardwood cuttings of Pomegranate cv Bhagwa were treated with a combination of different concentrations of IBA and NAA for 8 hours. The cuttings treated with 1500ppm IBA+1500 ppm NAA recorded highest sprouting and rooting percentage, maximum number of sprouts, greatest diameter of sprout and longest roots (Ahmad, 2017).

Dahale and Akola (2018) reported the effect of various concentrations of IBA and NAA on rooting and survival of Fig hardwood cuttings and found that combination of 1000 ppm IBA +NAA treatment gave maximum survival percentage (82.50 %) and percentage of rooted cuttings (58.66 %).

Yusnita *et al.* (2018) revealed combination of 1000ppm IBA + 1000ppm NAA as the best treatment for rooting and shoot sprouting in Malay apple (*Syzygium malaccense* L.).

Effect of season and type of cuttings on rooting

Period of collection has major influence on rooting capacity of cuttings. Cuttings of some plants regenerate throughout the year, while others are seasonal in rooting.

Mohanalakshmi *et al.* (2000) reported that semihardwood cuttings of curry leaf planted during May month recorded maximum rooting (30 %) followed by July (20 %).

Rahman *et al.* (2000) obtained maximum number of leaves per cutting (10.55), roots per plant (9.04), survival percentage (77.77 %) and root length (10.94 cm) in air layers of Litchi cv. BARI litchi-1 when treated with 2500 ppm of IBA during May month.

Ghosh and Ranjan (2005) conducted two year investigation on air layering in guava from January 2001 to December 2002. From the study it was concluded that, air layering in September, October and November month resulted in highest rooting success of 85 % as well as highest field survival.

Gowda *et al.* (2006) studied the influence of growth regulator IBA on rooting of rose apple cuttings (*Syzigium jambos* L.) and recorded maximum rooting during August month while lowest in October when treated with 5000 ppm of IBA.

Husen and Pal (2007) reported maximum callusing (20 %) and rooting (50 %) during June and August month of planting in stem cuttings of *Tectona grandis*.

Jadhav and Kumar (2007) studied the propagation of Phalsa (*Grewia subinaequalis*) through stem cuttings using different growth regulators under mist conditions in Dharwad. Among the different seasons tried, maximum rooting of cuttings were obtained in rainy season in mist as well as open condition (68.33 % and 53.33 % respectively) whereas, winter season was found to be not suitable for rooting of phalsa cuttings.

Rema *et al*. (2008) studied the different methods of vegetative propagation of Allspice *viz*., air layering, cuttings, stooling and approach grafting. The results showed rooting in all months with maximum rooting of cuttings and air layers during October and December.

Agnihotri *et al*. (2009) studied the influence of seasonal variation on root distribution of Litchi cv. Rose scented and concluded that profuse rooting was obtained during autumn (October) followed by rainy (August) and spring season (March).

Bijalwan *et al*. (2010) studied the effect of various concentrations of IBA (500, 1000, 1500, 2000 and 2500 ppm) and age of cuttings (juvenile and mature) on rooting behaviour of *Jatropha curcas* L. in Western Himalaya region in Uttarakhand during spring, monsoon and winter season. It was observed that juvenile cuttings treated with 1500 ppm of IBA resulted in maximum sprouting (100 %), rooting (90.5 %) and number of roots per cutting (6.30) whereas highest root length (10.7 cm) was observed in 2000 ppm of IBA during monsoon season. Similar result was obtained with mature cuttings treated with 2000 ppm IBA recorded highest sprouting (64.31 %), rooting (60.80 %), roots per cutting (3.20) and root length (5.9 cm) in monsoon season.

Gautam *et al*. (2010) studied the seasonal effect on rooting of softwood cuttings of Guava (*Psidium guajava* L.) and found that root formation was inhibited during extremely hot (May) and cold (January) months (10 and 20 % rooting).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Evaluation of curry leaf (*Murraya koenigii* L.) accessions for yield and quality" was carried out at the Department of Plantation Crops and Spices, in College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during 2016-18. The details of the experimental materials and methodology followed in the study are presented in this chapter. The whole programme was divided into two experiments.

EXPERIMENT NO. 1

EVALUATION OF CURRY LEAF ACCESSIONS FOR MORPHOLOGICAL AND BIOCHEMICAL CHARACTERS

3.1. Materials and methods

Materials used in this study consist of 30 accessions of curry leaf (Plate 1) maintained in the field gene bank of Department of Vegetable Science, Kerala Agricultural University collected from different sources and check variety Suvasini (Table 1).

3.2. Observations

Both quantitative and qualitative characters were observed and recorded from each accessions.

3.2.1. Plant Characters

a. Plant height

The plant height was measured from the ground level to tip of the main stem with the help of a measuring tape and expressed in metres.

b. Plant height at branching starts

Measured from the ground level to the point from which branching starts with the help of a measuring tape and expressed in centimeters.

c. Number of primary branches

The number of primary branches from each accession were counted and recorded.

Plate 1. General view of the experimental field

Table 1: Source of collection of curry leaf accessions

Accessions	Source
MK 103	Vellanikkara
MK 105	Vellanikkara
MK 106	Vellanikkara
MK 107	Vellanikkara
MK 109	Vellanikkara
MK 114	Vellanikkara
MK 117	Vellanikkara
MK 118	Vellanikkara
MK 119	Vellanikkara
MK 122	Vellanikkara
MK 125	Vellanikkara
MK 126	Vellanikkara
MK 129	Vellanikkara
MK 132	Vellanikkara
MK 134	Vellanikkara
MK 135	Vellanikkara
MK 136	Kaipamangalam
MK 141	Chirakkakode
MK 142	Valapad
MK 151	Thalikulam
MK 152	Thalikulam
MK 153	Thalikulam
MK 156	Chalakudy
MK 160	Chalakudy
MK 161	Chalakudy
MK 173	Puthoor
MK 181	Kavassery
MK 186	Elanadu
MK 192	Elanadu
MK 195	Elanadu

d. Number of secondary branches

The number of secondary branches emerging from primary branches were counted and total number was recorded.

e. Number of tertiary branches

The number of tertiary branches emerging from secondary branches were counted and total number was recorded.

f. Canopy spread

The canopy spread was measured in North-South and East-West direction with the help of a measuring tape and expressed in metres.

g.Stem colour

Recorded for each accession based on RHS colour chart.

h.Midrib colour

The leaf midrib colour of each accession was observed and recorded by using RHS colour chart.

i. Leaf petiole colour

The petiole colour of each accession was observed and recorded by using RHS Colour chart.

j. Leaf colour

Colour of mature leaflets for 20 leaves from each accession were recorded based on RHS colour chart.

k. Number of leaflets per leaf

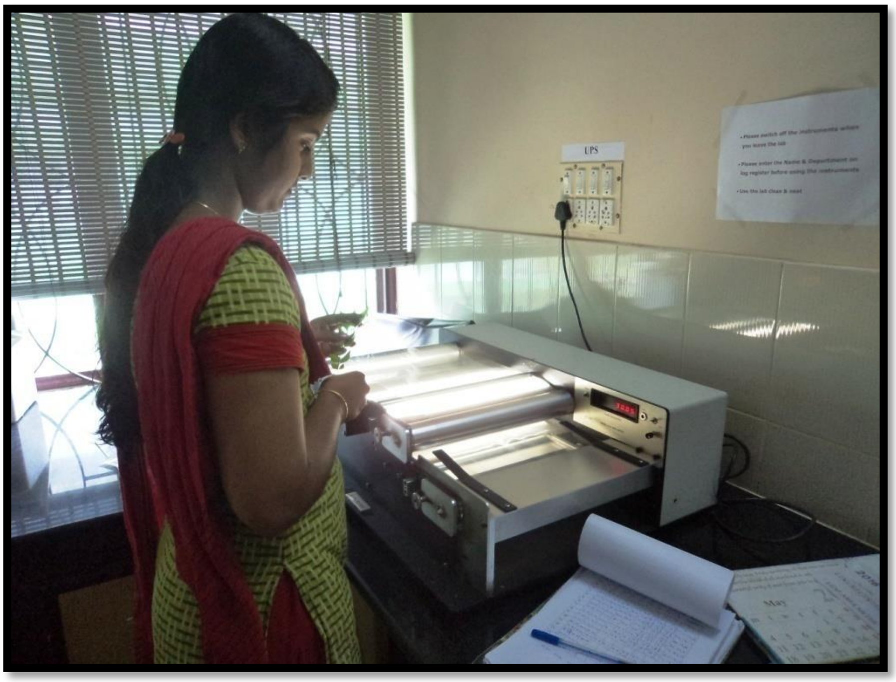
The total numbers of leaflets in a compound leaf from base to tip were measured for 20 leaves from each accession and average was recorded.

l. Leaf shape

The shape of leaflets of each 20 leaves were observed and compared with an accepted descriptor (Descriptor of leafy vegetables).

m. Leaf length

Fully opened seventh leaf from the tip was taken for measuring leaf characters. Leaf length was measured from base to tip leaf by using a measuring scale and expressed in centimeters.



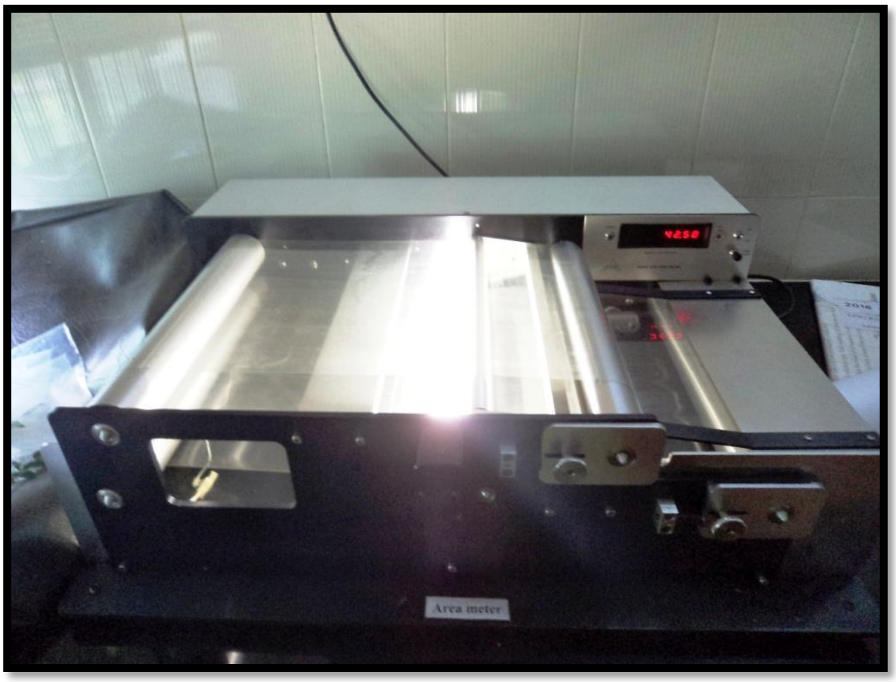


Plate 2. Leaf area measurement

n.Leaflet length

Length of leaflet was measured from the base of the lamina to the tip using a measuring scale and expressed in centimeters.

o.Leaflet width

The width of leaflet was measured from the broadest point on the lamina of the leaf and expressed in centimeters.

p.Leaf area

The leaf area was estimated by feeding the compound leaves into automatic portable leaf area meter (Plate 2) and expressed as cm^2.

q. Yield per plant

Leaves were harvested 3 times in a year in three seasons *viz*. rainy (July), winter (November) and summer (March) were weighed separately and the total yield was expressed as kg per plant per year.

r. Aroma and flavour

The fresh curry leaves from each accession were evaluated for colour, flavour, aroma, texture and overall acceptability by a 15 panel of testers. The panellists were asked to rate on a 9 point hedonic scale with the ratings: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 =Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; and 1 = Dislike extremely. The result was analysed by statistical software (SPSS- K related samples).

s. Incidence of pest and disease

Recorded for each accessions during the course of experiment.

3.2.2. Biochemical characters

The fresh mature leaves were collected from ten accessions and leaf samples were washed well under tap water to remove dust particles. The destalked leaves were air dried. The biochemical characterization was performed on both fresh and dry leaves. The mature leaf samples were shade dried for five days and the dried sample was used for analysis.

Essential oil content (%)

The curry leaf samples were subjected to hydro-distillation in Clevenger apparatus as per AOAC (1980). The fresh and dried leaf samples of 100g each were filled in apparatus with 300ml of water. The extraction was started at 100^0 c and later the temperature was reduced to 80^0 c. the extraction was continued for 4 hours and the essential oil was collected from the burette. The oil was dehydrated with anhydrous sodium sulphate (Na_2SO_4) and stored in cool dark place. The recovery of volatile oil was expressed in percentage.

$$\text{Oil recovery (\%)} = \frac{\text{Volume of extracted oil (V)}}{\text{Weight of the sample (W)}} \times 100$$

Crude fibre (%)

The crude fibre content of leaf sample was estimated by the method suggested by Sadasivam and Manickam (1992). Two grams of leaf sample (fresh and dried) were defatted and boiled with 200 ml of 1.25 per cent sulphuric acid for 10 minutes. This was filtered through muslin cloth and washed with boiling water to remove the acidic nature. The residue was again boiled with 200 ml of 1.25 per cent sodium hydroxide solution for 30 minutes. The residue was filtered through muslin cloth and washed with 25 ml of 1.25 per cent sulphuric acid, 50 ml distilled water and 25 ml alcohol. The residue was collected in previously weighed crucible (W_1) and kept in oven at 130^0c for 2 hour. It was cooled in a dessicator and weight as noted (W_2). The residue was ignited in muffle furnace at 600^0c for 30 minutes, cooled and weighed again (W_3). The crude fibre content was expressed in percentage.

$$\text{Crude fibre (\%)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{\text{Weight of sample}} \times 100$$

Total carbohydrates (%)

The carbohydrate content of curry leaf sample was estimated by anthrone method suggested by Sadasivam and Manickam (1992). 100mg sample was weighed into a boiling tube, added 10 ml of 2.5N HCl and kept in boiling water bath for three hours to hydrolyze the sample completely. After cooling to the room temperature, it was neutralized with sodium carbonate powder. The end point will be attained with the ceasing of effervescence upon adding sodium carbonate powder with the help of spatula and final volume was made up to 100mL with distilled water in a standard flask. The clear supernatant was collected after filtering and 1 ml aliquot was taken. Standards of 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standards were taken in different test tubes and volume was made up to 1ml in all the test tubes including sample. The distilled water was taken as blank. Anthrone reagent (4 ml) was then added to all the test tubes, heated for 5 minutes in boiling water bath and cooled rapidly. The absorbance reading of green/bluish green colour developed was taken at 630 nm. The carbohydrate content was calculated from the standard graph drawn and expressed in percentage.

Protein (%)

The protein content of curry leaf sample was estimated by Lowry's method as described by Sadasivam and Manickam (1992). Both fresh and dry leaf samples (0.5 g) were ground using tris buffer and centrifuged at 4ºC. The supernatant obtained was then used for protein estimation. Working standards of bovine serum albumin from 0.2 ml to 1 ml and 0.5 ml of sample extracts were pippetted out into a series of test tubes. The blank was set with 1 ml distilled water. The final volume in each tube was made to 1 ml with distilled water. A volume of 5 ml alkaline copper sulphate solution was added to all the tubes. It was mixed well and allowed to stand for 10 minutes. A volume of 0.5 ml of Folin Ciocalteu reagent was added to all the tubes. It was mixed well and kept at room temperature in dark for 30 minutes till the development of blue colour. The absorbance was recorded at 660 nm and the protein content was calculated from the standard graph drawn and expressed in percentage.

Total phenols (%)

Total phenol content of the leaf sample extracts was estimated using Folin-Ciocalteau reagent as per the method described by Sadasivam and Manickam (1992). The leaf samples (0.5g) were ground well in a mortar and pestle with 10-15 ml of 80 per cent ethanol. It was then centrifuged and the residue was collected and again extracted with ethanol. The supernatant were then pooled and evaporated to dryness. The residue was dissolved with 5ml of distilled water. The working standards were pipetted out into a series of test tubes along with sample extract (0.2ml). To each test tube including blank, 3ml distilled water was added. It was mixed with 0.5 ml Folin-Ciocalteau reagent and allowed to stand for 3 minutes. To all test tubes, 20 per cent sodium carbonate (2 ml) was added, mixed well. All the tubes were kept in boiling water for exactly one minute and cooled. The readings were taken in a spectrophotometer at 650 nm and phenol content of the sample was calculated from the standard graph drawn and expressed in percentage.

Chlorophyll content (mg 100g^{-1})

The chlorophyll content of leaf sample was estimated by DMSO method suggested by Hiscox and Israelstam (1979). Weighed 0.25 g of leaf sample and cut into small pieces and then transferred to conical flask. A volume of 15 ml DMSO (Dimethyl Sulfoxide) was added. The test tubes were incubated at 60 ^{0}c for 30 minutes, till the leaf becomes colourless. The final volume was made up to 25 ml using DMSO. The optical density values were read at 663 nm and 645nm and the chlorophyll content was calculated using the following formula.

a. mg chlorophyll 'a' 100g^{-1} of tissue= $12.7(A_{663})-2.69(A_{645}) \times \frac{V}{100 \times W \times A}$

b. mg chlorophyll 'b'100g $^{-1}$ of tissue=22.9(A_{645}) – 4.68(A_{663}) $\times \dfrac{V}{100 \times W \times A}$

c. mg total chlorophyll 100^{g-1} of tissue=20.2.9(A_{645}) – 8.02(A_{663}) $\times \dfrac{V}{100 \times W \times A}$

A=Absorbance at specific wavelengths

V=Final volume of chlorophyll extract in DMSO

W= Fresh weight of tissue extracted

Antioxidant capacity (mg AAE g^{-1})

The antioxidant capacity of curry leaves were estimated by the phosphomolybdenum reduction assay suggested by Prieto *et al*. (1999). The leaf powder of 1.0 g was taken and macerated well with 20 ml methanol and centrifuged. The clear supernatant was collected and used for assay. The reagent was prepared freshly by mixing 0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate in the ratio of 1:1:1. The aqueous solutions of ascorbic acid (100µg/ ml) served as standard. A volume of 0.5 ml supernatant along with 0.5 ml standard was pippetted out into test tubes. A volume of 0.5 ml methanol served as blank. Reagent mixture (4.5 ml) was added to each test tube and incubated in water bath at 90°C for 90 minutes. It was cooled and brought down to room temperature and absorbance was measured using spectrophotometer at 695 nm. The result was expressed as mg of ascorbic acid equivalents (AAE) g^{-1}.

Beta carotene (mg 100g^{-1})

The Beta carotene was estimated by method described by Ranganna (1997). The fresh and dry curry leaves (5g) were macerated well in 10 ml to 15 ml of acetone, with the help of pestle and mortar, adding a few crystals of anhydrous sodium sulphate. The supernatant was collected and residue was then extracted twice. The coloured supernatant transferred to a separating funnel and added 10 ml to 15 ml petroleum ether. It was mixed thoroughly until two layers separated out on standing. Discard the lower layer and collect the upper layer into a volumetric flask and made the volume to 100 ml with petroleum ether. The optical density values were recorded at 452 nm using petroleum ether as blank and Beta carotene content was calculated using the formula, expressed as mg $100g^{-1}$.

$$\text{Beta carotene (mg } 100g^{-1}) = \frac{\text{Optical desity} \times 13.9 \times 10^4 \times 100}{\text{Weight of sample} \times 560 \times 100}$$

Driage (%)

The fresh leaf samples from the selected trees were shade dried for five days. The dry weight of sample was recorded and expressed as percentage.

$$\text{Driage (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

EXPERIMENT NO. 2

STANDARDIZATION OF VEGETATIVE PROPAGATION THROUGH CUTTINGS

The effectiveness of various growth regulators (IBA and NAA) on rooting of three types of cuttings (hardwood, semihardwood and softwood) were evaluated in the second part of the experiment. The present study was carried out at College of Horticulture, Vellanikkara from March 2017 to February 2018 covering three seasons.

3.3. 1. Selection of trees and type of cuttings

High yielding curry leaf variety Suvasini of three year old plant was selected for taking stem cuttings. Three types of cuttings *viz.*, softwood, semi hardwood and hardwood cuttings having 4 to 5 nodes and 15 cm length were prepared.

3.3.2. Preparation of cuttings

The softwood cuttings were prepared from the top succulent portion of branches. The lateral shoots arising from nodes and the auxiliary sprouts were also used for the purpose

Semihardwood cuttings were taken from the middle portion of the branches, leaving a few centimetres from the tip and the hardwood portion of the branch. Hardwood cuttings were prepared from the mature and woody basal portion of the branch.

All the three cuttings were etiolated prior to the planting and numbers of cuttings per treatment were thirty (Plate 3 and 4).

3.3.3. Type of growth regulator and its preparation

Two different auxins, Indole 3-Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) were used for treating cuttings.

T_0 – Control

T_1 – 1000ppm IBA

T_2 – 2000ppm IBA

T_3– 1000 ppm NAA

T_4 – 2000 ppm NAA

T_5 - 1000ppm IBA +1000 ppm NAA

T_6 - 1000ppm IBA+ 2000 ppm NAA

T_7 - 2000ppm IBA+ 1000 ppm NAA

T_8 - 2000ppm IBA + 2000 ppm NAA

Plate 3. Preparation of media and cuttings

Plate 4. Types of cuttings

Two grams each of the growth regulators were taken and dissolved separately in one litre of distilled water to get a stock solution of 2000 ppm. From this 500 ml was taken and made up to 1000 ml to get a concentration of 1000ppm. Control was set as distilled water.

3.3.4.Potting

The protrays having 50 large cells were used for planting curry leaf cuttings.The portrays were filled with rooting media consisting of coirpith, vermicompost and vermiculite in the ratio of 3:1:1.

3.3.5. Method of application of growth regulator and planting of cuttings

The prepared softwood, semi hardwood and hardwood cuttings were given a flat cut in the top and a slanting cut of 1 cm just below a node in the basal portion. The cut end was dipped in the required concentrations of growth regulator for 45 seconds (quick dip treatment).

The growth regulator treated cuttings were planted immediately in the protrays filled with rooting media. Planting of cuttings was repeated in all three seasons *viz*., rainy, winter and summer. The cuttings were kept in mist chamber for rooting.

3.3.6. Lay out of experiment

The experiment was laid out in a Completely Randomized Design (CRD) with two replications and eight treatments. The number of cuttings per treatment was thirty. The experiment was repeated in three seasons *viz*., rainy, winter and summer.

3.4. Biometric observations

Ten cuttings were selected from each treatment for taking observations at monthly interval.

a. Days to sprouting

The days taken for producing sprouts were recorded separately for each treatment.

b. Number of emerged leaves

The number of emerged leaves per cutting from each treatment was counted and the mean number was computed after 30 days of planting.

c. Length of emerged leaves (cm)

The length of emerged leaves per cutting from each treatment was noted and the mean was expressed in centimetre after 90 days of planting.

d. Width of emerged leaves (cm)

The width of emerged leaves per cutting from each treatment was noted and the mean was expressed in centimetre after 90 days of planting.

e. Percentage establishment (%)

The number of cuttings which successfully rooted and produced new shoots after 180 days of planting were counted. The percentage establishment was expressed in percentage.

f. Number of primary roots

The numbers of primary roots were counted from successfully established cuttings by uprooting them and the mean number was noted after 180 days of planting.

g. Number of secondary roots

The numbers of secondary roots were counted from successfully established cuttings by uprooting them and the mean number was noted after 180 days of planting.

h. Length of primary root (cm)

The rooted cuttings were uprooted and length of primary root was noted from each treatment and the mean was expressed in centimetre.

i. Length of secondary root (cm)

The rooted cuttings were uprooted and length of secondary root was noted from each treatment and the mean was expressed in centimetre.

j. Root weight (g)

The rooted cuttings were uprooted and fresh root weight was noted from each treatment and the mean was expressed in grams.

Results

4. RESULTS

The investigation on "Evaluation of curry leaf accessions (*Murraya koenigii* L.) for yield and quality" was studied in the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur, during 2016-18. The results of the study are described in this chapter.

4.1. MORPHOLOGICAL CHARACTERS

4.1.1. Quantitative characters

4.1.1.1. Plant characters

Mean performance of curry leaf accessions (30 numbers) along with check variety Suvasini for different plant and yield characters are presented in table 2 to 6.

Plant height

Plant height is considered as an important parameter in the process of growth and development. Variation was observed among different accessions in relation to plant height. The plant height range varied from 2.23m to 5.21m (Table 2). Accession MK 103 recorded maximum plant height (5.21m). Plant height above 4 m was recorded in seven accessions namely MK 103 (5.21 m), MK 109 (4.91 m), MK 119 (4.01 m), MK 136 (4.87 m), MK 152 (4.67 m), MK 156 (4.01 m) and MK 181 (4.36 m). The check variety Suvasini recorded a plant height of 2.37 m. The minimum plant height was observed for MK 107 (2.23 m) followed by MK 126 (2.33 m).

Plant height at branching starts

Considerable variability was observed for plant height at branching starts ranging from 31.25 cm to 67.51 cm (Table 2). Plant height at branching was the lowest in MK 125 (31.25 cm) followed by MK 107 (32.36 cm) and MK 132 (32.66 cm). Accession MK 122 recorded highest plant height at branching (67.51 cm) followed by MK 136 (66.12 cm) and MK 117 (65.38 cm). Branching was observed at a plant height of 43.43 cm in Suvasini.

Table 2: Mean performance of curry leaf accessions based on plant height

Accessions	Plant height (m)	Plant height at branching starts (cm)
MK 103	5.21	49.12
MK 105	2.53	56.32
MK 106	3.38	64.12
MK 107	2.23	32.36
MK 109	4.91	39.53
MK 114	2.26	56.43
MK 117	3.73	65.38
MK 118	2.78	51.03
MK 119	4.01	37.62
MK 122	3.07	67.51
MK 125	2.84	31.25
MK 126	2.33	39.32
MK 129	2.82	49.31
MK 132	3.04	32.66
MK 134	3.11	35.44
MK 135	3.06	36.67
MK 136	4.87	66.12
MK 141	3.69	56.73
MK 142	3.41	41.03
MK 151	3.04	42.54
MK 152	4.67	53.21
MK 153	3.06	34.72
MK 156	4.01	59.06
MK 160	2.47	34.32
MK 161	2.66	37.51
MK 173	3.41	48.23
MK 181	4.36	48.61
MK 186	3.74	42.55
MK 192	2.52	55.81
MK 195	2.48	50.24
Suvasini	2.37	43.43
SE (m)	**0.15**	**2.59**
C.V.	**25.26**	**47.06**

Number of primary branches

The number of primary branches varied from 2 to 4 among different accessions (Table 3). The maximum numbers of primary branches (4 branches) were recorded for the accessions MK 107, MK 118, MK 126, MK 142 and MK 160 whereas check variety recorded three branches. Ten accessions *viz*., MK 105, MK 109, MK 132, MK 134, MK 135, MK 151, MK 153, MK 181, MK 192 and MK 195 recorded minimum branches (2 branches).

Number of secondary branches

Distinguishable difference was observed with respect to number of secondary branches among the accessions studied and it varied from 3 to 8. Three accessions MK126, MK 142 and MK 160 recorded highest number of secondary branches (8branches) whereas check variety recorded 5 numbers of secondary branches. The minimum numbers of secondary branches (3 branches) were recorded in six accessions *viz.*, MK 109, MK 132, MK 151, MK 153, MK 192 and MK 195 (Table 3).

Number of tertiary branches

The number of tertiary branches is one of the important attribute which influence the yield of curry leaf. Accession MK 142 recorded highest number of tertiary branches (48 numbers). The numbers of tertiary branches were greater than 40 in five accessions viz., MK 107, MK 118, MK 126, MK 142 and MK 160. Suvasini recorded 26 numbers of tertiary branches (Table 3). The values for tertiary were lesser than 20 numbers in six accessions namely MK 132, MK 135, MK 151, MK 153, MK 192 and MK 195.

North-South canopy spread

Considerable difference was observed in tree canopy spread taken in North- South direction ranging from 1.56 m to 4.57 m (Table 3). The branching spread were greater than 4 m for four accessions viz., MK 114 (4.26 m), MK 118 (4.57 m), MK 126 (4.28 m), MK 142 (4.32 m). The check variety Suvasini recorded 2.11 m as canopy spread. Five accessions namely MK 106 (1.56 m), MK 122 (1.82 m), MK 129 (1.88 m), MK 153 (1.82 m) and MK 161 (1.86 m) recorded lower canopy spread of less than 2m.

Table 3: Canopy spread and number of branches of curry leaf accessions

Accessions	Canopy spread (m)		Number of branches		
	N-S	**E-W**	**Primary**	**Secondary**	**Tertiary**
MK 103	3.66	2.51	3	6	36
MK 105	3.04	3.65	2	4	23
MK 106	1.56	1.52	3	6	32
MK 107	3.96	3.44	4	7	42
MK 109	2.83	3.04	2	3	22
MK 114	4.26	3.85	3	5	32
MK 117	3.39	3.04	3	5	26
MK 118	4.57	3.04	4	7	42
MK 119	3.65	2.52	3	5	33
MK 122	1.82	2.65	3	6	36
MK 125	2.13	2.54	3	5	28
MK 126	4.28	3.76	4	8	46
MK 129	1.88	2.8	3	5	27
MK 132	2.13	2.17	2	3	16
MK 134	2.48	3.11	2	4	22
MK 135	2.52	2.74	2	4	18
MK 136	3.07	3.72	3	6	38
MK 141	2.23	2.21	2	3	16
MK 142	4.32	4.78	4	8	48
MK 151	2.43	2.13	3	6	38
MK 152	3.35	3.38	2	3	16
MK 153	1.82	2.5	3	6	38
MK 156	2.53	2.31	2	3	16
MK 160	3.65	3.76	4	8	42
MK 161	1.86	1.91	3	5	28
MK 173	3.71	3.35	3	6	32
MK 181	2.19	2.74	2	4	24
MK 186	2.16	1.89	3	5	28
MK 192	2.32	3.06	2	3	14
MK 195	3.03	2.76	2	3	12
Suvasini	2.11	3.02	3	5	26
SE (m)	**0.16**	**0.15**	**0.216**	**1.911**	**10.43**
C.V.	**30.43**	**27.86**	**17.76**	**20.01**	**23.78**

East- West canopy spread

The maximum branching spread in relation to East-West direction was observed in accession MK 142 (4.78 m) followed by MK 114 (3.85 m), MK 126 and MK 129 (3.76 m each). Suvasini recorded branching spread of 3.02 m (Table 3).The lower branching spread of less than 2 m were observed in three accessions viz., MK 106 (1.52 m), MK 161 (1.91 m) and MK 186 (1.89 m).

4.1.1.2. Leaf characters

Data pertaining to the leaf and yield characters are presented in table 4and table 6 respectively.

Leaf length

Remarkable difference was observed with regard to leaf length (Plate 5) ranging from 14.71 cm to 21.81 cm (Table 4). The highest leaf length was recorded by accession MK 126 (21.81 cm) whereas MK 122 recorded lowest leaf length (14.71 cm). The leaf length value of more than 20 cm was recorded in four accessions namely MK 160 (21.18 cm), MK 142 (21.42 cm), MK 126 (21.81 cm) and MK 118 (20.20 cm). The check variety Suvasini recorded an average leaf length of 18.45 cm.

Number of leaflets per leaf

The number of leaflets per leaf varied from 16-22 numbers (Plate 6). Among the accessions MK 126, MK 142 and Suvasini recorded highest number of leaflets (22 numbers). The number of leaflets more than 20 were observed in seven accessions *viz*., MK 107 (21 numbers), MK 114 (21 numbers), MK 118 (21 numbers), MK 126 (22 numbers), MK 142 (22 numbers), MK 160 (21 numbers) and MK 161 (21 numbers). The lowest number of leaflets wereobserved in three accessions namely MK 135 (16 numbers), MK 153 (16 numbers) and MK 195 (16 numbers).

Plate 5. Variation in leaf length

Plate 6. Variation in number of leaflets per leaf

Table 4: Leaf characters of curry leaf accessions

Accessions	Leaf length (cm)	Number of leaflets per leaf	Leaflet length (cm)	Leaflet width (cm)	Leaf area (cm^2)
MK 103	18.66	20	3.66	1.56	42.63
MK 105	18.75	20	3.77	1.61	48.18
MK 106	15.88	20	3.46	1.25	40.54
MK 107	19.82	21	3.84	1.68	52.36
MK 109	16.13	20	2.97	1.26	40.19
MK 114	19.18	21	3.77	1.67	52.21
MK 117	17.15	19	3.23	1.38	29.06
MK 118	20.20	21	4.02	1.69	52.36
MK 119	18.66	20	2.96	1.57	44.08
MK 122	14.71	20	3.42	1.53	29.14
MK 125	16.78	20	3.18	1.28	36.35
MK 126	21.81	22	4.27	2.01	58.72
MK 129	15.85	19	3.27	1.48	40.67
MK 132	17.45	19	3.62	1.47	38.76
MK 134	16.79	18	3.51	1.37	38.76
MK 135	16.81	16	3.28	1.26	38.75
MK 136	15.73	17	3.27	1.37	32.25
MK 141	18.73	20	3.67	1.58	46.31
MK 142	21.42	22	4.56	1.77	66.46
MK 151	17.03	19	3.48	1.35	37.18
MK 152	17.71	18	3.36	1.35	38.49
MK 153	16.50	16	3.27	1.36	38.49
MK 156	16.92	18	3.13	1.45	33.48
MK 160	21.18	21	4.26	1.96	56.77
MK 161	18.75	21	3.77	1.67	51.78
MK 173	15.82	20	3.06	1.55	41.13
MK 181	17.84	17	3.21	1.39	38.11
MK 186	18.52	20	3.65	1.56	41.17
MK 192	16.98	18	3.15	1.41	36.24
MK 195	18.16	16	3.62	1.25	36.06
Suvasini	18.45	22	3.75	1.41	44.08
SE (m)	**0.33**	**0.31**	**0.07**	**0.03**	**1.61**
C.V.	**9.99**	**8.83**	**11.19**	**13.13**	**20.77**

Length of leaflet

Distinguishable difference was observed with respect to length of leaflet among the accessions studied (Table 4). The accession MK 142 recorded highest leaflet length (4.56 cm). The leaflet length above 4 cm was observed in accessions MK 118 (4.02 cm), MK 126 (4.27 cm), MK 142 (4.56 cm) and MK 160 (4.26 cm). The leaflet length of 3.75 cm was observed in Suvasini. Minimum leaflet length was recorded by MK 119 (2.96 cm) followed by MK 109 (2.97 cm).

Width of leaflets

Remarkable difference was noticed for width of leaflets ranging from 1.25 cm to 2.01 cm (Table 4). The highest leaflet width was observed in MK 126 (2.01 cm) followed by MK 160 (1.96 cm). Accessions MK 106 and MK 195 recorded lowest leaflet width (1.25 cm) followed by MK 109 and MK 135 (1.26 cm each). The check variety Suvasini recorded leaflet width of 1.41 cm.

Leaf area

Distinguishable difference was observed for leaf area (Plate 5) among accessions ranging from 29.06 cm^2 to 66.46 cm^2 (Table 4). Highest leaf area was recorded for accession MK 142 (66.46 cm^2) followed by MK 126 (58.72 cm^2) whereas accession MK 117 recorded lowest leaf area (29.06 cm^2) followed by MK 122 (29.14 cm^2). The leaf area of above 50 cm was observed in seven accessions namely MK 107 (52.36 cm^2), MK 114 (52.21 cm^2), MK 118 (52.36 cm^2), MK 126 (58.72 cm^2), MK 142 (66.46 cm^2), MK 160 (56.77 cm^2) and MK 161 (51.78 cm^2). The leaf area of 44.08 cm^2 was recorded in Suvasini.

Incidence of pest and disease

Incidence of leaf spot on curry leaf caused by *Colletotrichum gloeosporioides* was observed during the onset of rainy season (during the month of June to August). All the thirty accessions along with check variety Suvasini were affected by leaf spot disease during the time period (Plate 6). Percentage of leaf spot disease incidence ranged from 5 % to 30 % (Table 5). The lowest incidence of less than 5

% was noticed in three accessions namely MK 142, MK 160 and Suvasini. It was a severe problem in accessions MK 122 (30 %) and MK 15 % (30 %).

Table 5: Leaf spot disease incidence in curry leaf accessions

Accessions	Leaf spot (%)
MK 103	10.00
MK 105	12.00
MK 106	25.00
MK 107	9.00
MK 109	23.00
MK 114	7.00
MK 117	22.00
MK 118	15.00
MK 119	28.00
MK 122	30.00
MK 125	14.00
MK 126	8.00
MK 129	16.00
MK 132	18.00
MK 134	25.00
MK 135	27.00
MK 136	24.00
MK 141	9.00
MK 142	5.00
MK 151	30.00
MK 152	26.00
MK 153	12.00
MK 156	14.00
MK 160	5.00
MK 161	17.00
MK 173	18.00
MK 181	26.00
MK 186	11.00
MK 192	22.00
MK 195	26.00
Suvasini	5.00
SE (m)	**1.40**
C.V.	**44.41**

High incidence (30 %)

Low incidence (< 5 %)

Plate 7. Leaf spot disease incidence

4.1.1.3. Yield per plant

Considerable variability was observed with regard to fresh leaf yield among the accessions (Table 6). Among the seasons, fresh leaf yield per plant was higher in rainy season followed by winter season where as leaf yield was very low in summer season.

During rainy season, fresh leaf yield per plant ranged from 1.09 kg to 2.98 kg**.** The accession MK 126 recorded highest yield (2.98 kg) followed by MK 142 (2.82 kg) and MK 160 (2.78 kg). In rainy season, fresh leaf yield higher than 2 kg was recorded in fourteen accessions namely MK 103 (2.30 kg), MK 105 (2.73 kg), MK 107 (2.65 kg), MK 114 (2.60 kg), MK 117 (2.03 kg), MK 118 (2.56 kg), MK 122 (2.15 kg), MK 126 (2.98 kg), MK 141 (2.42 kg), MK 142 (2.82 kg), MK 160 (2.78 kg), MK 186 (2.54 kg), MK 192 (2.04 kg) and Suvasini (2.26 kg). The lowest yield was recorded in accessions MK 181 (1.09 kg), MK 195 (1.25 kg) and MK 109 (1.29 kg).

In winter season considerable difference was observed in fresh leaf yield per plant ranging from 0.64 kg (MK 181) to 1.91 kg (MK 107). Highest leaf yield was recorded in accession MK 107 (1.91kg) followed by MK 126 (1.80 kg), MK 118 (1.74 kg) and MK 125 (1.72 kg). 73 % of accessions recorded fresh leaf yield of above 1 kg. The fresh leaf yield lesser than 1 kg was observed in eight accessions *viz.*, MK 109 (0.85 kg), MK 132 (0.94 kg), MK 134 (0.84 kg), MK 153 (0.88 kg), MK 156 (0.65 kg), MK 173 (0.81 kg), MK 181 (0.64 kg) and MK 195 (0.79 kg). Suvasini recorded fresh leaf yield of 1.18 kg in winter season.

Remarkable difference was observed in fresh leaf yield per plant in summer season ranging from 0.41 kg (MK 156) to 0.85 kg (MK 142). The highest leaf yield was observed in accession MK 142 (0.85 kg) followed by MK 136 (0.82 kg) and MK 106 (0.81 kg). The lowest yield of less than 0.5 kg was recorded in five accessions *viz.*, MK 117 (0.49 kg), MK 134 (0.49 kg), MK 153 (0.48 kg), MK 181 (0.46 kg) and MK 156 (0.41 kg). A fresh leaf yield of 0.76 kg was recorded in Suvasini.

Measurable variation was observed in total fresh leaf yield/plant/year ranged from 2.19 kg (MK 181) to 5.42 kg (MK 126). Fresh leaf yield of more than 5 kg was observed in four accessions namely MK 107 (5.30 kg), MK 126 (5.42 kg), MK 142 (5.35 kg) and MK 160 (5.04 kg). The lowest leaf yield of less than 3 kg was recorded in eight accessions *viz*., MK 109 (2.67 kg), MK 132 (2.82 kg), MK 134 (2.79 kg), MK 156 (2.41 kg), MK 173 (2.64 kg), MK 181 (2.19 kg), MK 192 (2.20 kg) and MK (2.57 kg).A total fresh leaf yield of 4.20 kg was recorded in Suvasini.

Table 6: Fresh leaf yield characters of curry leaf accessions

Accessions	Yield per plant (kg)			Total yield/plant/year (kg)
	Rainy	Winter	Summer	
MK 103	2.30	1.55	0.74	4.58
MK 105	2.73	1.45	0.53	4.71
MK 106	1.83	1.02	0.81	3.66
MK 107	2.65	1.91	0.74	5.30
MK 109	1.29	0.85	0.54	2.67
MK 114	2.60	1.55	0.69	4.84
MK 117	2.03	1.51	0.49	4.03
MK 118	2.56	1.74	0.63	4.92
MK 119	1.96	1.30	0.60	3.86
MK 122	2.15	1.61	0.58	4.34
MK 125	1.93	1.72	0.64	4.29
MK 126	2.98	1.80	0.64	5.42
MK 129	1.88	1.53	0.71	4.12
MK 132	1.32	0.94	0.57	2.82
MK 134	1.47	0.84	0.49	2.79
MK 135	1.55	1.02	0.73	3.29
MK 136	1.63	1.05	0.82	3.50
MK 141	2.42	1.61	0.71	4.73
MK 142	2.82	1.68	0.85	5.35
MK 151	1.72	1.13	0.61	3.45
MK 152	1.50	1.00	0.59	3.09
MK 153	1.68	0.88	0.48	3.04
MK 156	1.35	0.65	0.41	2.41
MK 160	2.78	1.65	0.61	5.04
MK 161	1.52	1.11	0.73	3.36
MK 173	1.30	0.81	0.54	2.64
MK 181	1.09	0.64	0.46	2.19
MK 186	2.54	1.35	0.71	4.60
MK 192	2.04	1.35	0.54	2.20
MK 195	1.25	0.79	0.53	2.57
Suvasini	2.26	1.18	0.76	4.20
SE (m)	**0.09**	**0.06**	**0.02**	**0.18**
C.V.	**27.92**	**29.32**	**18.22**	**26.22**

4.1.1.4. Sensory evaluation

Consumer's acceptability regulates the marketability of produce. Since curry leaf is an herbal spice which is mainly used for flavouring the food products, sensory evaluation is an important factor in identifying superior accessions (Plate 8). All the thirty accessions were scored for various sensory traits viz., appearance, colour, flavour, aroma, texture and overall acceptability by panel of 15 judges based on nine point hedonic scale (Table 7). The data was then analysed by Kruskal–Wallis one-way analysis of variance and based on mean rank score accessions were ranked.

Among the accessions, MK 126 recorded high mean rank for appearance (7.46) followed by MK 118 (7.20), MK 160 (7.13), MK 125 (7.06) and Suvasini (7.06). The lowest mean rank for appearance was observed in the accession MK 181 (5.66). For colour, high mean rank value was observed in accession MK 126 (7.60) followed by MK 151 (7.33) and MK 141 (7.13) whereas MK 135 recorded the lowest value (6.00). The check variety recorded mean rank of 7.20 for colour.

The marketability of curry leaf depends on its spicy flavour and aroma. With respect to flavour of leaves, accession MK 126 recorded highest score of 7.40 while MK 135 recorded lowest value of 5.80. Eight accessions namely MK 107 (7.06), MK 118 (7.20), MK 119 (7.04), MK 126 (7.40), MK 141 (7.000, MK 142 (7.20), MK 160 (7.06) and MK 186 (7.06) were found superior in terms of flavour. For aroma, accession MK 119 and MK 126 recorded highest mean rank score of 7.33 whereas MK 114 recorded lowest score of 5.53. Based on aroma, eight accessions *viz.*, MK 107, MK 118, MK 119, MK 126, MK 141, MK 142, MK 160 and MK 186 recorded mean rank score of above 7. Suvasini recorded mean rank score of 6.46 and 6.86 for flavour and aroma.

The highest mean rank for texture was recorded in accession MK 126 (7.40) whereas lowest value was recorded in MK 195 (5.53). Mean rank value above 7 was recorded in four accessions namely MK 118 (7.26), MK 126 (7.40), MK 153 (7.01) and MK 160 (7.02). Among the accessions, highest mean rank value for overall acceptability was observed in accession MK 116 (7.33) whereas

MK 109 and MK 114 recorded the lowest value (5.80). Mean rank value of above 7 was recorded in seven accessions namely MK 118 (7.16), MK 126 (7.26), MK 141 (7.01), MK 142 (7.13) and MK 160 (7.33). The check variety Suvasini recorded mean rank of 6.93. Accession MK 126 recorded mean rank score of above 7.00 in all sensory traits and found as superior one in terms of sensory evaluation. In terms of flavour and aroma, eight accessions were found superior *viz*., MK 107, MK 118, MK 119, MK 126, MK 141, MK 142, MK 160 and MK 186.

Plate 8. Sensory evaluation

Table 7: **Sensory evaluation parameters of curry leaf accessions**

Accessions	Appearance	Colour	Flavour	Aroma	Texture	Overall acceptability
MK 103	6.53	6.73	6.53	7.26	6.40	6.60
MK 105	5.80	6.20	6.60	6.33	6.26	6.26
MK 106	6.60	6.26	6.13	6.53	5.86	6.13
MK 107	6.60	6.46	7.06	7.13	6.46	6.40
MK 109	6.26	6.26	6.40	6.86	5.80	5.80
MK 114	6.20	6.26	6.00	5.53	5.93	5.80
MK 117	6.73	6.80	6.80	6.33	6.46	6.20
MK 118	7.20	6.86	7.20	7.00	7.26	7.16
MK 119	6.40	6.40	7.04	7.33	6.46	6.80
MK 122	6.93	6.86	6.40	6.33	6.53	6.46
MK 125	7.06	6.33	6.06	6.80	6.33	6.66
MK 126	7.46	7.60	7.40	7.33	7.40	7.26
MK 129	6.80	6.80	6.60	6.60	6.46	6.26
MK 132	6.53	6.60	6.73	6.80	6.60	6.60
MK 134	6.73	6.40	6.73	6.33	6.40	6.73
MK 135	6.60	6.00	5.80	6.33	6.26	6.33
MK 136	6.80	6.60	6.80	6.60	6.66	6.86
MK 141	6.93	7.13	7.00	7.06	6.53	7.00
MK 142	6.80	6.60	7.20	7.23	6.66	7.13
MK 151	6.80	7.33	6.60	6.73	6.60	6.66
MK 152	6.20	6.13	6.40	6.26	6.40	6.33
MK 153	6.93	6.86	6.53	6.66	7.00	6.43
MK 156	6.40	6.53	6.40	5.93	6.46	6.46
MK 160	7.13	6.93	7.06	7.26	7.00	7.33
MK 161	6.53	6.40	6.73	6.53	6.46	6.86
MK 173	6.53	6.46	6.26	6.26	5.73	6.06
MK 181	5.66	6.20	6.46	5.73	6.20	5.86
MK 186	6.60	6.46	7.06	7.03	6.73	6.92
MK 192	6.53	6.33	6.46	6.20	6.66	6.13
MK 195	6.20	6.20	6.00	5.73	5.53	5.86
Suvasini	7.06	7.20	6.46	6.86	6.93	6.93
Chi-square value	**41.79**	**56.59**	**64.49**	**72.26**	**52.75**	**59.96**

Values in parenthesis indicates mean ranking score

4.1.2. Qualitative characters

The genotypes were characterized based on qualitative characters viz., stem colour, midrib colour, petiole colour, leaf colour and leaf shape. The qualitative characters observed are presented in table 8.

4.1.2.1. Plant character

Stem colour

No variation was observed with regard to stem colour in the genotypes studied and it was grey with white dots in all the genotype (Table 8).

4.1.2.2. Leaf characters

Midrib colour

Considerable variation was observed for midrib colour which varied from green and light red pink (Plate 9). Majority of the genotypes were green in colour including Suvasini whereas some genotypes had light red pink colour *viz.*, MK 107, MK 117, MK 126, MK 141, MK 151, MK 160 and MK 186.

Petiole colour

The petiole colour varied from green to red colour in the genotypes studied. Majority of the genotypes exhibited green petiole colour whereas some genotypes had light red pink petiole colour namely MK 107, MK 117, MK 126, MK 141, MK 151, MK 160 and MK 186.Suvasini exhibited green colour petiole (Table 8).

Leaf colour

The leaf colour varied considerably from green to dark green (Plate 9). Majority of the accessions exhibited dark green leaf colour including Suvasini whereas some accessions had green colour (MK 106, MK 107, MK 114, MK 122, MK 129, MK 134, MK 135, MK 151, MK 160, MK 173 and MK 186).

Leaf shape

Distinct variability was observed for leaf shape among the accessions studied (Plate 10). Most of the leaves were lanceolate in shape including the check variety Suvasini, whereas obovate leaf shape was observed in rest of the accessions namely MK103, MK 106, MK 109, MK 117, MK 125, MK 129, MK 134, MK 151, MK 153, MK 173 and MK 192.

Dark green

Green

Green midrib

Light red pink midrib

Plate 9. Variation in leaf and midrib colour

Obovate

Lanceolate

Grey with white dots

Plate 10. Variation in leaflet shape and stem colour

Table 8: Qualitative characters of curry leaf accessions

Sl. No.	Accessions	Stem colour	Midrib colour	Petiole colour	Leaf colour	Leaf shape
1	MK 103	Grey with white dots	Green	Green	Dark green	Obovate
2	MK 105	Grey with white dots	Green	Green	Dark green	Lanceolate
3	MK 106	Grey with white dots	Green	Green	Green	Obovate
4	MK 107	Grey with white dots	Light red pink	Light red pink	Green	Lanceolate
5	MK 109	Grey with white dots	Green	Green	Dark green	Obovate
6	MK 114	Grey with white dots	Green	Green	Green	Lanceolate
7	MK 117	Grey with white dots	Light red pink	Light red pink	Dark green	Obovate
8	MK 118	Grey with white dots	Green	Green	Dark green	Lanceolate
9	MK 119	Grey with white dots	Green	Green	Dark green	Lanceolate
10	MK 122	Grey with white dots	Green	Green	Green	Lanceolate
11	MK 125	Grey with white dots	Green	Green	Dark Green	Obovate
12	MK 126	Grey with white dots	Light red pink	Light red pink	Dark green	Lanceolate
13	MK 129	Grey with white dots	Green	Green	Green	Obovate
14	MK 132	Grey with white dots	Green	Green	Dark Green	Lanceolate
15	MK 134	Grey with white dots	Green	Green	Green	Obovate

Table 8: Qualitative characters of curry leaf accessions (contd..)

Sl. No.	Accessions	Stem colour	Midrib colour	Petiole colour	Leaf colour	Leaf shape
16	MK 135	Grey with white dots	Green	Green	Green	Lanceolate
17	MK 136	Grey with white dots	Green	Green	Dark green	Lanceolate
18	MK 141	Grey with white dots	Light red pink	Light red pink	Dark green	Lanceolate
19	MK 142	Grey with white dots	Green	Green	Dark green	Lanceolate
20	MK 151	Grey with white dots	Light red pink	Light red pink	Green	Obovate
21	MK 152	Grey with white dots	Green	Green	Dark green	Lanceolate
22	MK 153	Grey with white dots	Green	Green	Dark green	Obovate
23	MK 156	Grey with white dots	Green	Green	Dark Green	Lanceolate
24	MK 160	Grey with white dots	Light red pink	Light red pink	Green	Lanceolate
25	MK 161	Grey with white dots	Green	Green	Dark green	Lanceolate
26	MK 173	Grey with white dots	Green	Green	Green	Obovate
27	MK 181	Grey with white dots	Green	Green	Dark green	Lanceolate
28	MK 186	Grey with white dots	Light red pink	Light red pink	Green	Lanceolate
29	MK 192	Grey with white dots	Green	Green	Dark green	Obovate
30	MK 195	Grey with white dots	Green	Green	Dark Green	Lanceolate
31	Suvasini	Grey with white dots	Green	Green	Dark Green	Lanceolate

4.2. CORRELATION ANALYSIS

High yield of produce is the most important objective of crop programme. Since yield is a complex trait which depends up on number of parameters, it is essential to know the interrelationship between yield and its component traits. A correlation study was conducted between major quantitative characters and yield. The characters used for correlation included plant height, plant height at which branching starts, number of primary branches, number of secondary branches, number of tertiary branches, North-South canopy spread, East-West canopy spread, leaf length, number of leaflets per leaf, length of leaflet, width of leaflet, leaf area and yield and were measured at 0.05 and 0.01 level by Pearson correlation coefficient table 9.

Plant height was not significantly correlated to any of the characters. Plant height at branching starts was positively correlated to plant height (0.240). The number of primary branches were positively correlated to plant height at branching starts (0.008) while number of secondary branches was significantly and positively correlated to primary branches (0.718). Significant and positive correlation was observed w number of tertiary branches with number of primary (0.690) and secondary branches (0.893). North-South canopy spread was significantly and positively correlated with primary (0.640), secondary (0.620) and tertiary branches (0.589). Significant and positive correlation was recorded for East-West canopy spread with number of primary (0.604), secondary (0.562) tertiary branches (0.427) and North-South canopy (0.701).

Leaf length was significantly and positively correlated to number of primary (0.722), secondary (0.641), tertiary branches (0.692), canopy spread in North- South (0.673) and East-West direction (0.470). Significant and positive correlation was observed for number of leaflets per leaf with leaf length (0.565), number of primary (0.649), secondary (0.638), tertiary branches (0.674) and North-South canopy spread (0.455). Number of leaflets per leaf was positively correlated with East-West canopy spread (0.281). Length of leaflet was significantly and positively correlated to number of primary (0.737), secondary (0.691), tertiary branches (0.646), canopy spread in North South (0.482) and East-

West direction (0.489), leaf length (0.826) and number of leaflets per leaf (0.579). Significant and positive correlation was observed for width of leaflet with length of leaflet (0.757), number of leaflets per leaf (0.737), leaf length (0.796), canopy spread in North-South (0.579) and East-West direction (0.455) and number of primary (0.717), secondary (0.738), tertiary branches (0.725). Leaf area was significantly and positively correlated to number of primary (0.785), secondary (0.767), tertiary branches (0.800), canopy spread in North-South (0.587) and East-West direction (0.543), leaf length (0.864), number of leaflets per leaf (0.699), length (0.819) and width of leaflet (0.803).

Fresh leaf yield was significantly and positively correlated with number of primary (0.712), secondary (0.706) and tertiary branches (0.759), North-South (0.646) and East-West canopy spread (0.469), leaf length (0.777), number of leaflets (0.540), length (0.632) and width of leaflet (0.629) and leaf area (0.829). Negatively correlated to plant height (0.084) and plant height at branching starts (0.105).

Table 9: Correlation analysis for yield and quantitative characters in curry leaf accessions

	1	2	3	4	5	6	7	8	9	10	11	12	13
1													
2	0.240^{NS}												
3	-0.262^{NS}	0.008^{NS}											
4	-0.240^{NS}	-0.111^{NS}	0.718**										
5	-0.205^{NS}	-0.123^{NS}	0.690**	0.893**									
6	-0.052^{NS}	0.174^{NS}	0.640**	0.620**	0.589**								
7	-0.112^{NS}	0.015^{NS}	0.604**	0.562**	0.427*	0.701**							
8	-0.308^{NS}	-0.261^{NS}	0.722**	0.641**	0.692**	0.673**	0.470**						
9	-0.233^{NS}	0.008^{NS}	0.649**	0.638**	0.674**	0.455*	0.281^{NS}	0.565**					
10	-0.430*	-0.338^{NS}	0.737**	0.691**	0.646**	0.482**	0.489**	0.826**	0.579**				
11	-0.366*	-0.077^{NS}	0.717**	0.738**	0.725**	0.579**	0.455*	0.796**	0.737**	0.757**			
12	-0.369*	-0.285^{NS}	0.785**	0.767**	0.800**	0.587**	0.543**	0.864**	0.699**	0.819**	0.803**		
13	-0.084^{NS}	-0.105^{NS}	0.712**	0.706**	0.759**	0.646**	0.469**	0.777**	0.540**	0.632**	0.629**	0.829**	

1. Plant height (m)
2. Height at branching starts (cm)
3. No. of primary branches
4. No. of secondary branches
5. No. of tertiary branches
6. N-S canopy spread (m)
7. E-W canopy spread (m)
8. Leaf length (cm)
9. No. of leaflets per leaf
10. Leaflet length (cm)
11. Leaflet width (cm)
12. Leaf area (cm^2)
13. Total yield (kg/plant/year)

*Significant at 5 % level

** Significant at 1 % and 5 % level

4.3. CLUSTER ANALYSIS

Cluster analysis is the most suitable approach for determining the genetic diversity among accessions and to facilitate the selection of suitable germplasm. Cluster analysis was done based on thirteen parameters *viz.*, plant height, plant height at which branching starts, number of primary, secondary and tertiary branches, North-South and East- West canopy spread, leaf length, number of leaflets, length and width of leaflet, leaf area and yield. Accessions coming under each cluster are listed in Fig 1.

Based on cluster analysis, all the thirty curry leaf accessions under the study were grouped into twelve clusters (Table 10). Scoring was done in such a way that, accessions with the highest value recorded value get a score of one, and the final ranking as done by adding up the individual score of each character. Thus the cluster with lowest rank is considered as superior. The study revealed that cluster 1 contained highest number of accessions (5 accessions) followed by cluster 3 and 11 having four accessions, cluster 2, cluster 6 and cluster 8 having three accessions, cluster 5 and 12 having two accessions. Only one accession each was observed in cluster 4, 7, 9 and 10.

Table 10: Clustering pattern in curry leaf accessions

Cluster groups	Accessions
Cluster 1	MK 105, MK 141, MK 103, MK 186, MK 161
Cluster 2	MK 134, MK 135, MK 125
Cluster 3	MK 106, MK 156, MK 119, MK 173
Cluster 4	MK 136
Cluster 5	MK 126, MK 142
Cluster 6	MK 107, MK 160, MK 118
Cluster 7	MK 114
Cluster 8	MK 109, MK 129, MK 152
Cluster 9	MK 132
Cluster 10	MK 153
Cluster 11	MK 192,MK 195, MK 151, MK 181
Cluster 12	MK 117, MK 122

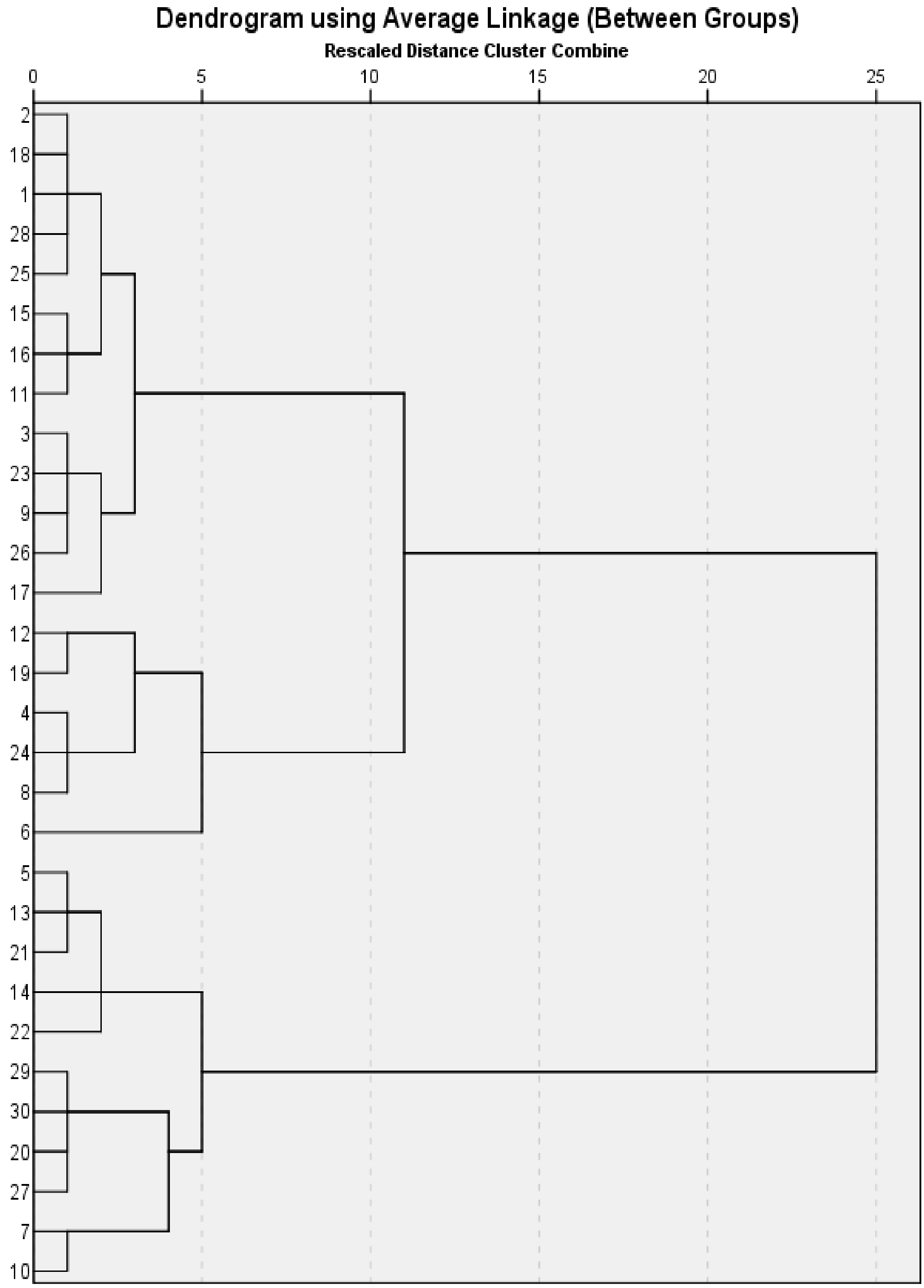


Fig. 1: Distribution of clusters in dendrogram

Table 11 (a) : Range and mean values of different characters in cluster analysis of curry leaf accessions

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10	Cluster 11	Cluster 12	Total mean
Plant height (m)	2.53-5.21 (3.56)	2.84-3.11 (3.00)	3.38-4.01 (3.70)	4.87 (4.87)	2.33-3.41 (2.87)	2.23-2.78 (2.49)	2.26 (2.26)	2.82-4.91 (4.13)	3.04 (3.04)	3.06 (3.06)	2.48-4.36 (3.10)	3.07-3.73 (3.40)	3.29
Height at branching starts (cm)	37.51-56.73 (47.21)	31.25-36.67 (33.96)	59.06-77.62 (68.34)	67.12 (67.12)	39.32-41.03 (40.17)	32.86-51.03 (41.94)	76.43 (76.43)	39.53-53.21 (46.37)	32.66 (32.66)	34.72 (34.72)	42.54-55.81 (49.17)	67.51-75.38 (71.44)	50.79
Primary branches	2-3 (2.50)	2-3 (2.50)	2-3 (2.50)	3.00 (3.00)	4.00 (4.00)	2-4 (3.00)	3.00 (3.00)	2-3 (2.50)	2.00 (2.000	3.00 (3.00)	2-3 (2.50)	3.00 (3.00)	2.79
Secondary branches	4-8 (6.00)	4-5 (4.50)	3-6 (4.50)	6.00 (6.00)	7-8 (7.50)	5-8 (6.50)	5.00 (5.00)	3-5 (4.00)	3.00 (3.00)	6.00 (6.00)	3-6 (4.50)	5-6 (5.50)	5.16
Tertiary branches	23-42 (32.50)	18-28 (23.00)	16-33 (24.50)	36.00 (36.00)	42.00 (42.00)	28-46 (37.00)	32.00 (32.00)	16-27 (21.50)	16.00 (16.00)	34.00 (34.00)	12-38 (25.00)	26-36 (31.00)	29.54
N-S canopy spread (m)	1.86-3.66 (2.59)	2.13-2.52 (2.37)	1.56-3.71 (2.86)	3.07 (3.07)	4.28-4.32 (4.20)	3.65-4.57 (4.00)	4.26 (4.26)	1.88-3.35 (2.68)	2.13 (2.13)	1.82 (1.82)	2.19-3.03 (2.49)	1.82-3.39 (2.60)	2.93
E-W canopy spread (m)	1.89-3.65 (2.43)	2.54-3.11 (2.79)	1.52-3.35 (2.42)	3.72 (3.72)	3.76-4.78 (4.27)	3.04-3.76 (3.41)	3.85 (3.85)	2.8-3.38 (3.07)	2.17 (2.17)	2.50 (2.50)	2.13-3.06 (2.67)	2.65-3.04 (2.84)	3.01

Table 11 (b): Range and mean values of different characters in cluster analysis of curry leaf accessions

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10	Cluster 11	Cluster 12	Total mean
Leaf length (cm)	18.52-18.75 (18.68)	16.78-16.81 (16.79)	15.82-18.66 (16.82)	15.73 (15.73)	21.42-21.81 (21.61)	19.82-21.18 (20.40)	19.18 (19.18)	15.85-17.71 (16.56)	17.45 (17.45)	16.5 (16.50)	16.98-18.16 (17.50)	14.71-17.15 (15.93)	17.76
No. of leaflets per leaf	20-21 (20.20)	16-20 (18)	18-20 (19.50)	17 (17)	22 (22)	21 (21)	21 (21)	18-20 (19)	19 (19)	16 (16)	16-19 (17.5)	19-20 (19.50)	19.14
Length of leaflet (cm)	3.65-3.77 (3.70)	3.18-3.51 (3.32)	2.96-3.46 (3.15)	3.27 (3.27)	4.27-4.56 (4.41)	3.84-4.26 (4.04)	3.77 (3.77)	2.97-3.36 (3.20)	3.62 (3.62)	3.27 (3.27)	3.15-3.62 (3.36)	3.23-3.42 (3.32)	3.53
Width of leaflet (cm)	1.56-1.67 (1.59)	1.26-1.37 (1.30)	1.25-1.57 (1.45)	1.37 (1.37)	1.77-2.01 (1.89)	1.68-1.96 (1.77)	1.67 (1.67)	1.26-1.48 (1.36)	1.47 (1.47)	1.36 (1.36)	1.25-1.41 (1.35)	1.38-1.53 (1.45)	1.50
Leaf area (cm^2)	41.17-51.78 (46.01)	36.35-38.76 (37.95)	33.48-44.08 (39.80)	32.25 (32.25)	58.72-66.46 (62.59)	52.36-56.77 (53.83)	52.1 (52.21)	38.49-40.67 (39.78)	38.76 (38.76)	38.49 (38.49)	36.06-38.11 (36.89)	29.06-29.14 (29.10)	42.30
Total yield (kg/plant/year)	3.36-4.73 (4.39)	2.79-4.29 (3.45)	2.41-3.86 (3.14)	3.50 (3.50)	5.35-5.42 (5.38)	4.92-5.30 (5.08)	4.84 (4.84)	2.67-4.12 (3.29)	2.82 (2.82)	3.04 (3.04)	2.19-3.45 (2.60)	4.03-4.34 (4.18)	3.81

Range and mean values for each character in each cluster is presented in table 11.

The mean value for plant height varied from 2.26m to 4.87 m with highest value recorded in cluster 4 (4.87 m). Plant height at branching starts (mean value) ranged from 32.66 m (cluster 9) to 76.43 m (cluster 7).

The highest number of primary (4 numbers), secondary (7.50 numbers) and tertiary branches (42.00numbers) were observed in cluster 5. The number of secondary (4.50 numbers) and tertiary branches (25.00 numbers) were recorded lowest in cluster 11.

The maximum branching spread (mean value) in North-South direction was observed in cluster 7 (4.26 m) and in East-West direction it was observed in cluster 5 (4.27 m).

The mean value for leaf length ranged from 15.73 cm (cluster 4) to 21.61 cm (cluster 5). The number of leaflets per leaf (mean value) ranged from 16 to 22 with highest value recorded in cluster 5 (22).

Cluster 5 recorded highest value (mean) for length (4.41 cm) and width of leaflet (1.89 cm). The lowest mean value for length of leaflet recorded in cluster 3 (3.15 cm) whereas cluster 2 recorded lowest width value (1.30 cm).

The mean value for leaf area ranged from 29.10 cm^2 to 62.59 cm^2 with highest value recorded in cluster 5. For fresh leaf yield, the mean value ranged from 2.60 kg to 5.38 kg with maximum yield recorded in cluster 5 (5.38 kg) followed by cluster 6 (5.08 kg) and cluster 7 (4.84 kg). The lowest yield (mean) was recorded in cluster 11 (2.60 kg) followed by cluster 9 (2.82 kg).

Cluster 5 was found to be superior over other clusters and it includes accessions MK 126 and MK 142. Cluster 5 recorded highest number of tertiary branches (340.50 numbers), East-West canopy spread (4.77 m), leaf length (21.61 cm), number of leaflets per leaf (22 numbers), length of leaflet (4.41 cm), width of leaflet (1.89 cm) and leaf area (62.59 cm^2) (Table 11). These quantitative characters directly influence the fresh yield of curry leaf. Highest fresh leaf yield was recorded in cluster 5 (5.38 kg).

Cluster 6 was found to be the next best cluster in terms of number of primary (3.00 numbers), secondary (6.50 numbers) and tertiary branches (37.00

numbers), leaf length (20.40 cm), number of leaflets (21), length (4.04 cm) and width of leaflet (1.77cm), leaf area (53.83 cm^2) and fresh leaf yield (5.08 kg). Cluster 6 includes accessions MK 107, MK 118 and MK 160.

The next best performing cluster was cluster 7 having only one accession MK 114. Cluster 7 recorded lowest plant height among all cluster groups (2.26m). The second highest East-West canopy spread (3.85 m) and number of leaflets (21 numbers) was recorded in cluster 7. Fresh yield was observed as 4.84 kg.

The fourth best performing cluster group was cluster 1 having largest number of accessions viz., MK 105, MK 141, MK 103, MK 186 and MK 161. Cluster 1 recorded yield of 4.39 kg in fresh weight basis.

Based on the cluster analysis four promising clusters were selected and from these ten accessions having superior characters were selected for further biochemical analysis.

4.4. BIOCHEMICAL CHARACTERS

Curry leaf is popular in India because of its nutritional content and widely used in various systems of medicine. Consumers are focusing mainly on quality and nutritional profile of the produce. Therefore understanding the variations in bioactive compounds have greater role in developing better quality varieties through crop improvement programme. The data pertaining to biochemical characters like essential oil, crude fibre, total carbohydrate, protein, total phenol, antioxidant capacity, beta carotene and driage are listed in table 12 to table 16. Based on cluster analysis, thirty accessions of curry leaf were grouped into 12 clusters. Among them four, clusters (clusters 1, 5, 6 and 7) found superior in terms of yield and sensory scores and from those four clusters, ten superior accessions were selected. These ten accessions include two from cluster 5 (MK 126, MK 142), three from cluster 6 (MK 107, MK 118 and MK 160), one from cluster 7 (MK 114) and four from cluster 1 (MK 103, MK 105, MK 141 and MK 186). Biochemical characterization was done on ten accessions along with check variety Suvasini in both fresh and dry leaf sample.

4.4.1. Essential oil

Essential oil in curry leaf is responsible for the characteristic aroma and flavour of leaves and it is reported to have various industrial uses (Plate 11). The dry leaves showed higher percentage of essential oil than fresh leaves. The essential oil recovery of fresh leaves ranged from 0.370 (MK 103) to 0.50 % (MK 186) whereas in dry leaves it varied from 0.71 (MK 103) to 1.09 % (MK 186). Highest essential oil content in fresh leaf was found to be in accession MK 186 (0.50 %) which was on par with MK 141 (0.49 %), MK 142 (0.48 %) and MK 160 (0.48 %). In dry leaves accession MK 142 and MK 186 showed highest essential oil content (1.07 to 1.09 %). The essential oil content was more than 1% for four accessions namely MK 141 (1.06 %), MK 142 (1.07 %), MK 160 (1.04 %) and MK 186 (1.09 %).The check variety Suvasini showed 0.44 % essential oil in fresh and 0.92 % in dry leaves (Table 12).

Table 12: Essential oil and crude fibre content of curry leaf accessions

Accessions	Essential oil (%)		Crude fibre (%)	
	Fresh	Dry	Fresh	Dry
MK 103	0.37^{f}	0.71^{h}	6.44^{c}	11.13^{cd}
MK 105	0.41^{e}	0.80^{g}	5.79^{f}	9.74^{h}
MK 107	0.43^{de}	0.86^{f}	6.40^{c}	10.64^{ef}
MK 114	0.46^{bc}	0.98^{d}	7.50^{b}	11.07^{ab}
MK 118	0.46^{bc}	0.97^{d}	7.91^{a}	11.53^{ab}
MK126	0.41^{e}	0.85^{f}	6.35^{cd}	10.58^{fg}
MK141	0.49^{ab}	1.06^{bc}	6.41^{c}	10.91^{de}
MK142	0.49^{ab}	1.07^{ab}	6.56^{c}	11.23^{bc}
MK160	0.48^{ab}	1.04^{c}	5.94^{ef}	9.98^{h}
MK186	0.50^{a}	1.09^{a}	8.09^{a}	11.65^{a}
Suvasini	0.44^{cd}	0.92^{e}	6.08 ^{de}	10.29^{g}
C.D (0.05)	0.027	0.036	0.270	0.303

Essential oil

Crude fibre

Plate 11. Essential oil and crude fibre

4.4.2. Crude fibre

Considerable variability was observed in crude fibre content of fresh and dry leaves. The crude fibre content was higher in dry leaves than fresh leaves (Plate 10). In fresh leaves crude fibre content ranged from 5.79 (MK 105) to 8.09 % (MK 186) where as in dry leaves values ranged from 9.74 (MK 105) to 11.65 % (MK 186).The crude fibre content in fresh leaves was more than 7 % in three accessions namely MK 114 (7.50 %), MK 118 (7.91 %) and MK 186 (8.09 %). The lowest crude fibre content was recorded by MK 105 (5.79 %) followed by MK 160 (5.94 %). In dry leaves the highest crude fibre content was recorded in accession MK 186 (11.65 %), MK 118 (11.53 %) and MK 114 (11.07 %) whereas lowest in MK 105 (9.74 %) followed by MK 160 (9.98%). The check variety Suvasini recorded fibre content of 6.08 % in fresh leaves and 10.29 % in dry leaves (Table 12).

4.4.3. Total carbohydrate content

Distinguishable variability was observed in total carbohydrate in fresh and dry leaves ranging from 14.45 (MK 103) to 15.99 % (MK 126) and 17.51 (MK 103) to 19.74 % (MK 126) respectively (Table 13). In fresh leaves, highest total carbohydrate was observed in accession MK 126 (15.99 %) followed by MK 142 (15.66 %) whereas MK 103 recorded lowest (14.45 %). The carbohydrate content of less than 15 % was observed in three accessions viz., MK 103 (14.45 %), MK 107 (14.89 %) and MK 186 (14.77 %). Accession MK 126 (19.74 %) recorded highest carbohydrate content in dry leaves while MK 103 recorded the lowest value (17.51 %). The values of carbohydrate content in dry leaves more than 19 % was observed in four accessions namely MK 126 (19.74 %), MK 141 (19.42 %), MK 142 (19.34 %) and MK 160 (19.13 %). The carbohydrate content in Suvasini varied from 15.55 % in fresh leaves and 18.82 % in dry leaves.

4.4.4. Protein content

Remarkable difference was observed in protein content ranging from 4.96 to 6.00 % in fresh leaves and 7.59 to 9.37 % in dry leaves (Table 13). The highest protein content was observed in MK 126 (6.00 %) followed by MK 114 (5.88 %), Suvasini (5.86 %) and MK 141 (5.85 %) in fresh leaves. In dry leaves accession MK 126 recorded highest protein content (9.37 %) followed by MK 114 (9.22 %), Suvasini (9.21%) and MK 141 (9.15 %) whereas MK 103 recorded lowest value (7.59 %).

Table 13: Carbohydrate and protein content of curry leaf accessions

Accessions	Carbohydrate (%)		Protein (%)	
	Fresh	Dry	Fresh	Dry
MK 103	14.45^{f}	17.51^{i}	5.76^{b}	8.11^{f}
MK 105	15.37^{c}	18.52^{e}	4.96^{d}	7.59^{h}
MK 107	14.89^{de}	18.27^{f}	5.35^{c}	7.87^{g}
MK 114	15.00^{d}	18.13^{g}	5.88^{b}	9.22^{b}
MK 118	15.59^{b}	18.86^{d}	5.80^{b}	8.43^{d}
MK126	15.99^{a}	19.74^{a}	6.00^{a}	9.37^{a}
MK141	15.65^{b}	19.42^{b}	5.85^{b}	9.15^{b}
MK142	15.66^{b}	19.34^{b}	5.80^{b}	8.30^{e}
MK160	15.62^{b}	19.13^{c}	5.73^{b}	7.96^{g}
MK186	14.77^{e}	17.69^{h}	5.82^{b}	8.65^{c}
Suvasini	15.55^{b}	18.82^{d}	5.86^{b}	9.21^{b}
C.D (0.05)	0.140	0.108	0.111	0.121

4.4.5. Total phenol

Considerable variability was observed in phenol content of fresh and dry leaves (Table 14).The highest phenolic content was recorded in dry leaves than fresh leaves ranging from 0.40 (MK 114) to 0.58 % (MK 105). The highest phenolic content was recorded by accession MK 105 in both fresh (0.31 %) and dry leaves (0.58 %) whereas lowest by MK 114 in fresh (0.20 %) and dry leaves

(0.40 %) respectively. Suvasini recorded phenolic content of 0.27 % in fresh leaves. In dry leaves, the phenolic content of greater than 0.5 % was observed in six accessions namely MK 105 (0.58 %), MK 107 (0.54 %), MK 118 (0.52 %), MK 142 (0.57 %), MK 160 (0.56 %) and Suvasini (0.55 %).

4.4.6. Antioxidant capacity

The antioxidant capacity of curry leaves recorded remarkable difference in their content in fresh and dry leaves (Table 14). The fresh leaves recorded maximum antioxidant capacity ranging from 3.06 to 3.44 mg AAE g^{-1}. The maximum antioxidant capacity was recorded by accession MK 102 and MK 105 (3.44 to 3.45 mg AAE g^{-1}) and the minimum was recorded by MK 186 (2.86 mg AAE g^{-1}) followed by MK 141 (3.06 mg AAE g^{-1}). The antioxidant capacity reduced during drying and it ranged from 1.53 to 2.16 mg AAE g^{-1}. Accession MK 105 recorded maximum antioxidant capacity (2.16 mg AAE g^{-1}) and MK 186 recorded minimum (1.53 mg AAE g^{-1}). In dry leaves, the antioxidant capacity value greater than 2 mg was observed in three accessions *viz.*, MK 160 (2.02 mg AAE g^{-1}), MK 105 (2.16 mg AAE g^{-1}) and MK 142 (2.06 mg AAE g^{-1}).The check variety Suvasini recorded values of 3.19 mg in fresh and 1.94 mg AAE g^{-1}in dry leaves.

4.4.7. Beta carotene

The beta carotene content of curry leaves recorded significant difference in fresh and dry stage. The content of beta carotene in fresh leaves ranged from 7.85 mg to 8.81 mg $100g^{-1}$ (Table 14). The maximum beta carotene content in fresh leaves were recorded in three accessions MK 186, MK 105 and MK 142 (8.80 to 8.81 mg $100g^{-1}$) whereas Suvasini recorded value of 8.24 mg $100g^{-1}$. The minimum beta carotene content was recorded in accession MK 118 (7.85 mg $100g^{-1}$) followed by MK 114 (7.89 mg $100g^{-1}$) and MK 126 (7.91 mg $100g^{-1}$). In dry leaves, beta carotene content ranged from 4.33 mg to 6.46 mg $100g^{-1}$. The maximum beta carotene content was recorded by MK 105 (6.46 mg $100g^{-1}$) whereas Suvasini recorded 5.93 mg $100g^{-1}$. The beta carotene content of more than 6 mg was observed in three accessions namely MK 105 (6.46mg $100g^{-1}$), MK 142 (6.36 mg $100g^{-1}$) and MK 186 (6.33 mg $100g^{-1}$). The lowest beta carotene value of less than 5 mg was observed in four accessions *viz.*, MK 118 (4.33 mg $100g^{-1}$), MK 114 (4.55 mg $100g^{-1}$), MK 126 (4.84 mg $100g^{-1}$) and MK 141 (4.98 mg $100g^{-1}$).

Table 14: Total phenol, antioxidant capacity and beta carotene content of curry leaf accessions

Accessions	**Total phenol (%)**		**Antioxidant capacity (mg AAE g^{-1})**		**Beta carotene (mg $100g^{-1}$)**	
	Fresh	**Dry**	**Fresh**	**Dry**	**Fresh**	**Dry**
MK 103	0.25^{f}	0.44^{f}	3.16^{c}	1.77^{d}	8.16^{b}	5.10^{f}
MK 105	0.31^{a}	0.58^{a}	3.45^{a}	2.16^{a}	8.81^{a}	6.46^{a}
MK 107	0.27^{cd}	0.54^{c}	3.24^{b}	1.92^{c}	8.24^{b}	5.80^{d}
MK 114	0.20^{g}	0.40^{g}	3.38^{b}	1.97^{bc}	7.89^{c}	4.55^{i}
MK 118	0.28^{cd}	0.52^{d}	3.35^{b}	1.93^{c}	7.85^{c}	4.33^{j}
MK126	0.26^{de}	0.49^{e}	3.18^{c}	1.81^{d}	7.91^{c}	4.84^{h}
MK141	0.25^{ef}	0.49^{e}	3.06^{d}	1.60^{ef}	8.15^{b}	4.98^{g}
MK142	0.29^{b}	0.57^{b}	3.44^{a}	2.06^{b}	8.81^{a}	6.36^{b}
MK160	0.28^{bc}	0.56^{b}	3.36^{b}	2.02^{bc}	8.16^{b}	5.19^{e}
MK186	0.27^{cde}	0.49^{e}	2.86^{e}	1.53^{f}	8.80^{a}	6.33^{b}
Suvasini	0.27^{cd}	0.55^{c}	3.19^{c}	1.94^{c}	8.24^{b}	5.93^{c}
C.D (0.05)	0.014	0.011	0.060	0.106	0.097	0.069

4.4.8. Total chlorophyll content

Total chlorophyll, chlorophyll ‘a’ and chlorophyll ‘b’ content of ten accessions along with Suvasini was calculated and given in the table 15. Fresh leaves exhibited maximum chlorophyll content and up on drying decreased considerably. The content of chlorophyll ‘a’ in fresh leaves varied considerably from 0.77 mgto 1.15 mg $100g^{-1}$. Maximum chlorophyll content was recorded in accession MK 142 (1.15 mg $100g^{-1}$) followed by MK 141 (1.13 mg $100g^{-}1$) and MK 126 (1.12 mg $100g^{-}1$) whereas MK 105 recorded the lowest content (0.77 mg $100g^{-1}$). In dry leaves MK 142 recorded highest content (0.81 mg $100g^{-1}$) whereas lowest was recorded by MK 105 (0.60 mg $100g^{-1}$). Suvasini recorded a chlorophyll content of 1.10 mg in fresh and 0.69 mg $100g^{-1}$ in dry leaves respectively.

Considerable variation was noticed with chlorophyll ‘b’ content. The chlorophyll ‘b’ content ranged from 0.17 mg (MK 105) to 0.25 mg $100g^{-1}$ (MK 103) in fresh leaves. In dry leaves, accession MK 142 exhibited maximum chlorophyll ‘b’ content (0.12 mg $100g^{-1}$) whereas MK 105 recorded the minimum content (0.01 mg $100g^{-1}$). The check variety Suvasini recorded 0.23 mg and 0.07 mg $100g^{-1}$ in fresh and dry leaves respectively.

The total chlorophyll content ranged from 0.97 mg to 1.47 mg $100g^{-1}$ in fresh leaves and 0.72 mgto 0.85 mg $100g^{-1}$ in dry leaves. Highest chlorophyll content as recorded in MK 103 (1.47 mg $100g^{-1}$) followed by MK (1.36 mg) whereas MK 105 recorded the lowest value (0.97 mg $100g^{-1}$) in fresh leaves. Accession MK 103 (0.85 mg $100g^{-1}$) recorded maximum total chlorophyll content and minimum in MK 105 (0.72 mg $100g^{-1}$) in dry leaves. Total chlorophyll content in Suvasini varied from 1.36 mg in fresh and 0.80 mg $100g^{-1}$ in dry leaves.

Table 15: Chlorophyll content of curry leaf accessions

Accessions	Chlorophyll 'a' ($mg\ 100g^{-1}$)		Chlorophyll 'b' ($mg\ 100g^{-1}$)		Total chlorophyll ($mg\ 100g^{-1}$)	
	Fresh	**Dry**	**Fresh**	**Dry**	**Fresh**	**Dry**
MK 103	1.05^{ab}	0.68^{c}	0.25^{a}	0.08^{b}	1.47^{a}	0.85^{a}
MK 105	0.77^{c}	0.60^{f}	0.17^{f}	0.01^{i}	0.97^{e}	0.72^{g}
MK 107	1.00^{b}	0.62^{e}	0.23^{abc}	0.06^{de}	1.33^{bc}	0.79^{cd}
MK 114	1.09^{ab}	0.68^{c}	0.23^{abc}	0.05^{e}	1.29^{bcd}	0.78^{de}
MK 118	1.04^{ab}	0.67^{d}	0.19^{ef}	0.02^{h}	1.22^{cd}	0.77^{e}
MK126	1.12^{a}	0.72^{b}	0.23^{abc}	0.07^{b}	1.29^{bcd}	0.78^{de}
MK141	1.13^{a}	0.72^{b}	0.22^{cd}	0.04^{f}	1.38^{ab}	0.81^{b}
MK142	1.15^{a}	0.81^{a}	0.24^{ab}	0.12^{a}	1.34^{bc}	0.79^{c}
MK160	1.11^{ab}	0.69^{c}	0.23^{abc}	0.07^{bc}	1.31^{bcd}	0.79^{c}
MK186	1.04^{ab}	0.67^{d}	0.21^{de}	0.03^{g}	1.18^{d}	0.75^{f}
Suvasini	1.10^{ab}	0.69^{c}	0.23^{abc}	0.07^{cd}	1.36^{ab}	0.80^{b}
C.D (0.05)	0.108	0.009	0.020	0.007	0.129	0.010

4.4.9. Driage

The driage percentage of fresh leaves expressed measurable difference and it varied from 51.63 to 66.30 % (Table 16).The maximum driage was observed in accession MK 107 (66.30 %) which was on par with MK 105 (65.93 %) whereas Suvasini recorded 56.44 % driage. The driage value of more than 60 % was observed in four accessions namely MK 103 (60.90 %), MK 105 (65.93 %), MK 107 (66.30 %) and MK 114 (60.74 %).The lowest driage content was exhibited by MK 186 (51.63 %) followed by MK 142 (52.16 %).

Table 16: Percent driage of curry leaf accessions

Accessions	Driage (%)
MK 103	60.90[b]
MK 105	65.93[a]
MK 107	66.30[a]
MK 114	60.74[b]
MK 118	56.46[c]
MK126	53.24[de]
MK141	56.47[c]
MK142	52.16[ef]
MK160	53.76[d]
MK186	51.63[f]
Suvasini	56.44[c]
C.D (0.05)	1.351

4.5. VEGETATIVE PROPAGATION THROUGH STEM CUTTINGS

Effect of different concentrations of IBA and NAA (1000ppm, 2000ppm and in combination) on rooting of softwood, semi-hardwood and hardwood stem cuttings of curry leaf variety Suvasini was evaluated in three seasons *viz*., rainy, winter and summer. The observations on days to sprouting were recorded. The observations on leaf characters were recorded at 60 and 90 days of planting whereas the root characters were observed after 180 days of planting. The effect of auxin formulations (IBA and NAA), cutting types (softwood, semihardwood and hardwood cuttings), interaction effect of auxin formulations with cutting types are described in the table 17 to 24.

4.5.1. Effect of hormones and type of cuttings on propagation in rainy season

Days to sprouting

Number of days taken for the appearance of first green coloured sprout on the stem cuttings in each season was recorded (Plate 12) and mean value for rainy season is presented in the table17. Though the effect of auxin formulation on cuttings were found non significant, the least number of days for sprouting (7.55 days) was observed when cuttings were treated 1000ppm IBA + 2000ppm NAA formulation (T_6) followed by 2000ppm IBA + 2000ppm NAA formulation (T_8) where 7.66 days were recorded. The maximum number of days (9.16 days) for sprouting was observed in cuttings treated with 1000 ppm NAA (T_3). With regard to the effect of cutting type, the softwood cuttings recorded lowest number of days for sprout initiation (6.81 days) and maximum days for sprouting was taken by hardwood cuttings (10.18 days).

It was evident from the table 17 that the interaction effect of auxin formulations × cutting type recorded wide variation on number of days for sprouting. Though the interaction effect on days to sprouting was found to be non significant, the least number of days for sprout initiation (5.50 days) was recorded in C_1T_8 (softwood cuttings x 2000ppm IBA + 2000ppm NAA) followed by C_1T_6 (softwood cuttings x 1000ppm IBA + 2000ppm NAA) whereas maximum days for sprouting (11.50 days) was recorded in C_3T_3 (hardwood cuttings x 1000 ppm

Softwood cutting

Semihardwood cutting

Hardwood cutting

Plate 12. Planting and sprouting of cuttings in mist chamber

NAA followed by C_3T_6 (hardwood cuttings x 1000ppm IBA +2000ppm NAA). The untreated cuttings failed to sprout in all treatments and seasons.

Table 17: Effect of growth regulators and type of cuttings on days to sprouting during rainy season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	6.50	7.50	10.00	8.05
2000ppm IBA (T_2)	7.00	8.50	9.00	8.50
1000ppm NAA (T_3)	8.50	9.00	11.50	9.16
2000ppm NAA (T_4)	7.50	8.50	10.00	8.50
1000ppm IBA+1000ppm NAA (T_5)	6.50	8.00	10.50	8.00
1000ppm IBA+2000ppm NAA (T_6)	6.00	7.50	11.00	7.55
2000ppm IBA+1000ppm NAA (T_7)	7.00	8.00	9.00	8.16
2000ppm IBA+2000ppm NAA(T_8)	5.50	7.50	10.00	7.66
Mean	6.81	8.18	10.18	

Factors	C.D.(0.05)	S.E.(m)
Growth regulator (T)	NS	0.57
Cutting type (C)	1.03	0.35
Interaction (T×C)	NS	0.99

Percent of sprouting

The percentage of sprouting was significantly affected by auxin formulations. The maximum sprouting of 38.70 % was recorded when cuttings were treated with 2000ppm IBA + 2000 ppm NAA (T_8) followed by 2000ppm IBA + 1000 ppm NAA (T_7) where 36.93 % of sprouting was observed (table 18). Significant difference was observed in sprouting percentage with respect to different types of cuttings. In rainy season, maximum sprouting (35.62 %) was recorded by hardwood cuttings (C_3) while the lowest sprouting (22.37 %) was observed with softwood cuttings (C_1).

In terms of interaction effect, C_3T_8 (hardwood cuttings 2000ppm IBA + 2000ppm NAA) resulted in maximum sprouting of 46.75 % which was on par with C_3T_7(hardwood cuttings x 2000ppm IBA + 1000ppm NAA) and C_2T_8 (semihardwood cuttings x 2000ppm IBA + 2000ppm NAA) where sprouting ranged from 45.30 to 45.35 % (table 18). The lowest sprouting of 13.35 % was recorded in C_1T_3(softwood cuttings x 1000ppm NAA).

Number of emerged leaves

The number of emerged leaves per cutting recorded (Plate 13) and observed considerable variation (table 19). The auxin formulation T_2 (2000ppm IBA) recorded maximum number of leaves (6.83) followed by T_6 (1000ppm IBA + 2000ppm NAA) (6.68) and T_8 (2000ppm IBA + 2000ppm NAA) (6.50). The lowest number of leaves (5.33) was recorded by T_3 (1000ppm NAA). In the case of effect of cutting types, semihardwood cuttings (C_2) recorded maximum number of leaves (7.12) while softwood (C_1) recorded the lowest value (4.68).

Though the interaction effect was non significant, it was observed from the data (Table 19). C_2T_7 (semihardwood cuttings x 2000ppm IBA + 1000ppm NAA) recorded maximum number of leaves (7.50) followed by C_2T_8 (semihardwood cuttings x 2000ppm IBA + 2000ppm NAA) and C_3T_8 (hardwood cuttings x 2000ppm IBA + 2000ppm NAA) where number of leaves were recorded as 7.00. The minimum number of leaves (3.00) was observed in C_1T_3 (softwood cuttings x 1000ppm NAA).

Table 18: Effect of growth regulators and type of cuttings on sprouting of cuttings during rainy season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	22.05	25.05	31.90	26.33
2000ppm IBA (T_2)	24.95	32.50	36.30	31.25
1000ppm NAA (T_3)	13.35	22.05	21.95	19.12
2000ppm NAA (T_4)	18.95	22.60	25.95	22.50
1000ppm IBA+1000ppm NAA (T_5)	26.10	34.95	40.55	33.86
1000ppm IBA+2000ppm NAA (T_6)	26.20	38.45	36.20	33.61
2000ppm IBA+1000ppm NAA (T_7)	23.35	42.10	45.35	36.93
2000ppm IBA+2000ppm NAA(T_8)	24.05	45.30	46.75	38.70
Mean	22.37	32.87	35.62	

Factors	C.D.(0.05)	S.E.(m)
Growth regulator (T)	1.596	0.543
Cutting type (C)	0.977	0.333
Interaction (T×C)	2.764	0.941

Softwood cutting

Semihardwood cutting

Hardwood cutting

Plate 13. Leaf emergence in cuttings

Table 19: Effect of growth regulators and type of cuttings on number of leaves per cuttings during rainy season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	5.50	6.00	5.50	5.66
2000ppm IBA (T_2)	6.00	6.50	6.50	6.83
1000ppm NAA (T_3)	3.00	4.50	5.00	5.33
2000ppm NAA (T_4)	6.00	5.50	5.50	5.50
1000ppm IBA+1000ppm NAA (T_5)	4.50	6.50	6.50	5.66
1000ppm IBA+2000ppm NAA (T_6)	4.00	6.00	6.00	6.66
2000ppm IBA+1000ppm NAA (T_7)	5.00	7.50	6.50	6.16
2000ppm IBA+2000ppm NAA(T_8)	5.50	7.00	7.00	6.50
Mean	4.68	7.12	6.31	

Factors	C.D.(0.05)	S.E.(m)
Growth regulator (T)	NS	0.507
Cutting type (C)	0.911	0.310
Interaction (T×C)	NS	0.878

Percentage establishment

Further observations were recorded in survived cuttings in rainy season and it was observed that only hardwood cuttings (C_3) treated with 2000ppm IBA+ 2000 ppm NAA (T_8) survived after 60 days of planting. The percentage of establishment recorded was 3.3 % (Plate 14).

Leaf and root characters

The survived cutting recorded leaf length of 11.4 cm and width of 1.45 cm. With regard to root characters, the number of primary and secondary roots in the survived cutting was found to be 6.00 to 17.00 respectively (Plate 14). The mean length of primary and secondary roots recorded was 5.32 cm and 3.7 cm respectively. The fresh weight of root was obtained as 1.12 g.

4.5.2. Effect of hormones and type of cuttings on propagation of curry leaf in winter season

Days to sprout

The cuttings planted in winter season took more time for sprout initiation than rainy season (Table 20). Though the effect of auxin formulation was non significant, cuttings treated with 2000ppm IBA + 1000 ppm NAA (T_7) recorded minimum days for sprouting (9.83 days) while 1000 ppm NAA (T_3) recorded maximum days (11.50 days). With regard to cutting type, softwood cuttings recorded minimum days for sprouting (9.12 days) while hardwood recorded maximum number of days (12.25 days).

Even though, the interaction effect was found non significant for days to sprout, lowest number of days for sprouting (8.00 days) was observed in C_1T_2 (softwood x 2000ppm IBA) and C_1T_8 (softwood × 2000ppm IBA+2000ppm NAA). The maximum days for sprouting (13.50 days) was recorded in C_3T_3 (hardwood cutting x 1000ppm NAA) and C_3T_5 (hardwood cutting x1000ppm IBA + 1000ppm NAA).

After 90 days of planting

After 180 days of planting

Plate 14. Survival of cuttings after 90 and 180 days of planting

Table 20: Effect of growth regulators and type of cuttings on days to sprout during winter season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	8.50	11.00	11.00	11.00
2000ppm IBA (T_2)	8.00	10.50	10.50	10.16
1000ppm NAA (T_3)	9.50	12.50	13.50	11.50
2000ppm NAA (T_4)	8.50	12.00	13.00	11.00
1000ppm IBA+1000ppm NAA (T_5)	8.50	11.00	13.50	11.00
1000ppm IBA+2000ppm NAA (T_6)	9.00	10.50	12.50	10.66
2000ppm IBA+1000ppm NAA (T_7)	8.50	9.50	11.50	9.83
2000ppm IBA+2000ppm NAA(T_8)	8.00	10.00	12.00	10.33
Mean	9.12	10.87	12.25	

Factors	**C.D.(0.05)**	**S.E.(m)**
Growth regulator (T)	NS	0.471
Cutting type (C)	0.848	0.289
Interaction (T×C)	NS	0.816

Sprouting percentage

Significant difference was observed for the percentage of sprouting among different concentrations hormones and type of cuttings (Table 21). The maximum sprouting of 33.25 % was recorded when cuttings were treated with 2000ppm IBA + 2000 ppm NAA (T_8) followed by 2000ppm IBA + 1000 ppm NAA (T_7) where 28.46 % of sprouting was observed. The lowest sprouting success was observed in 1000ppm NAA (20.26 %). Among the different types of cuttings, maximum sprouting (34.06 %) was recorded by Hardwood cuttings (C_3) while the lowest sprouting (18.37 %) was observed with softwood cuttings (C_1).

In terms of interaction effect, C_3T_8 (hardwood cuttings × 2000ppm IBA + 2000ppm NAA) and C_3T_6 (hardwood cuttings x 1000ppm IBA + 2000ppm NAA) recorded maximum sprouting of 43.20 % and 40.45 % respectively. The lowest sprouting of 16.00 % was recorded in C_1T_4 (softwood cuttings x 1000ppm IBA + 1000ppm NAA) followed by C_1T_5 (softwood cuttings x 1000ppm IBA + 2000ppm NAA) (16.30 %) and C_2T_3 (semihardwood cuttings x 1000ppm NAA) (16.75 %).

Number of emerged leaves

For the number of emerged leaves per cutting in winter, auxin formulations T_6 (1000 ppm IBA +2000ppm NAA) and T_8 (2000ppm IBA +2000ppm NAA) recorded maximum number of leaves (6.33) whereas T_3 (1000 ppm NAA) and T_4 (2000ppm NAA) recorded the lowest value of 4.33 and 4.50 respectively (Table 22). Among the cutting types, semihardwood cuttings (C_2) recorded maximum number of leaves (6.87) while softwood (C_1) recorded the lowest value (3.31).

Though the interaction effect was non significant, it was observed from the data (Table 22) C_2T_6 (semihardwood cuttings × 1000ppm IBA + 2000ppm NAA) and C_2T_8 (semihardwood cuttings × 2000ppm IBA + 2000ppm NAA) recorded maximum number of leaves (8.50) whereas the minimum number of leaves (2.00) was observed in C_1T_3 (softwood cuttings x 1000ppm NAA).

Leaf and root characters

Further observations could not be recorded as the emerged leaves wilted and rotting of cuttings were observed after 40 days of planting. No cuttings were survived in the field and cent percent mortality was observed.

Table 21: Effect of growth regulators and type of cuttings on sprouting of cuttings during winter season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	17.90	22.05	32.45	24.13
2000ppm IBA (T_2)	20.70	24.85	36.75	27.43
1000ppm NAA (T_3)	18.00	16.75	26.05	20.26
2000ppm NAA (T_4)	16.00	20.10	27.85	21.32
1000ppm IBA+1000ppm NAA (T_5)	16.30	24.50	28.25	23.01
1000ppm IBA+2000ppm NAA (T_6)	17.10	26.95	40.45	28.16
2000ppm IBA+1000ppm NAA (T_7)	20.95	26.90	37.55	28.46
2000ppm IBA+2000ppm NAA(T_8)	20.05	24.50	43.20	33.25
Mean	18.37	23.32	34.06	

Factors	C.D.(0.05)	S.E.(m)
Growth regulator (T)	1.592	0.542
Cutting type (C)	0.975	0.332
Interaction (T×C)	2.757	0.939

Table 22: Effect of growth regulators and type of cuttings on number of leaves per cuttings during winter season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	3.00	6.00	5.50	4.83
2000ppm IBA (T_2)	3.50	7.50	6.00	5.33
1000ppm NAA (T_3)	2.00	5.50	4.50	4.33
2000ppm NAA (T_4)	3.50	7.00	5.50	4.50
1000ppm IBA+1000ppm NAA (T_5)	4.00	6.50	6.50	5.23
1000ppm IBA+2000ppm NAA (T_6)	3.50	8.50	7.00	6.33
2000ppm IBA+1000ppm NAA (T_7)	4.00	8.00	6.50	5.66
2000ppm IBA+2000ppm NAA(T_8)	4.50	8.50	7.00	6.33
Mean	3.31	6.87	5.81	

Factors	C.D.(0.05)	S.E.(m)
Growth regulator (T)	1.42	0.486
Cutting type (C)	0.87	0.298
Interaction (T×C)	NS	0.842

4.5.3. Effect of hormones and type of cuttings of curry leaf in summer

In summer season, cuttings showed poor sprouting percentage. Even though the cuttings were sprouted, they withered immediately after one week of sprouting. Hence no observations on shoot and root characters could be recorded.

Days to sprouting

Cuttings required more time for sprout initiation (Table 23) in summer when compared to other two seasons (more than 10 days). Though the effect of auxin formulation on cuttings were found non significant, the least number of days for sprouting (10.50 days) was observed when cuttings were treated with 1000 ppm IBA + 2000 ppm NAA formulation (T_6) and 2000 ppm IBA + 2000 ppm NAA formulation (T_8). The maximum number of days (12.50 days) for sprouting was taken in cuttings treated with 1000 ppm NAA (T_3). Among the different types of cuttings, early sprouting (9.68 days) was observed in softwood cuttings and sprouting was late in semihardwood (12.25 days).

The interaction effect of auxin formulations ×cutting type on number of days for sprouting was found non significant (Table 23). The least number of days for sprout initiation (8.50 days) was recorded in C_1T_8 (softwood cuttings ×2000 ppm IBA +2000 ppm NAA) and C_1T_6 (softwood cuttings×2000 ppm NAA) whereas maximum days for sprouting (15.50 days) was recorded in C_3T_3 (hardwood cuttings× 1000 ppm NAA).

Percentage of sprouting

Sprouting percentage was significantly affected by auxin formulations. Maximum sprouting was recorded in T_8 where cuttings were treated with 2000 ppm IBA + 2000 ppm NAA, T_7 (2000 ppm IBA + 1000 ppm NAA) and T_6 (1000 ppm IBA + 2000 ppm NAA) with values of 29.28, 26.83 and 26.65 % respectively. The lowest sprouting percentage (18.33 %) in summer was recorded by 1000 ppm NAA (T_3). With respect to type of cuttings, maximum sprouting (29.20 %) was recorded by hardwood cuttings (C_3) while the lowest sprouting (19.01 %) was observed with softwood cuttings (C_1).

In terms of interaction effect, significant difference was observed (Table 24) with sprouting percentage. C_3T_8 (hardwood cuttings × 2000 ppm IBA + 2000 ppm NAA) resulted in maximum sprouting of 36.40 % which was on par with C_3T_6 (hardwood cuttings × 1000 ppm IBA + 2000 ppm NAA) in which sprouting of 34.25 % was recorded. The lowest sprouting of 13.95% was recorded in C_1T_3 (softwood cuttings × 1000 ppm NAA.

Table 23: Effect of growth regulators and type of cuttings on days to sprout during summer season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	10.00	12.00	13.50	12.16
2000ppm IBA (T_2)	9.50	11.50	14.50	11.16
1000ppm NAA (T_3)	11.50	14.00	15.50	12.50
2000ppm NAA (T_4)	10.50	12.00	15.00	12.00
1000ppm IBA+1000ppm NAA (T_5)	10.00	13.00	13.50	11.33
1000ppm IBA+2000ppm NAA (T_6)	8.50	12.50	14.00	10.50
2000ppm IBA+1000ppm NAA (T_7)	9.50	11.50	12.50	10.83
2000ppm IBA+2000ppm NAA(T_8)	8.50	11.00	13.00	10.50
Mean	9.68	12.25	12.37	

Factors	C.D.(0.05)	S.E.(m)
Growth regulator (T)	NS	0.710
Cutting type (C)	1.27	0.43
Interaction (T×C)	NS	1.23

Leaf and root characters

Due to high temperature, sprouted cuttings started to withering 35 days of planting and further observations could not be recorded. No cuttings were survived in the field and cent percent mortality was observed (Plate 15).

Table 24: Effect of growth regulators and type of cuttings on sprouting of cuttings during summer season

Growth regulator (T)	Softwood (C_1)	Semihardwood (C_2)	Hardwood (C_3)	Mean
1000ppm IBA (T_1)	16.25	16.25	24.90	20.33
2000ppm IBA (T_2)	21.40	21.40	28.25	23.88
1000ppm NAA (T_3)	13.95	13.95	22.05	18.33
2000ppm NAA (T_4)	15.45	15.45	23.05	19.63
1000ppm IBA+1000ppm NAA (T_5)	20.15	20.15	32.80	25.88
1000ppm IBA+2000ppm NAA (T_6)	22.40	22.40	34.25	26.65
2000ppm IBA+1000ppm NAA (T_7)	21.95	21.95	31.95	26.83
2000ppm IBA+2000ppm NAA(T_8)	20.60	20.60	36.40	29.28
Mean	19.01	23.33	29.20	

Factors	C.D.(0.05)	S.E.(m)
Growth regulator (T)	1.429	0.487
Cutting type (C)	0.875	0.298
Interaction (T×C)	2.476	0.843

Softwood cuttings

Semihardwood cuttings

Plate 15. Mortality of cuttings in the field

Discussion

5. DISCUSSION

Curry leaf is an evergreen plant, mostly distributed in tropical and subtropical regions. *Murraya koeinigii* is one of the herbal spices, which dominates all other spices due to its characteristic aroma, flavour and medicinal value. It is an important export commodity from India and fetches good foreign revenue. The curry leaves are rich source of carbazole alkaloids, carbohydrates, proteins, fibers, minerals and vitamins. Various bioactive compounds present in curry leaf make it versatile for treating several diseases and also as a potential source for providing useful drugs.

Characterization facilitates to quantify the genetic variability among different accessions and to have clear knowledge of its diversity. Since curry leaf is a cross pollinated crop and naturalized in many areas including forests and wastelands throughout the Indian subcontinent, high amount of heterogeneity with respect to morphological characters was reported by Verma and Rana (2011).

In the present investigation, thirty accessions of curry leaf were evaluated for important morphological characters and yield. The data was then subjected to statistical analysis to get mean performance of accessions. Clustering analysis was performed to group the accessions and based on ranking ten superior accessions were identified. Biochemical analysis was then carried out in these ten accessions to select the best genotypes in terms of quality. Correlation analysis facilitated to have knowledge of mutual relationship between important morphological traits and fresh leaf yield.

Further, the effect of two growth regulators (IBA and NAA) and three type of stem cuttings (softwood, semi-hardwood and hardwood) on rooting of curry leaf variety Suvasini in three different seasons *viz.*, rainy, winter and summer was evaluated. The data was then statistically analyzed.

5.1. Morphological characterization

The morphological characterization is important for assessing the genetic diversity of germplam and further utilization for crop improvement. Verma and

Rana (2011) analyzed the genetic diversity within and among the wild populations of *Murraya koenigii* by ISSR markers and the study revealed high amount of genetic variations within the population. In the present study, the morphological characters recorded considerable variation among the thirty accessions.

5.1.1. Plant characters

Plant height is an important trait which determines the growth and vigour of the plant. In the present study, plant height varied from 2.23 m to 5.21 m. Agba and Adiaha (2018) reported variation in plant height ranging from 68.77 cm to 118.21 cm in two year old curry leaf plant. Similar findings were reported by Subha *et al*. (2010) in a two year old plantation. Optimum plant height is one of the desirable characters of curry leaf. Based on the plant height, the accessions were grouped and the details are furnished in the table25. Among thirty accessions studied, MK 103 recorded maximum plant height (5.21 m). Plant height of more than 4 m was recorded in 23 % of accessions namely MK 103, MK 109, MK 119, MK 136, MK 152, MK 156 and MK 181.The check variety Suvasini recorded a plant height of 2.37 m. The accessions MK 107 (2.23 m) followed by MK 126 (2.33 m) were observed to be dwarf which is desirable for high density planting.

With respect to plant height at branching starts considerable variability was observed and presented in the table 26. It ranged from 31.25 to 67.51 cm. The branching height is an ideal character of genotype. In the present context, plant height at branching was the lowest in MK 125 (31.25 cm) followed by MK 107 (32.36 cm) and MK 132 (32.66 cm). Accession MK 122 recorded highest plant height at branching (67.51 cm) followed by MK 136 (66.12 cm) and MK 117 (65.38 cm). Branching was observed at a plant height of 43.43 cm in Suvasini.

Table 25: Grouping of accessions based on plant height

Class	No. of accessions	Name of accessions	Frequency (%)
High (>5m)	1	MK 103	3.22
Medium (3 to 5m)	18	MK 109, MK 119, MK 136, MK 152, MK 156, MK 181, MK 106, MK 117, MK 122, MK132, MK 134, MK 135, MK 141, MK 142, MK 151, MK 153, MK 173, MK 186	58.06
Low (<3m)	12	MK 105, MK 107, MK 114, MK 118, MK 125, MK 126, MK 129, MK 160, MK 161, MK 192, MK 195,Suvasini	38.70

Table 26: Grouping of accessions based on branching height

Class	No.of accessions	Name of accessions	Frequency (%)
High (>60 cm)	4	MK 106, MK 117, MK 122, MK 136	12.90
Medium (40-60 cm)	17	MK 103, MK 105, MK 114, MK 118, MK 125, MK 129, MK 141, MK 142, MK 151, MK 152, MK 156, MK 173, MK 181, MK 186, MK 192, MK195,Suvasini	54.83
Low (<40 cm)	10	MK 107, MK 109, MK 119,MK 126, MK 132, MK 134,MK 135, MK 153, MK 160,MK 161	32.25

The number of branches in the plant is an important trait which directly influences the yield of plant. New flushes emerge on younger branches. The number of primary branches varied from 2 to 4 among different accessions. The maximum number of primary branches (4 numbers) was recorded for the accessions MK 107, MK 118, MK 126, MK 141 and MK 160 which was higher than Suvasini (2 numbers). With respect to the number of secondary and tertiary branches, accession MK 141 recorded highest number of branches (8 numbers of secondary and 48 numbers of tertiary branches). The numbers of tertiary branches were greater than 40 in five accessions namely MK 107, MK 118, MK 126, MK 141 and MK 160 while less than 20 were recorded in five accessions *viz*., MK 132, MK 142, MK 156, MK 192 and MK 195.Based on the number of tertiary branches, the accessions were grouped into three classes and details are furnished in the table 27. The check variety Suvasini recorded 5 and 26 numbers of secondary and tertiary branches respectively. Similar findings were reported by Jagadeeshkanth and Sankaranarayanan (2014).

The next important plant character which has direct effect on yield of curry leaf is the canopy spread. Wide variation was observed for canopy spread in North-South and East-West direction. The maximum canopy spread in North-South direction ranged from 1.56 to 4.57 m where as it varied from 1.52 m to 4.78 m in East-West direction. In North-South direction, the branching spread was greater than 4 m for four accessions *viz.*, MK 114, MK 118, MK 126 and MK 142. 16 % of the accessions recorded lower canopy spread of less than 2m. The maximum branching spread in relation to East-West direction was observed in accession MK 142 (4.78 m) followed by MK 114 (3.85 m), MK 126 and MK 1129 (3.76 m each). Suvasini recorded branching spread of 2.1 m in North-South and 3.02 m in East-West direction.

Table 27: Grouping of accessions based on tertiary branches

Class	No. of accessions	Name of accessions	Frequency (%)
High (>40)	5	MK 107,MK 118, MK 126, MK 142, MK 160	16.12
Medium (20-40)	19	MK 103, MK 105, MK 106, MK 109, MK 114, MK 117, MK 119, MK 12, MK 125, MK 129, MK 134, MK 141, MK 136, MK 152, MK 161, MK 173, MK 181, MK 186, Suvasini	61.29
Low (< 20)	7	MK 132, MK 135, MK 151, MK 153, MK 156, MK 192, MK 195	22.50

5.1.2. Leaf characters

Leaf characters are one among the key components for selecting high yielding genotypes. Real knowledge of leaf characters are desirable for identifying superior ones. Wide variation was observed in leaf length, number of leaflets per leaf, length and width of leaflet, leaf area and yield.

Remarkable difference was observed with regard to leaf length ranging from 14.71 cm to 21.81 cm with a mean value of 17.86 cm. The highest leaf length was recorded by accession MK 126 (21.81 cm) followed by MK 142 (21.42 cm) whereas MK 122 recorded lowest leaf length (14.71 cm) followed by MK 136 (15.73 cm). About 43 % of accessions recorded leaf length value of more than 18 cm.

Lalitha *et al.* (1997) evaluated fifteen genotypes of curry leaf collected from Kerala and Tamilnadu and reported wide variation in number of leaflets ranging from 14.17 to 21.35. The number of leaflets per leaf in the present study varied from 16 to 22 numbers with mean value of 19 numbers which is in agreement with the earlier findings. Subha *et al*. (2010) also reported similar trend in curry leaf accessions grown in Tamilnadu (17-20 numbers). Among the accessions, MK 126, MK 142 and Suvasini recorded highest number of leaflets (22 numbers) whereas MK 135, MK 153 and MK 195 recorded lowest number of leaflets per leaf (16 numbers). Majority of accessions (73.33 %) recorded more than 19 numbers of leaflets per leaf.

The length and width of leaflet have direct effect on leaf area. Among the accessions, MK 142 recorded highest leaflet length (4.56 cm) and MK 119 recorded the lowest value (2.96 cm). The leaflet length above 4 cm was observed in four accessions *viz*., MK 118, MK 126, MK 142 and MK 160 while Suvasini recorded 3.75 cm. The width of leaflet ranged from 1.25 cm to 2.01 cm. The highest leaflet width of 2.01 cm was recorded in MK 126 followed by MK 160 (1.96 cm). The check variety Suvasini recorded 1.41 cm of leaflet width and two accessions namely MK 106 and MK 195 recorded the lowest value (1.25 cm).Similar trend was reported by Lalitha *et al*. (1997) where the length of leaflet ranged from 2.52 cm to 5.36 cm and width from 0.97 cm to 2.54 cm respectively.

Leaf area is one of the key character for selecting high fresh leaf yielding types. In the present investigation, leaf area ranged from 29.06 cm^2 to 66.46 cm^2 (Fig. 2). Lalitha *et al*. (1997), revealed similar trend in leaf area ranging from 30.6 cm^2 to 75.6 cm^2 in fifteen curry leaf accessions. Highest leaf area was recorded by MK 142 (66.46 cm^2) followed by MK 126 (58.72 cm^2). The results are in line with the findings of Subha *et al*. (2010), where they recorded mean leaf area of 54.77 cm^2 in curry leaf. The lowest value was recorded in two accessions MK 117 (29.06 cm^2) followed by MK 122 (29.14 cm^2). Leaf area of above 50 cm^2 was observed in seven accessions viz., MK 107, MK 114, MK 118, MK 126, MK 142, MK 160 and MK 161. Suvasini recorded a leaf area of 44.08 cm^2 which is in agreement with findings of Hedge *et al*., (2012).

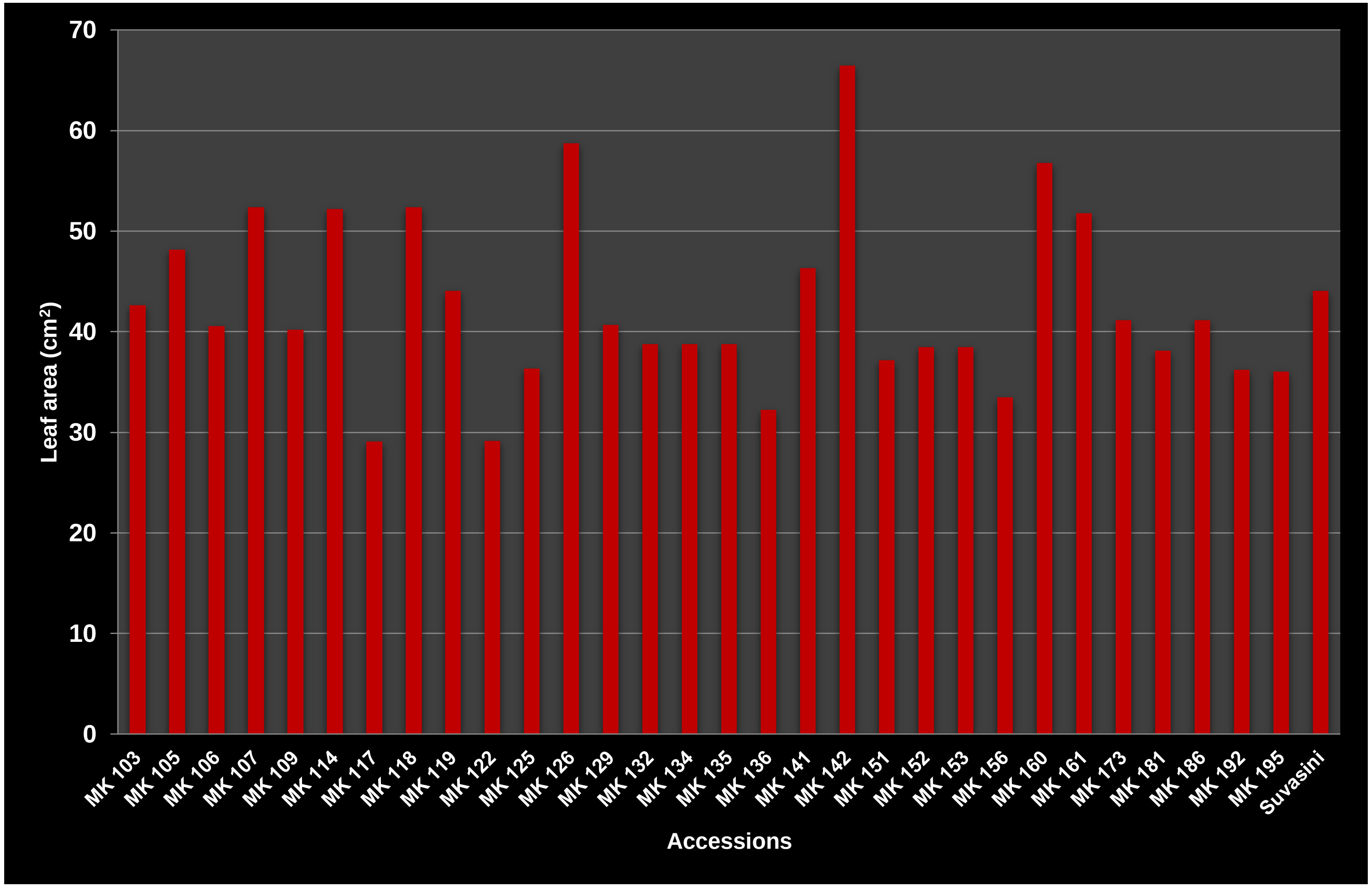


Fig. 2. Leaf area of curry leaf accessions

Incidence of leaf spot disease (*Colletotrichum gleosporoides*) was observed during the onset of rainy season. The percentage of disease incidence varied from 5 % to 30 % among the accessions and it was classified into three classes (Table28).The lowest incidence of less than 5 % was noticed in three accessions namely MK 142, MK 160 and Suvasini. The disease was severe problem in MK 122 and MK 151 (30 %). Rojasra *et al*. (2015) reported incidence of leaf spot disease in curry leaf in Gujarat region during rainy season.

Table 28. Grouping of accessions based on leaf spot disease

Class	No. of accessions	Name of accessions	Frequency (%)
High (>20 %)	13	MK 106, MK 109, MK 117, MK 119, MK 122, MK 134, MK 135, MK 136, MK 151, MK 152, MK 181, MK 192, MK 195	41.93
Medium (10-20 %)	11	MK 103, MK 105, MK 118, MK 125, MK 129, MK 132, MK 153, MK 156, MK 161, MK 173, MK 186	35.48
Low (< 20 %)	7	MK 107, MK 114, MK 126, MK 141, MK 142, MK 160, Suvasini	22.50

5.1.3. Yield

Fresh leaf yield is a complex character that decides the superiority of the accession from the others. In rainy season, fresh leaf yield per plant was higher than summer and winter. This may be due to the favourable weather parameters especially moisture content in root zone throughout the season.

During rainy season, fresh leaf yield per plant ranged from 1.09 kg to 2.98 kg. The accession MK 126 recorded highest fresh leaf yield (2.98 kg) followed by MK 142 (2.82 kg) and MK 160 (2.78 kg) respectively. When compared to dry season (summer) per cent increase in leaf yield of MK 126 in rainy season was found to be 365.62 %. A fresh leaf yield of more than 2 kg was recorded in 46 %

of accessions namely MK 103, MK 105, MK 107, MK 114, MK 117, MK118, MK 122, MK 126, MK 141, MK 142, MK 160, MK 186, MK 192 and Suvasini. The higher yield in rainy season could be due to high rate of nutrient uptake and photosynthesis, physiological activities which might be responsible for the formation of more photosynthates which resulted in higher yield. Similarly a high yield in rainy season was also reported by Hedge *et al*. (2012).

The reduction in fresh leaf yield in winter might be due to the unfavourable environmental condition especially due to low temperature. It may be also due to the assimilation of nutrients for flower formation than leaf production (Agba and Adiaha, 2018). The leaf yield ranged from 0.64 kg to 1.91 kg. Highest leaf yield was recorded in accessions MK 107 (1.91 kg) followed by MK 126 (1.80 kg), MK 118 (1.74 kg) and MK 125 (1.72 kg) respectively. In 73 % of accessions, fresh leaf yield was above 1 kg during winter (Fig.3). The check variety Suvasini recorded a yield of 1.18 kg. Subha *et al*. (2010) evaluated annual growth pattern in curry leaf and reported high fresh leaf yield in monsoon ranging from 530.39 g to 690.52 g than winter season where leaf yield varied from 305.00 g to 450.65 g per plant. Similar findings of low yield were reported by Selvarajan *et al.*(2010) and Devi (2016) in coriander and Lataye *et al*. (2016) in fenugreek during rabi season.

Among the seasons, the lowest fresh leaf yield was recorded in summer. The poor growth of crop due to insufficient moisture and high temperature resulted in lower yield. Considerable variation was observed in fresh leaf yield in summer season ranging from 0.41 kg (MK 156) to 0.85 kg (MK 142). The highest leaf yield was observed in accession MK 142 (0.85 kg) followed by MK 136 (0.82 kg) and MK 106 (0.81 kg) respectively. A fresh leaf yield of 0.76 kg was recorded in Suvasini in summer. Moniruzzaman *et al*. (2014) reported seasonal variation in the leaf yield of coriander and it was lower in summer than the other seasons.

Lalitha *et al*. (1997) evaluated fifteen accessions and reported average fresh leaf yield of curry leaf from four harvests in the range of 0.375 kg to 3.35 kg. Based on total leaf yield, the accessions were characterized into different groups and given in the table 29. In the present investigation, the total fresh leaf yield varied from 2.19 kg to 5.42 kg. Highest fresh leaf yield was recorded in accession MK 126 (5.42 kg). It may be due to highest number of primary (4 numbers), secondary (8 numbers) and tertiary (46 numbers) branches, maximum canopy spread in North-South (4.28 m) and East-West direction (3.76 m), highest leaf length (21.81 cm), number of leaflets per leaf (22 numbers), length and width of leaflet (4.27 cm and 2.01 cm respectively) and leaf area (58.72 cm^2) respectively. The results are in line with Agba and Adiaha (2018) in curry leaf and Augustine, (2016) in coriander where they indicated that high yield of genotypes are due to high value of yield contributing parameters. Fresh leaf yield of more than 5 kg was observed in four accessions namely MK 107 (5.30 kg), MK 126 (5.42 kg), MK 142 (5.35 kg) and MK 160 (5.04 kg) respectively. The lowest leaf yield of less than 3 kg was recorded in eight accessions *viz.*, MK 109, MK 132, MK 134, MK 156, MK 173, MK 181, MK 192 and MK 195. A total fresh leaf yield of 4.20 kg was recorded in Suvasini.

Table 29: Grouping of accessions based on total leaf yield (kg/plant/year)

Class	No. of accessions	Name of accessions	Frequency (%)
High (>5 kg/plant)	4	MK 107, MK 126,MK 142, MK 160	12.90
Medium (3-5 kg/plant)	19	MK 103, MK 105, MK 114, MK 117, MK 118, MK 122, MK 125, MK 129, MK 141, MK 186, MK 106, MK 119, MK 135, MK 136, MK 151, MK 152, MK 153, MK 161,Suvasini	61.29
Low (<3 kg /plant)	8	MK 109, MK 132, MK 134, MK 156, MK 173, ,MK 181, MK 192, MK 195	25.80

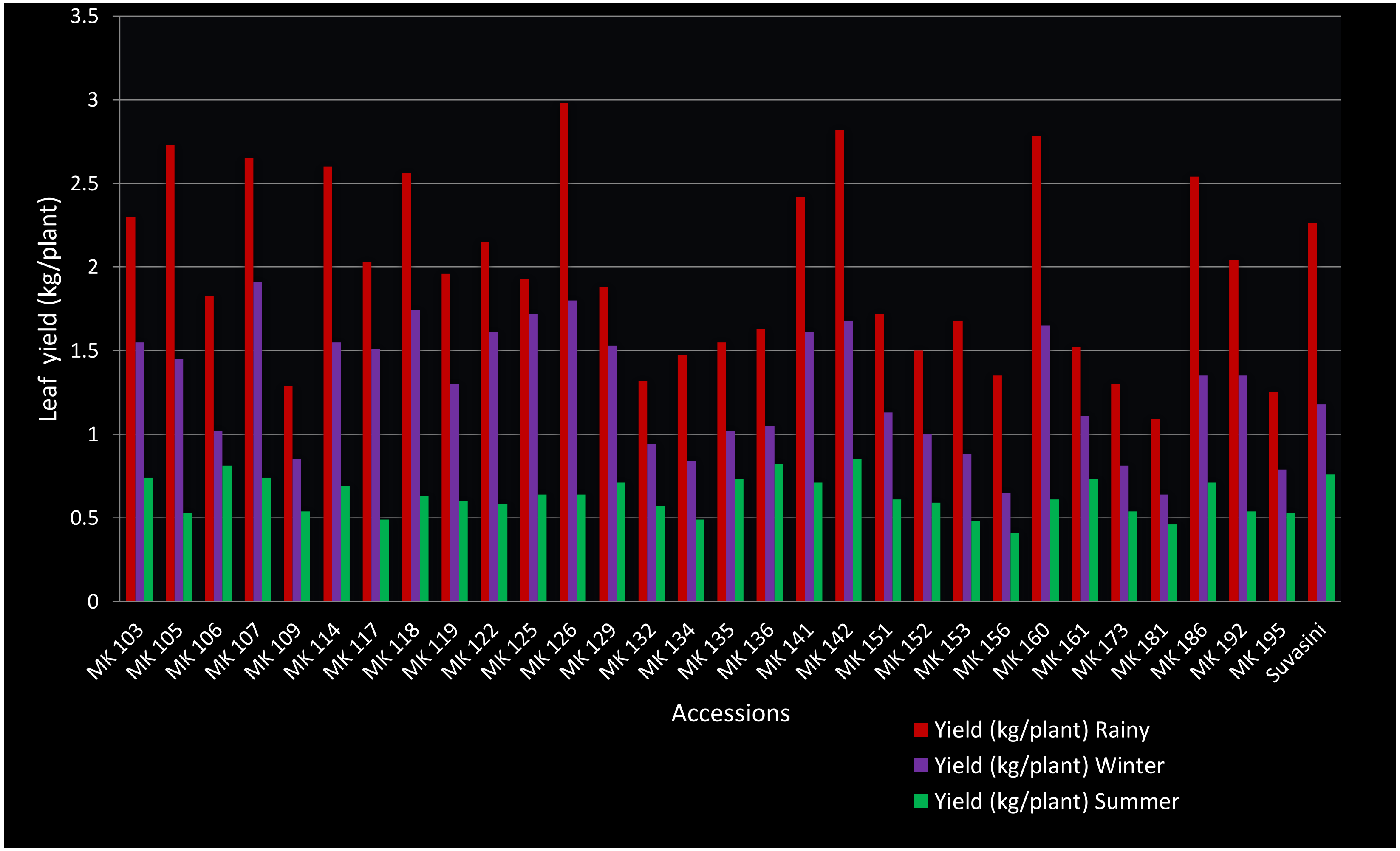


Fig. 3. Fresh leaf yield per plant during three seasons

5.1.4. Sensory evaluation

Curry leaf is a herbal spice which is mainly used for flavouring the food products. Sensory evaluation is an important factor in identifying superior accessions. All the thirty accessions were scored for various sensory traits *viz.*, appearance, colour, flavour, aroma, texture and overall acceptability by a panel of 15 judges based on nine point hedonic scale. Among the accessions, MK 126 recorded high mean rank for appearance (7.46) followed by MK 118 (7.20), MK 160 (7.13) and MK 125 (7.06). For colour, high mean rank value was observed in accession MK 126 (7.60) followed by MK 151 (7.33) and MK 141 (7.13). Suvasini recorded mean rank score of 7.06 and 7.20 for appearance and colour respectively.

The marketability of curry leaf depends on its spicy flavour and aroma. With respect to flavour and aroma, eight accessions were identified as superior with a mean sensory score of above 7 *viz.*, MK 107, MK 118, MK 119, MK 126, MK 141, MK 142, MK 160 and MK 186. The check variety Suvasini recorded a mean rank score of 6.46 and 6.86 for flavour and aroma.

The highest mean rank for texture was recorded in accession MK 126 (7.40) whereas lowest value was recorded in MK 195 (5.53). The check variety Suvasini recorded 6.90 mean rank score for texture. Among the accessions, highest mean rank value for overall acceptability was observed in accession MK 118 (7.40) followed by MK 160 (7.33) whereas check variety recorded 6.93 mean score. Accession MK 126 recorded mean rank score of above 7.00 in all sensory traits and found as superior one in terms of sensory evaluation.

5.1.5. Qualitative characters

Curry leaf accessions were characterized based on qualitative traits (Table 30). No variation was observed with regard to stem colour in the genotypes studied and it was grey with white dots in all the genotype. Considerable variation was observed for midrib colour which varied from green to light red pink colour. Majority of the accessions (76 %) were having green midrib and petiole whereas 24 % possess light red pink. The leaf colour varied considerably from green to dark green. Leaf colour was found dark green in 63 % of accessions and the remaining were green in colour. Only two leaflet shape was recorded in the curry leaf accessions studied, with 19 % of accessions having lanceolate shape and rest of them have obovate shape. Aju *et al*. (2018) conducted macroscopic evaluation of curry leaves and the findings were similar to present study. Majority of leaflets are dark green in colour with lanceolate shape. High variability for morphological characters in curry leaf was observed in the presented study was similar to the earlier report by Lalitha *et al*. (1997).

Table 30: Grouping of accessions based on qualitative characters

Characters	**Class**	**Number of accessions**	**Frequency (%)**
Stem colour	Grey with white dots	30	100.00
Midrib colour	Green	23	76.00
	Light red pink	7	23.00
Petiole colour	Green	23	76.00
	Light red pink	7	23.00
Leaf colour	Dark green	19	63.00
	Green	11	36.00
Leaf shape	Obovate	9	30.00
	Lanceolate	21	70.00

5.2. CORRELATION STUDIES

A correlation study was conducted between major quantitative characters and yield. The characters used for correlation included plant height, plant height at which branching starts, number of primary branches, number of secondary branches, number of tertiary branches, North- South canopy spread, East-West canopy spread, leaf length, number of leaflets per leaf, length of leaflet, width of leaflet, leaf area and yield and were measured at 0.05 and 0.01 level by Pearson correlation coefficient.

Fresh leaf yield was significantly and positively correlated with number of primary (0.712), secondary (0.706) and tertiary branches (0.759), North-South (0.646) and East-West canopy spread (0.469), leaf length (0.777), number of leaflets per leaf (0.540), length (0.632) and width of leaflet (0.629) and leaf area (0.829). Yield is negatively correlated to plant height (0.084) and plant height at which branching starts (0.105). Thus, it can be concluded that higher number of branches, maximum canopy spread in both directions, leaf length, number of leaflets per leaf, length and width of leaflet and leaf area significantly increased the fresh leaf yield. Jagadeeshkanth and Sankaranarayanan (2014) reported the same parameters can contribute to high yield.

Plant height was not significantly correlated to any of the characters. Plant height at which branching starts was positively correlated to plant height. The number of primary branches were positively correlated to plant height at which branching starts while number of secondary branches was significantly and positively correlated to primary branches. Significant and positive correlation was observed with number of tertiary branches and number of primary (0.690) and secondary branches (0.893). Thus, it can be concluded that with increase in number of primary branches, number of secondary and tertiary branches increases.

North-South canopy spread was significantly and positively correlated with primary (0.640), secondary (0.620) and tertiary branches (0.589). Thus, it can be inferred that canopy spread is determined by the number of primary, secondary and tertiary branches. Significant and positive correlation was recorded for East-West canopy spread with number of primary (0.604), secondary (0.562) tertiary branches (0.427) and North-South canopy (0.701).

Leaf length was significantly and positively correlated to number of branches, canopy spread in North-South (0.673) and East-West direction (0.470). Significant and positive correlation was observed for number of leaflets per leaf with leaf length (0.565), number of branches and North-South canopy spread (0.455). Number of leaflets per leaf was positively correlated with East-West canopy spread (0.281). Length of leaflet was significantly and positively correlated to number of branches, canopy spread, leaf length and number of leaflets per leaf. Significant and positive correlation was observed for width of leaflet with length of leaflet, number of leaflets per leaf, leaf length, canopy spread and number of branches. Leaf area was significantly and positively correlated to number of branches, canopy spread, and leaf length, number of leaflets per leaf, length and width of leaflet.

Thus, it can be inferred that fresh leaf yield is significantly and positively correlated to number of primary, secondary and tertiary branches, canopy spread in North- South and East- West direction, leaf length, number of leaflets, length and width of leaflet and leaf area.

5.3. CLUSTER ANALYSIS

Cluster analysis was found to be very useful for finding high yielding curry leaf accessions. On the basis of cluster analysis, all the thirty accessions were grouped into twelve clusters. Highest number of accessions (five accessions) MK 103, MK 105, MK 141, MK 161 and MK 186 were grouped under cluster 1 based on ranking. Cluster 2 and 6 accounted for three accessions each (MK 125, MK 134 and MK 135 in cluster 2 and MK 107, MK 118 and MK 160 in cluster 6). The second largest cluster 3 and cluster 11 includes four accessions (MK 106, MK 119, MK 153 and MK 173 in cluster 3 and cluster 11 includes MK 192, MK 195, MK 151 and MK 181). Cluster 4, 7, 9 and 10 contains only one genotype (MK 136 in cluster 4, MK 114 in cluster 7, MK 132 in cluster 9 and MK 153 in cluster 10). Two accessions each were found in cluster 5 and cluster 12 (MK 126 and MK 142 in cluster 5 and MK 117 and MK 122 in cluster 12). Based on the cluster mean value, it was observed that highest mean plant height was observed in cluster 4 (4.87 m) while lowest in cluster 7 (2.26 m). The plant height at branching starts was low in cluster 9 (32.66 cm) whereas cluster 7 recorded 76.43 cm. The highest number of primary (4 numbers), secondary (8 numbers) and tertiary branches (42 numbers) were observed in cluster 5. The number of secondary (4.50 numbers) and tertiary branches (25.00 numbers) were recorded lowest in cluster 11. The maximum branching spread (mean value) in North-South direction was observed in cluster 7 (4.26 m) and in East-West direction it was observed in cluster 5 (4.27 m).

The mean value for leaf length ranged from 15.73 cm (cluster 4) to 21.61 cm (cluster 5). The number of leaflets per leaf (mean value) ranged from 16 to 22 with highest value recorded in cluster 5 (22). Cluster 5 recorded highest value (mean) for length (4.41 cm) and width of leaflet (1.89 cm). The lowest mean value for length of leaflet recorded in cluster 3 (3.15 cm) whereas cluster 2 recorded lowest width value (1.30 cm). The mean value for leaf area ranged from 29.10 cm^2 to 62.59 cm^2 with highest value recorded in cluster 5. For fresh leaf yield, the mean value ranged from 2.60 kg to 5.38 kg with maximum yield recorded in cluster 5 (5.38 kg) followed by cluster 6 (5.08 kg) and cluster 7 (4.84 kg). The lowest yield (mean) was recorded in cluster 11 (2.60 kg) followed by cluster 9 (2.82 kg). The accession MK 126 recorded highest fresh leaf yield of 5.42 kg followed by MK 142 (5.35 kg).

Based on cluster analysis, thirty accessions of curry leaf were grouped into 12 clusters. Among them four, clusters (clusters 1, 5, 6 and 7) were found superior in terms of yield and sensory scores and from those four clusters, ten superior accessions were selected. These ten accessions include two from cluster 5 (MK 126, MK 142), three from cluster 6 (MK 107, MK 118 and MK 160), one from cluster 7 (MK 114) and four from cluster 1 (MK 103, MK 105, MK 141 and MK 186).

5.4. BIOCHEMICAL CHARACTERS

Biochemical characterization was done on ten accessions selected based on cluster analysis along with check variety Suvasini in both fresh and dry leaf sample. Wide range of variation was observed in biochemical content of fresh and dry samples.

Essential oil in curry leaf is responsible for the characteristic aroma and flavour of leaves and it showed variability in fresh and dry leaves. The dry leaves showed higher percentage of essential oil than fresh leaves. In the present study, the essential oil recovery of fresh leaves ranged from 0.370 % (MK 103) to 0.50 % (MK 186) whereas in dry leaves it varied from 0.71 % (MK 103) to 1.09 % (MK 186). The result of present study is similar to findings of Ramalakshmi *et al*. (2000) in which they could obtain higher oil recovery in shade dried leaf sample. The values reported in their study were 0.66 % for fresh leaves and 1.0 % for shade dried leaves.

Highest essential oil content in fresh leaf was recorded in accession MK 186 (0.50 %) which was on par with MK 141 (0.49 %), MK 142 (0.48 %) and MK 160 (0.48 %). Chowdhury *et al*. (2008) also reported 0.5 % essential oil yield from fresh leaves in his study. In dry leaves, accession MK 142 and MK 186 showed highest essential oil content (1.07 to 1.09 %). Verma and Rana (2011) reported variation in leaf oil recovery in samples collected from 58 populations across India and it ranged from 0.14 to 0.80 % in shade dried leaf samples. Similarly, Walde *et al*. (2005) reported essential oil yield of 0.83 % on dry weight basis. The check variety Suvasini yielded 0.44 % essential oil in fresh and 0.92 % in dry leaves which is in agreement with the study conducted by Madalageri *et al.* (1997) in Suvasini. Sakhale *et al.*(2017) reported that the increase or decrease in essential oil content during drying depends on plant species, time of collection and drying method.

Crude fibre refers to the structural carbohydrates made of cellulose. hemicelluloses and lignin in the plant cell wall and it is a form of dietary fibre. Dietary fibre lowers cholesterol level, risk of coronary heart disease, diabetes and cancer. Considerable variability was observed in crude fibre content of fresh and dry leaves (Fig. 4). In fresh leaves crude fibre content ranged from 5.79 % (MK 105) to 8.09% (MK 186) whereas in dry leaves values ranged from 9.74 % (MK 105) to 11.65 % (MK 186). Similar result was reported by Igara *et al.* (2016) where crude fibre content was recorded as 6.30% in fresh leaves. The lowest crude fibre content was recorded by MK 105 (5.79 %) followed by MK 160 (5.94 %). In dry leaves the highest crude fibre content was recorded in accession MK 186 (11.65 %), MK 118 (11.53 %) and MK 114 (11.07 %) whereas lowest in MK 105 (9.74 %) followed by MK 160 (9.98 %). The results are in line with findings of Zhang *et al*. (2011) where crude fibre content in dry leaves recorded as 11.80 %. The check variety Suvasini recorded fibre content of 6.08 % in fresh leaves and 10.29% in dry leaves.

Carbohydrates provide building blocks for plant structural components and deliver energy for plant growth. Total carbohydrate in fresh and dry leaves of curry leaf ranged from 14.45 % (MK 103) to 15.99 % (MK 126) and 17.51 % (MK 103) to 19.74 % (MK 126) respectively. In fresh leaves, highest total carbohydrate was observed in accession MK 126 (15.99 %) followed by MK 142 (15.66 %) whereas MK 103 recorded lowest (14.45 %). The carbohydrate content of less than 15 % was observed in three accessions viz., MK 103 (14.45 %), MK 107 (14.89 %) and MK 186 (14.77 %). Similar result was reported by Igara *et al*. (2016) where 15.6 % carbohydrate in fresh curry leaf sample was recorded. Accession MK 126 (19.74 %) recorded highest carbohydrate content in dry leaves while MK 103 recorded the lowest value (17.51 %). The carbohydrate content in Suvasini varied from 15.55 % in fresh leaves and 18.82 % in dry leaves. Similar trend of higher amount of carbohydrate content in dry leaves than fresh leaves was reported by Snehal and Madhuhar, (2012) in stevia leaves.

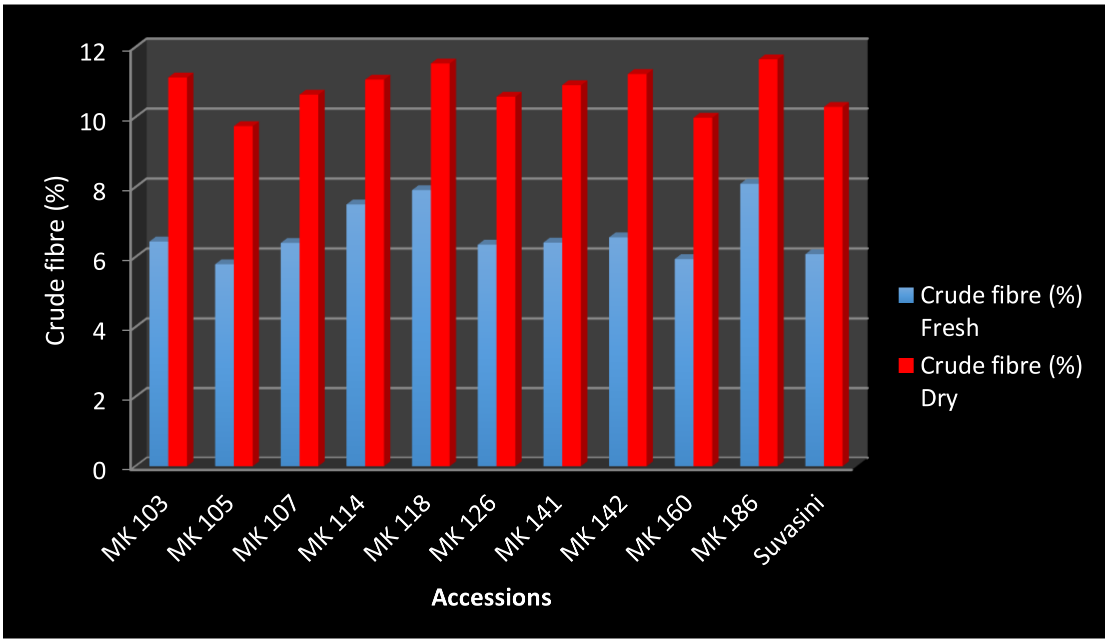


Fig. 4. Crude fibre content of curry leaf accessions

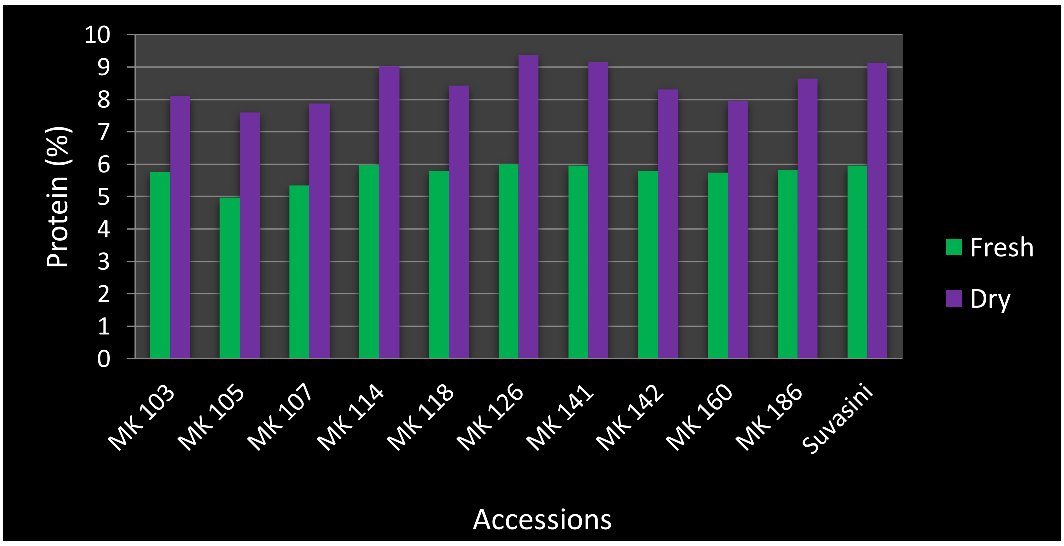


Fig. 5. Protein content of curry leaf accessions

The proteins in the leaf can make fair contributions to protein diet as proteins are involved in formation of hormones, enzymes and structural membranes. Remarkable difference was observed in protein content ranging from 4.96 to 6.00 % in fresh leaves and 7.59 to 9.37 % in dry leaves (Fig.5). The results are in agreement with findings of Gul *et al*. (2012) where 5.65 % of protein in fresh leaves was reported. The highest protein content was observed in MK 126 (6.00 %) followed by MK 114 (5.88 %), Suvasini (5.86 %) and MK 141 (5.85 %) in fresh leaves. Zhang *et al.* (2011) reported 8.38 to 11.8 % protein content in dry leaf. In the present study, accession MK 126 recorded highest protein content in dry leaves (9.37 %) followed by MK 114 (9.22 %), Suvasini (9.21 %) and MK 141 (9.15 %) whereas MK 103 recorded lowest value (7.59 %). Higher amount of protein in dry leaves than that of fresh leaves may be due to reduction in moisture content and net increase in dry mass.

Fresh leaves exhibited maximum chlorophyll content and up on drying chlorophyll content get reduced. Similar result was reported by Mahanom *et al.* (1999). Fresh leaves recorded maximum chlorophyll content and up on drying content decreased considerably. The content of chlorophyll 'a' in fresh leaves varied considerably from 0.77 mg to 1.15 mg 100 g^{-1}. Maximum chlorophyll content was recorded in accession MK 142 (1.15 mg 100g^{-1}) followed by MK 141 (1.13 mg 100g^{-1}) and MK 126 (1.12 mg 100g^{-1}) whereas MK 105 recorded the lowest content (0.77 mg 100g^{-1}). In dry leaves MK 142 recorded highest content (0.81 mg 100g^{-1}) whereas lowest was recorded by MK 105 (0.60 mg 100g^{-1}). Suvasini recorded a chlorophyll content of 1.10 mg in fresh and 0.69 mg 100 g^{-1} in dry leaves respectively

Considerable variation was noticed with chlorophyll 'b' content. The chlorophyll 'b' content ranged from 0.17 mg (MK 105) to 0.25 mg 100 g^{-1}(MK 103) in fresh leaves. In dry leaves, accession MK 142 exhibited maximum chlorophyll ‘b' content (0.12 mg 100 g^{-1}) whereas MK 105 recorded the minimum content (0.01 mg 100g^{-1}). The check variety Suvasini recorded 0.23 mg and 0.07 mg 100 g^{-1} in fresh and dry leaves respectively.

The total chlorophyll content ranged from 0.97 mg to 1.47 mg 100 g^{-1} in fresh leaves and 0.72 mg to 0.85 mg 100 g^{-1}in dry leaves (Fig. 6). Highest chlorophyll content was recorded in MK 103 (1.47 mg 100 g^{-1}) followed by MK 141 (1.38 mg 100 g^{-1}) whereas MK 105 recorded the lowest value (0.97 mg 100 g^{-1}) in fresh leaves. Lalitha *et al.* (1997) reported a total chlorophyll content of 0.177 mg g^{-1}' in fresh curry leaves. Accession MK 103 (0.85 mg 100 g^{-1}) recorded maximum total chlorophyll content and minimum in MK 105 (0.72 mg 100g^{-1}) in dry leaves. Total chlorophyll content in Suvasini varied from 1.36 mg in fresh and 0.80 mg 100 g^{-1}in dry leaves

Phenolic compounds are phytochemicals, with antioxidant and antimicrobial properties, thereby prevents inflammation allergies and degenerative diseases. The highest phenol content was recorded in dry leaves than fresh leaves ranging from 0.40 % (MK 114) to 0.58 % (MK 105). The highest content of phenol was recorded by accession MK 105 in both fresh (0,31 %) and dry leaves (0.58 %) whereas lowest in MK 114 in fresh (0.20 %) and dry leaves (0.40 %) respectively (Fig. 7). Gul *et al.* (2012) and Nguyen *et al.* (2012) reported 0.23 to 0.31 % content of phenol in fresh leaves which is similar to the present result. Suvasini recorded a phenol content of 0.27% in fresh leaves

Curry leaf posses strong antioxidant properties and enhance the metabolism of body by reducing human stress and their by decreasing cell metabolism. Antioxidant activity of *Murraya koenigii* is due to the high phenol content (Sophiyamol *et al.*, 2017). In the present study, fresh leaves recorded maximum antioxidant capacity ranging from 3.05 to 3.44 mg AAE g^{-1} (Fig.8).The highest antioxidant capacity value was recorded by accession MK 102 and MK 105 (3.44 to 3.45 mg AAE g^{-1}) while the minimum content was recorded by MK 186 (2.86 mg AAE g^{-1}) followed by MK 141 (3.06 mg AAE g^{-1}). The antioxidant capacity reduced during drying and it ranged from 1.53 to 2.16 mg AAE g^{-1}. Accession MK 105 recorded maximum antioxidant capacity (2.16 mg AAE g^{-1}) and MK 186 recorded minimum (1.53 mg AAE g^{-1}).

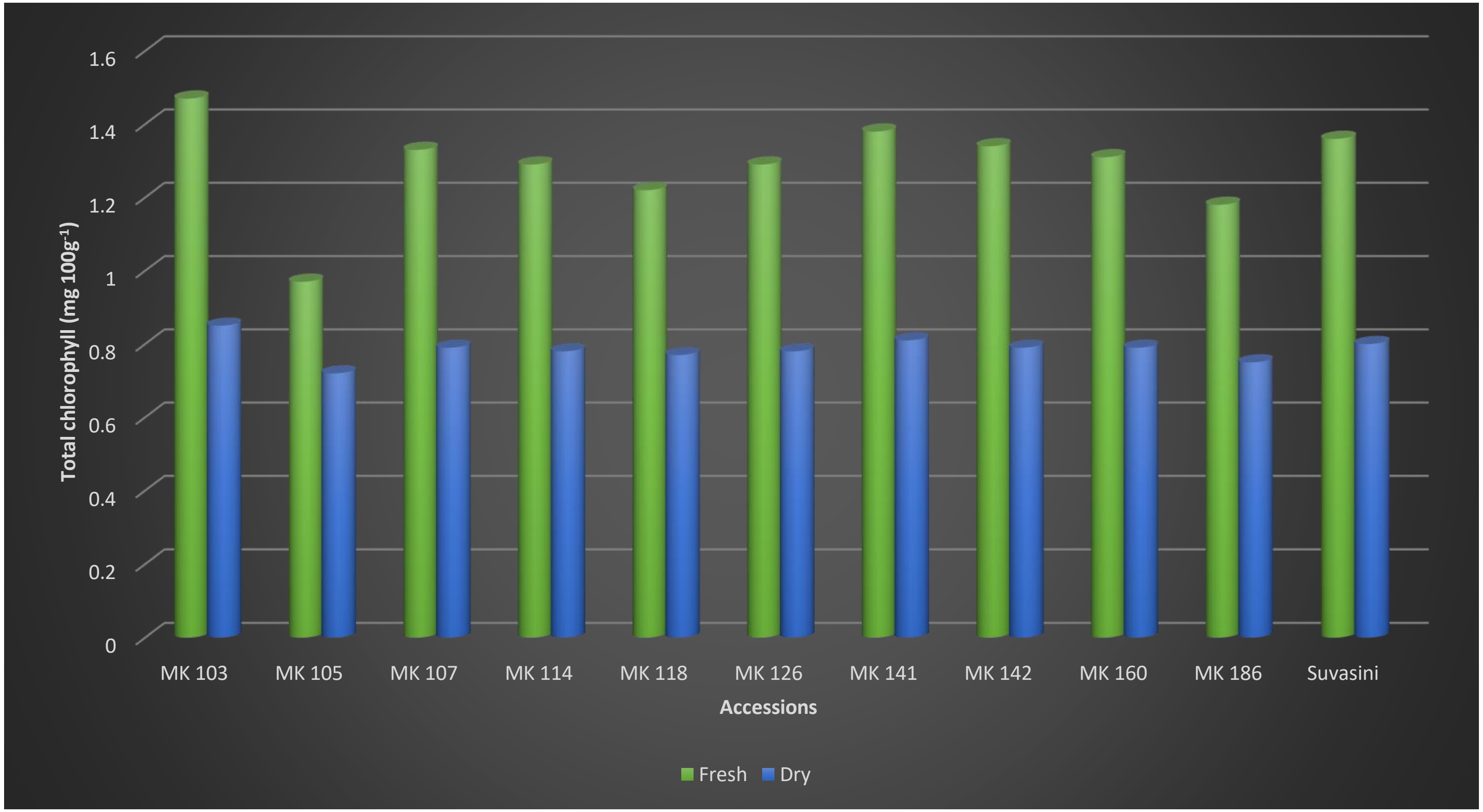


Fig. 6. Total chlorophyll content of curry leaf accessions

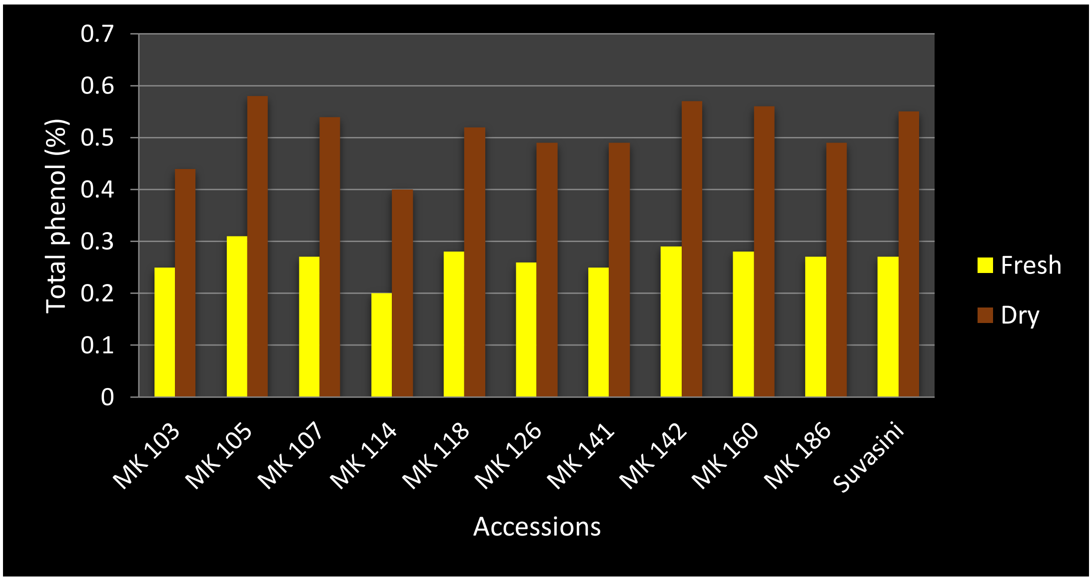


Fig. 7. Total phenol content of curry leaf accessions

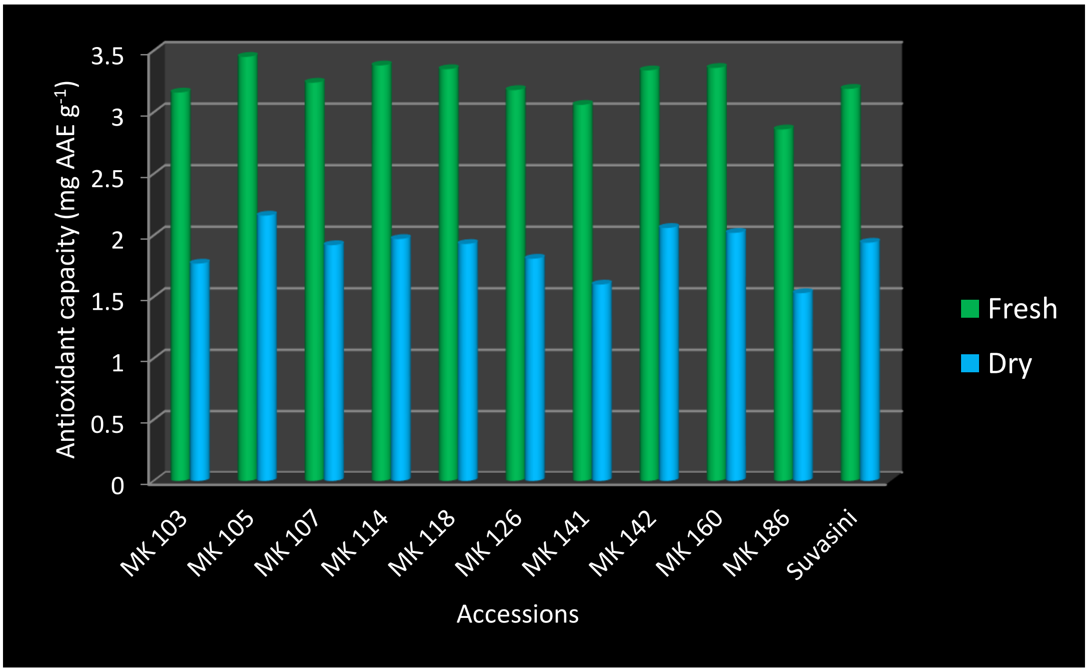


Fig. 8. Antioxidant activity of curry leaf accessions

Rao *et al.* (2011) reported similar findings where antioxidant capacity value varied from 5.10 mg AAE g^{-1} in fresh and 3.01 mg AAE g^{-1} in dry curry leaves.

Vitamin A helps to provide good vision and healthy immune system. It we fights cancer by inhibiting the production of DNA in cancerous cells. Beta-carotene is an antioxidant which acts as a precursor of vitamin A (retinol). The loss of beta carotene up on drying was reported by Kaur *et al.* (2008) in mint and Vyankatrao *et al*. (2014) in leafy vegetables. The beta carotene content of fresh leaves ranged from 7.85 mg to 8.81 mg 100 g^{-1} (Fig. 9). Beta carotene content of curry leaves was recorded as 9.32 mg 100 g^{-1} of edible portion on fresh weight basis by Tee and Lim (1991). The highest beta carotene content in fresh leaves were recorded in three accessions MK 186. MK 103 and MK 142 (8.80 to 8.81 mg 100 g^{-1}) whereas Suvasini recorded 8.24 mg 100g^{-1}. Similar finding was reported by Raju *et al.* (2017) where 8.95 mg/100 g^{-1} beta carotene on fresh weight basis was recorded. The minimum beta carotene content was recorded in accession MK 118 (7.85 mg 100 g^{-1}') which was on par with MK 114 (7.89 mg 100 g^{-1}) and MK 126 (7.91 mg 100g^{-1}). The shade dried curry leaves contain 5.49 mg of beta carotene per 100 g dry weight (Palaniswamy *et al.*, 2003). The results are in agreement with present study, the beta carotene content ranged from 4.33 mg to 6.46 mg 100g^{-1}. The maximum beta carotene content was recorded by MK 103 (6.46 mg 100g^{-1}) whereas Suvasini recorded 5.93 mg 100g^{-1}.

The maximum driage was observed in accession MK 107 (66.30%) which was on par with MK 105 (65.93 %) whereas Suvasini recorded 56.44 % driage (Fig.10). The lowest driage was observed in MK 186 (51.63%) followed by MK 142 (52.16%). Sakhale *et al*. (2017) reported 44.4 % yield of shade dried (9 days) curry leaves.

From the biochemical characterization it was concluded that, accession MK 186 recorded highest oil content of 1.09 % and maximum content of crude fibre (> 11.61 %) was observed in two accessions viz., MK 118 and MK 186. Accession MK 126 recorded highest content of total carbohydrate (15.99 %) and

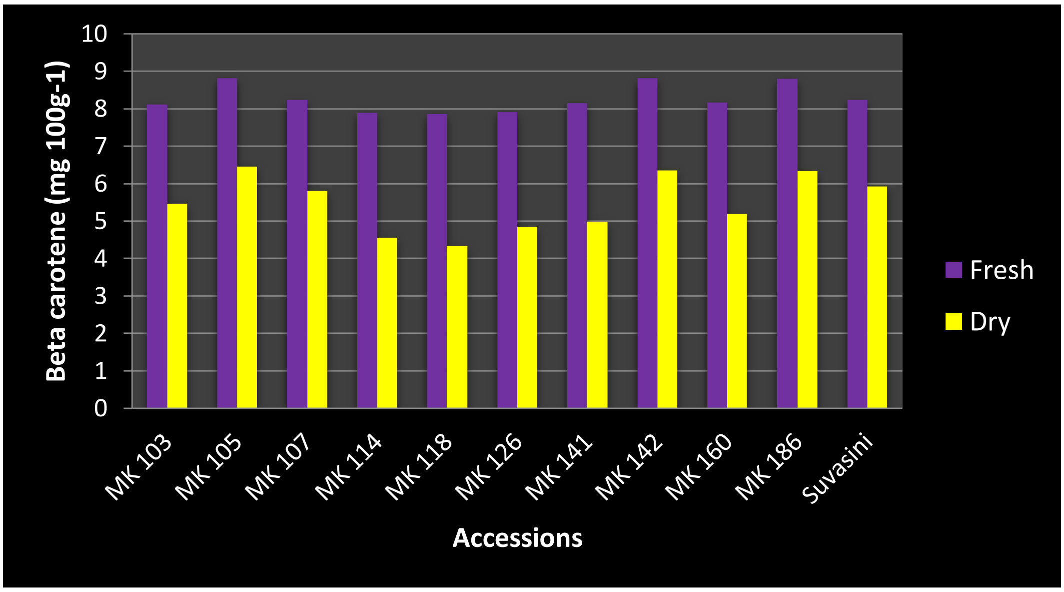


Fig. 9. Beta carotene content of curry leaf accessions

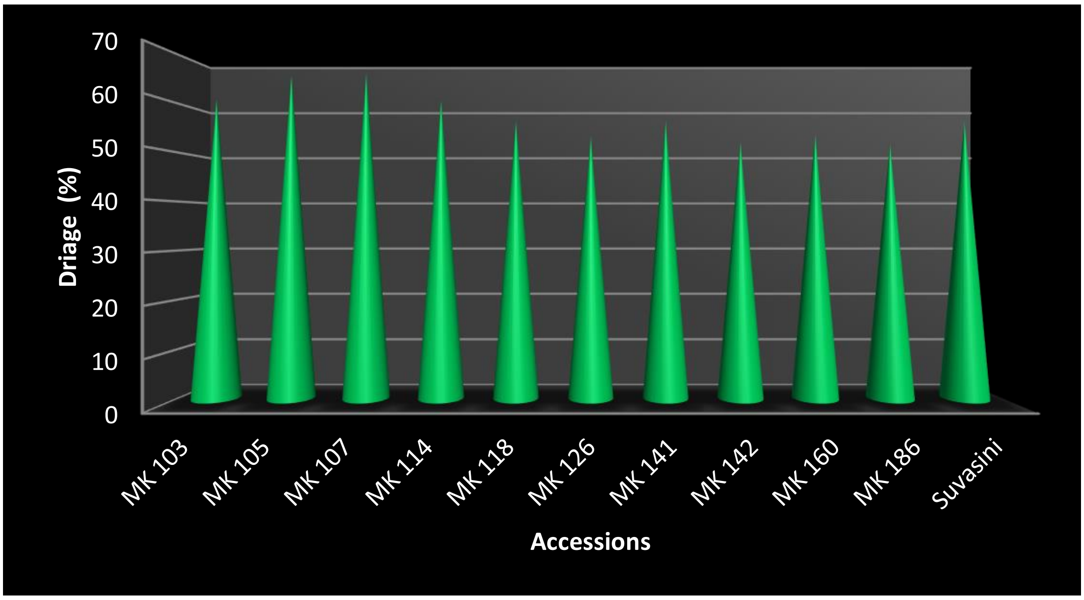


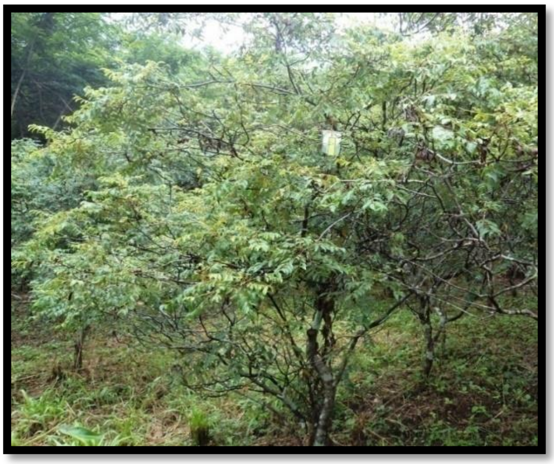
Fig. 10. Driage of curry leaf accessions

protein (6.00 %). The highest content of total phenol (0.31 %) and antioxidant activity (3.45 mg AAE g^{-1}) was recorded in MK 105. The higher beta carotene content (> 8.80 mg $100g^{-1}$) was recorded in three accessions namely MK 105, MK 142 and MK 186.

Based on yield and quality parameters two promising types were identified *viz.*, MK 142 and MK 126. Both of them recorded higher leaf yield of more than 5 kg/plant/year. Accession MK 142 recorded highest beta carotene content while MK 126 recorded highest content of carbohydrate and protein (Plate 16).

Accessions MK 105 and MK 186 found to be the next best promising types in terms of yield and quality. Both the accessions recorded total leaf yield of more than 4.60 kg/plant/year and found to be rich source of beta carotene. Besides this, MK 105 recorded highest content of total phenol and antioxidant activity while MK 186 recorded highest oil content and crude fibre content.

MK 126



MK 142

MK 105

MK 186

Plate 16. Promising curry leaf accessions

5.3. VEGETATIVE PROPAGATION THROUGH STEM CUTTINGS

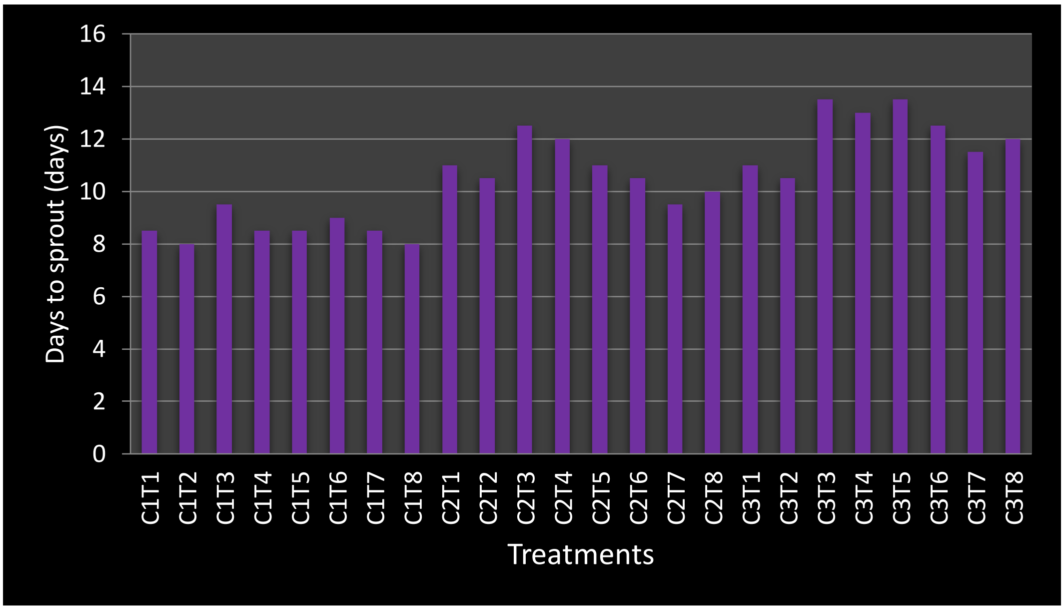
The success of rooting in cuttings depends upon the species and cultivar, condition of cutting wood, type of cuttings (hardwood, semihardwood cuttings and softwood), season, amount of internal auxin and many other factors (Hartmann *et al*. 2010). Auxin is essential for rooting commencement. Cuttings are failed to root initiation when internal auxin amount is not enough to accelerate. Hence, external auxin is widely used on the stem cuttings for accelerating the formation of adventitious roots. The greater survivability of IBA over NAA is due to its greater low mobility, greater chemical stability and slow degradation.

In the present study, curry leaf was found to be a difficult to root species, mainly due to lack of activity of one or more of the internal co-factors necessary for root formation. The propagation study was conducted in three different seasons *viz.*, rainy, winter and summer using growth regulators IBA, NAA and their combinations in three types of stem cuttings (softwood, semihardwood and hardwood).

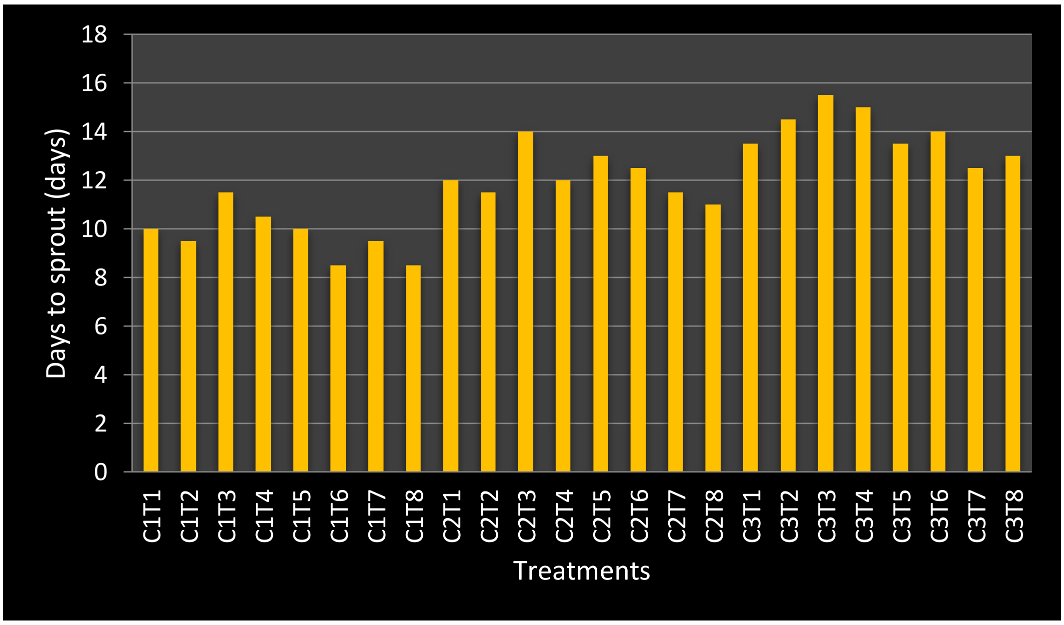
5.3.1. Days to sprout initiation

Number of days taken for the appearance of first green coloured sprout on the stem cutting was recorded. Irrespective of season of propagation and auxin treatment, there was significant difference in time taken for sprouting in softwood, semihardwood and hardwood cuttings (Fig. 11). The untreated cuttings failed to produce sprouts in all treatment combinations and seasons. Even though, time taken for sprouting was found to be non significant, the lowest value was recorded for softwood cuttings when compared to semihardwood and hardwood cuttings. It may be due to the delicate and leafy nature of softwood cuttings over other two cuttings.

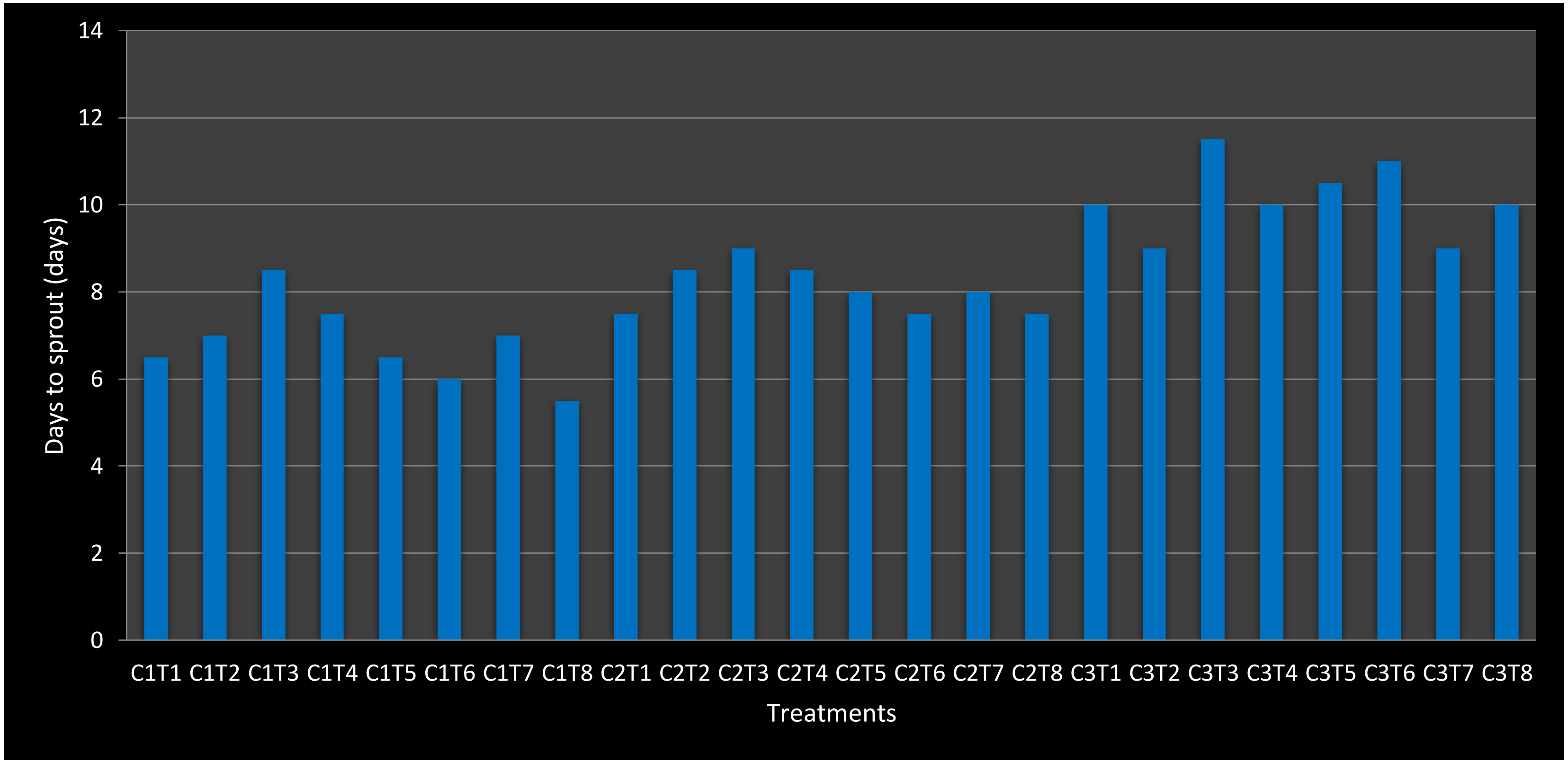
Among the three seasons, days to sprout initiation was recorded lowest in rainy season (6.81 days), followed by winter (9.12 days) and summer (9.68 days) in softwood cuttings. Singh and Srivastava, (1962) reported that, time taken for



Winter season



Summer season



Rainy season

Fig. 11. Days to sprout during winter, summer and rainy seasons

sprouting in summer increases due to the rise in temperature and dropping of humidity.

With respect to auxin formulations, 1000 ppm IBA +2000 ppm NAA (T_6) and 2000 ppm IBA +2000 ppm NAA (T_8) recorded minimum days for sprouting in rainy (7.55 to 7.66 days) and summer months (10.50 days) while in winter 2000 ppm IBA +1000 ppm NAA recorded minimum days (9.83 days). In case of interaction effect, softwood cuttings treated with 2000 ppm IBA +2000 ppm NAA (C_1T_8) reported minimum days for sprout emergence (5.50 days in rainy, 8.0 days in winter and 8.50 days in summer). A similar finding was reported by Ganjure *et al*. (2012) in chrysanthemum where cuttings treated with 2000 ppm IBA recorded minimum days for sprouting (8.60 days).

Percentage of sprouting

Percentage of sprouting significantly varied in all seasons and treatment combination. Hardwood cuttings and 2000ppm IBA +2000ppm NAA recorded maximum percentage of sprouting while softwood cuttings and 1000ppm NAA recorded lowest sprouting in three seasons. The better number of sprouts per cutting with auxin treatment may be due to the better absorption and translocation of nutrients. Maximum sprouting was observed in rainy season (46.75 %) and minimum in summer (36.40 %).

In rainy season, the maximum sprouting of 38.70 % was recorded when cuttings were treated with 2000ppm IBA + 2000ppm NAA (T_8) while 1000ppm NAA (T_3) recorded minimum (19.12 %). With respect to the effect of cutting type was concerned, maximum sprouting (35.62 %) was recorded by hardwood cuttings (C_3)while the lowest (22.37 %) with softwood cuttings (C_1).In terms of interaction effect, maximum sprouting was recorded in C_3T_8 (hardwood cuttings × 2000ppm IBA + 2000ppm NAA) which was on par with C_3T_7 (hardwood cuttings × 2000ppm IBA + 1000ppm NAA) and C_2T_8 (semihardwood cuttings × 2000ppm IBA + 2000ppm NAA) where sprouting ranged from 45.30 to 46.75 %. The lowest sprouting of 13.35 % was recorded in C_1T_3 (softwood cuttings × 1000ppm NAA).

The maximum sprouting of 33.25 % was recorded in winter season, when cuttings were treated with 2000ppm IBA + 2000ppm NAA (T_8) whereas 1000ppm NAA (T_3) recorded lowest value (20.26 %). Among the different types of cuttings, maximum sprouting (34.06 %) was recorded by hardwood cuttings (C_3) while the lowest sprouting of 18.37 % in softwood cuttings (C_1). The interaction effect, C_3T_8 (hardwood cuttings × 2000ppm IBA + 2000ppm NAA) and C_3T_6 (hardwood cuttings × 1000ppm IBA + 2000ppm NAA) recorded maximum sprouting of 43.20 % and 40.45 % respectively. The lowest sprouting of 16.00 % was recorded in C_1T_4(softwood cuttings × 2000ppm NAA) followed by C_1T_5 (16.30 %) and C_2T_3 (16.75 %) during winter. Similar findings were reported by Rafael (2006) where maximum number of sprouts per cutting was observed when hardwood cuttings of fig were treated with 2000ppm IBA.

The lowest sprouting success was recorded in summer due to unfavourable weather parameters especially high temperature. The maximum sprouting (29.28 %) was recorded when cuttings were treated with 2000ppm IBA + 2000ppm NAA (T_8) and the lowest sprouting (18.33 %) in by 1000ppm NAA (T_3). Among the different types of cuttings, maximum sprouting (29.20 %) was recorded by hardwood cuttings (C_3) while the lowest sprouting (19.01 %) was observed with softwood cuttings (C_1). The interaction effect of C_3T_8 (hardwood cuttings × 2000ppm IBA + 2000ppm NAA) resulted in maximum sprouting of 36.40 % which was on par with C_3T_6 (hardwood cuttings × 1000ppm IBA + 2000ppm NAA) in which sprouting of 34.25% was recorded. The lowest sprouting of 13.95 % was recorded in C_1T_3 (softwood cuttings × 1000ppm NAA).

Singh *et al*. (2013) reported maximum number of sprouts (17.77) and sprouted cuttings (6.29) when treated with 2000ppm of IBA in lemon. Similarly, highest sprouting, rooting and maximum number of sprouts in hardwood cuttings of pomegranate treated with combination of IBA+NAA (1500 ppm) was reported by Sharma *et al.* (2009).

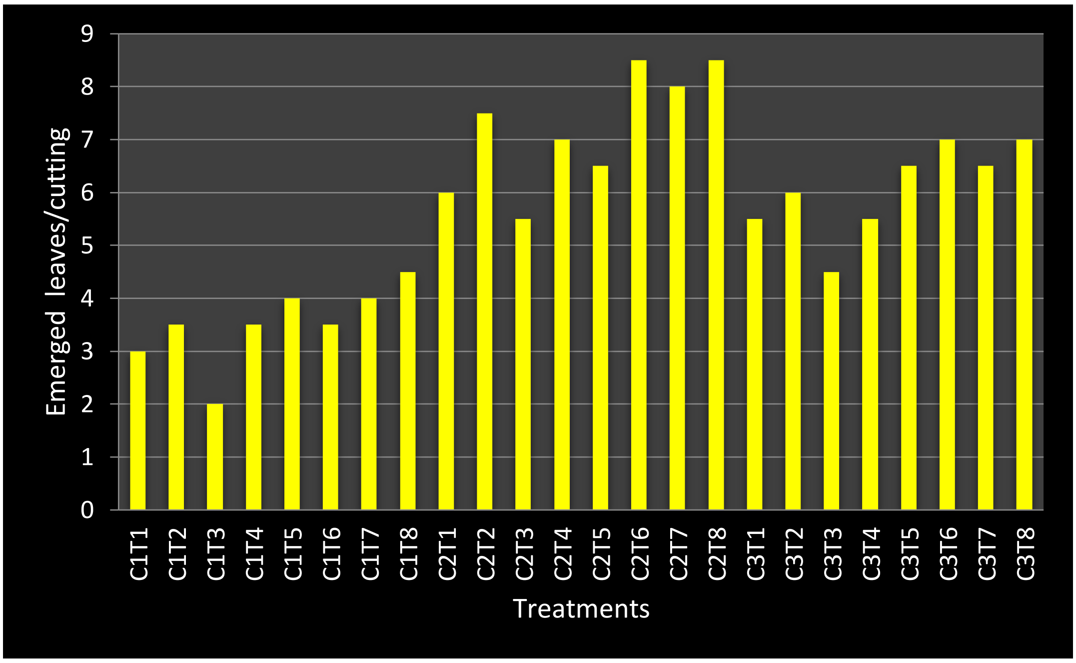
Gautam *et al*. (2010) reported that poor growth of cuttings during summer and winter months may be due to low activity of cambium and its proliferation in unfavourable environmental conditions.

Number of emerged leaves

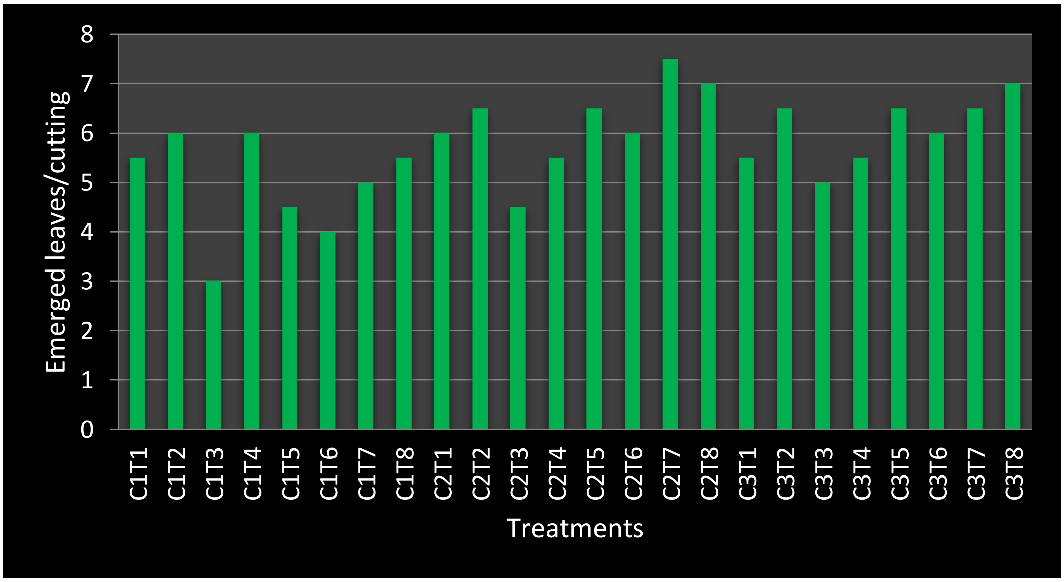
Maximum number of leaves per cutting was observed in winter season than rainy season. In summer season, the sprouted cuttings were failed to produce leaves and cuttings showed decaying and drying (Fig.12).

In rainy season, auxin formulation T_2 (2000 ppm IBA) recorded maximum number of leaves (6.83) followed by T_6 (1000 ppm IBA + 2000 ppm NAA) and T_8 (2000 ppm IBA + 2000 ppm NAA) where number of leaves per cutting varied from 6.50 to 6.66. The lowest number of leaves (5.33) was recorded by T_3 (1000 ppm NAA). In case of effect of cutting types, semihardwood cuttings (C_2) recorded maximum number of leaves (7.12) while softwood (C_1) recorded the lowest value (4.68). Similar result was reported by Deb *et al*. (2009) in lemon where maximum number of leaves per cutting (34.30) was obtained when treated with 2000 ppm IBA. Though the interaction was non significant, C_2T_7 (semihardwood cuttings × 2000 ppm IBA + 1000 ppm NAA) recorded maximum number of leaves (7.50) and C_1T_3 (softwoodwood cuttings × 1000 ppm NAA) recorded minimum number of leaves (3.00). The results are in line with the findings of Kumar and Kausik (1995) where maximum number of leaves per cutting was observed when hardwood cuttings of lemon cv. Baramasi when treated with 2000 ppm IBA during July month.

The auxin formulations T_6 (1000 ppm IBA +2000 ppm NAA) and T_7 (2000 ppm IBA +1000 ppm NAA) recorded maximum number of leaves (6.33) whereas T_5 (1000 ppm IBA +1000 ppm NAA) recorded the lowest value (5.23) in winter. In terms of cutting types, semihardwood cuttings (C_2) recorded maximum number of leaves (6.87) while softwood (C_1) recorded the lowest value (3.31). The interaction effect C_2T_6 (semihardwood cuttings × 1000 ppm IBA + 2000 ppm NAA) and C_2T_8 (semihardwood cuttings × 2000 ppm IBA + 2000 ppm NAA) recorded maximum number of leaves (8.50) whereas the minimum number of leaves (2.00) was observed in C_1T_3 (softwoodwood cuttings × 1000 ppm NAA) in winter.



Winter season



Rainy season

Fig.12. Number of emerged leaves per cutting during winter and rainy season

Leaf and root characters

The observations on leaf characters and rooting could not be recorded as none of the cuttings under any treatment showed rooting except hardwood cutting treated 2000ppm IBA + 2000ppm NAA in rainy season. Similarly, Phalsa cuttings recorded maximum rooting (68.33 %) in rainy season (Jhadhav and Kumar, 2007). The percentage of establishment was recorded as 3.3 %. The cuttings recorded mean leaf length of 11.4 cm and width of 1.45 cm after 90 days of planting. With regard to root characters, the survived cutting recorded 6.00 numbers of primary roots and 17.00 numbers of secondary roots. The mean length of primary and secondary root was recorded as 5.32 cm and 3.7 cm respectively. The fresh weight of root was obtained as 1.12 g. Similarly, Vinaykumar*et al*. (2008) recorded maximum rooting with combination of 2000ppm of IBA+NAA in *Thumbergia grandiflora* cuttings (63.73 %).

Mohanalakshmi *et al*. (2000) reported the increased survival rate of hardwood cuttings of curry leaf with increased concentration of IBA. Ranganathappa *et al.* (2002) recorded highest rooting (37.50 %) in hardwood cuttings of curry leaf. Similarly, Swetha (2005) revealed that IBA at 2000ppm concentration was found better for root induction in Indian lavender .With respect to the seasonal effect, Hartmann *et al*. (2010) reported that cuttings taken during summer fail to produce roots in *Rubusideaus*. Whereas Husen and Pal (2007) recorded more callusing and rooting in Tectona cuttings planted during June and August. Sreeja (1999) reported similar result in Allspice cuttings under Kerala conditions. The high amount of tannins and phenolic compounds present in the curry leaf stem may hinder root formation. Softwood cuttings are rich in phenols whereas hardwood cuttings are rich in starch (6.83%) which showed significant positive correlation with rooting (Reddy *et al*. 1998).Similar findings were reported by Rema and Krishnamoorthy (1994) in Clove where hardwood, semihardwood and softwood cuttings from etiolated and non etiolated shoots treated with IBA failed to develop adventitious roots in Kerala conditions.

Even though success of vegetative propagation through stem cuttings was found to be very low, hardwood cutting treated 2000ppm IBA + 2000ppm NAA in rainy season showed an establishment rate of 3.3 %. Since curry leaf is a difficult to root plant, it took 3 months for root initiation. The stem cuttings fail to root in all treatments during winter and summer seasons. As far as the type of cuttings concerned, hardwood cuttings performed well in all treatments. The emergence of sprouts and leaves in the cuttings may be due to presence of inactive buds which get activated by the application of growth regulators. Intensive research is needed in the vegetative propagation of curry leaf through stem cuttings under Kerala conditions.

Summary

6.SUMMARY

The present investigation on "Evaluation of curry leaf (*Murraya koenigii* L.) accessions for yield and quality" was carried out at the Department of Plantation Crops and Spices, in College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during 2016-18. The summary of the study are presented in this chapter.

- The morphological characters and biochemical characters depend highly on the accessions included in the study.
- In the present study, considerable variation was observed among the thirty accessions along with the check 'Suvasini' for plant and leaf characters (quantitative and qualitative) *viz.*. plant height (m), plant height at branching starts (cm), number of primary, secondary and tertiary branches, canopy spread in North-South and East-West direction (m), leaf length (cm), number of leaflets per leaf, length and width of leaflets (cm), leaf area (cm^2), leaf yield (kg/plant/year), incidence of pest and disease (%) and aroma and flavour.
- Among the thirty accessions, MK 103 was found as the tallest with maximum plant height (5.21 m) whereas MK 107 (2.23 m) followed by MK 126 (2.33m) were found as dwarf.
- The lowest branching height is an ideal character of genotype. In the present study, branching height was the lowest in MK 125 (31.25 cm) and 32.25 % accessions recorded lowest value of < 40 cm. Accession MK 122 recorded highest plant height at branching (67.51 cm).
- New flushes emerges on younger branches and hence the number of branches in the plant is an important trait which directly influences the yield. The number of primary branches varied from 2 to 4 and number of secondary from 3 to 8 among different accessions. The numbers of tertiary branches were greater than 40 in 16.12 % of accessions while less than 20

were recorded in 22.50 % of the accessions. Accession MK 142 recorded highest number of tertiary branches (48 numbers).

- The maximum canopy spread in North-South direction ranged from 1.56 to 4.57 whereas, it varied from 1.52 m to 4.78 m in East-West direction. In North South direction, the branching spread was greater than 4 m for four accessions viz., MK 114, MK 118, MK 126 and MK 141. The maximum branching spread in relation to East-West direction was observed in accession MK 142 (4.78 m) followed by MK 114 (3.85 m), MK 126 and MK 1129 (3.76 m each).
- The highest leaf length was recorded by accession MK 126 (21.81 cm) whereas MK 122 recorded lowest leaf length (14.71 cm). About 43 % of accessions recorded leaf length value of more than 18 cm.
- Majority of accessions (73.33 %) recorded more than 19 numbers of leaflets per leaf. Accessions MK 126, MK 142 and Suvasini recorded highest number of leaflets (22 leaflets) whereas MK 135, MK 153 and MK 195 recorded lowest number of leaflets per leaf (16 leaflets).
- Among the accessions, MK 142 recorded highest leaflet length (4.56 cm) while MK 119 recorded the lowest value (2.96 cm). The width of leaflet ranged from 1.25 cm to 2.01 cm with the highest leaflet width of 2.01 cm in MK 126 followed by MK 160 (1.96 cm).
- In the present investigation, leaf area ranged from 29.06 cm^2 to 66.46 cm^2. Highest leaf area was recorded by MK 142 (66.46 cm^2) followed by MK 126 (58.72 cm^2) and the lowest in two accessions MK 117 (29.06 cm^2) followed by MK 122 (29.14 cm^2).
- The incidence of leaf spot disease observed during onset of monsoon and percent incidence varied from 5 % to 30 % among the accessions. The lowest incidence of less than 5 % was noticed in three accessions namely MK 142, MK 160 and Suvasini.

- Fresh leaf yield is a complex character that decides the superiority of the accession from the others. Among the seasons, fresh leaf yield per plant was higher in rainy season followed by winter and very low in summer..Summer season harvest recorded lowest leaf yield of less than 1 kg/plant with highest yield in MK 142.
- In the present investigation, the total fresh leaf yield per plant varied from 2.19 kg to 5.42 kg. Highest fresh leaf yield of above 5 kg/plant/year was recorded in four accessions *viz.*, MK 126 (5.42 kg), MK 107 (5.30 kg), MK 142 (5.35 kg) and MK 160 (5.04 kg).
- Aroma and flavour are the important parameters in curry leaf and based on sensory evaluation, eight accessions were identified as superior with a mean sensory score of above 7 namely MK 107, MK 118, MK 119, MK 126, MK 141, MK 142, MK 160 and MK 186.
- No variation was observed with regard to stem colour in the genotypes studied and it was grey with white dots in all the genotype. Among the accessions, 76 % were having green midrib and petiole while 24 % possess light red pink. Leaf colour was found dark green in 63 % of accessions and the remaining were green in colour. Only two leaflet shape was recorded in the accessions studied, with 19 % of accessions having lanceolate shape and rest of them have obovate.
- The correlation study conducted between major quantitative characters and yield revealed that fresh leaf yield was significantly and positively correlated with number of primary (0.712), Secondary (0.706) and tertiary branches (0.759), North-South (0.646) and East-West canopy spread (0.469), leaf length (0.777), number of leaflets per leaf (0.540), length (0.632) and width of leaflet (0.629) and leaf area (0.829). Yield was negatively correlated to plant height (0.084) and branching height (0.105).
- On the basis of cluster analysis, all the thirty accessions were grouped into twelve clusters. Among them four clusters (clusters 1, 5, 6 and 7) were

found superior in terms of yield and sensory scores and ten superior accessions were selected. Two from cluster 5 (MK 126, MK 142), three from cluster 6 (MK 107. MK 118 and MK 160), one from cluster 7 (MK 114) and four from cluster 1 (MK 103, MK 105, MK 141 and MK 186).

- Biochemical characterization was done on selected accessions along with check variety in both fresh and dry leaf sample. Wide range of variation was observed in biochemical content of fresh and dry samples.
- The dry leaves yielded higher percentage of essential oil, antioxidant activity and beta carotene content than fresh leaves. The accession MK 186 recorded higher oil recovery of 1.09 % in dry leaf sample.
- The maximum content of crude fibre was recorded in two accessions namely MK 118 (11.53 %) and MK 186 (11.65 %) while the lowest content was observed in MK 105 (9.74 %).
- Total carbohydrate in curry leaf ranged from 14.45 % to 15.99 % with highest in MK 126. Remarkable difference was observed in protein content and ranged from 4.00 % to 6.00 % with highest content in MK 126.
- The highest phenol content was recorded in dry leaves than fresh leaves ranging from 0.40% (MK 114) to 0.58 % (MK 105). The highest content of phenol was recorded by accession MK 105 in both fresh (0.31 %) and dry leaves (0.58 %) whereas lowest in MK 114 in fresh (0.20 %) and dry leaves (0.40 %) respectively.
- In the present study, fresh leaves recorded maximum antioxidant capacity ranging from 3.06 to 3.45 mg AAE g^{-1}. The highest antioxidant capacity value was recorded by MK 105 (3.45 mg AAE g^{-1}) while the minimum content was recorded by MK 186 (2.86 mg AAE g^{-1}) followed by MK 141 (3.06 mg AAE g^{-1}).
- Fresh leaves recorded maximum content of beta carotene when compared to dry leaves. The beta carotene content of fresh leaves ranged from 7.85

mg to 8.81 mg 100g^{-1}. Three accessions namely MK 105, MK 142 and MK 186 recorded higher content of beta carotene (> 8.80 mg 100g^{-1}).

- Fresh leaves exhibited maximum chlorophyll content and up on drying chlorophyll content get reduced. The total chlorophyll content ranged from 0.97 mg to 1.47 mg 100g^{-1} in fresh leaves. Highest chlorophyll content was recorded in MK 103(1.47 mg 100g^{-1}) followed by MK 141 (1.38 mg 100g^{-1}) whereas MK 105 recorded the lowest value (0.97 mg 100g^{-1}) in fresh leaves.
- Among the accessions, driage ranged from 51 % to 66 % with highest value recorded in two accessions namely MK 105 (65.93 %) and MK 107 (66.3 %).
- Based on yield and quality parameters two curry leaf types MK 142 and MK 126 were identified as most promising followed by MK 105 and MK 186.
- Curry leaf is a difficult to root plant and it took 6 months for rooting in vegetative propagation through stem cuttings of Suvasini. Among the cuttings, softwood cutting recorded early sprouting irrespective of season and growth regulator whereas maximum sprouting was observed in hardwood cuttings.
- Irrespective of season and cutting type, higher concentration of IBA and NAA (combination of 2000ppm IBA and NAA) resulted in maximum sprouting, number of leaves and establishment percentage.
- Among the three seasons, early sprouting was recorded in rainy season (6.81 days), followed by winter (9.12 days) and summer (9.68 days) in softwood cuttings. With respect to growth regulators, 1000ppm IBA +2000ppm NAA and 2000ppm IBA +2000ppm NAA recorded minimum days for sprouting in rainy (7.55 to 7.66 days) and summer months (10.50 days) whereas in winter 2000ppm IBA +1000ppm NAA recorded minimum days (9.83 days).

- Hardwood cuttings and 2000ppm IBA +2000ppm NAA recorded maximum percentage of sprouting while softwood cuttings and 1000ppm NAA recorded lowest sprouting in all the three seasons. Maximum sprouting was observed in rainy season (46.75 %) and minimum in summer (36.40%).
- The maximum number of leaves per cutting was observed in winter season compared to rainy season. During winter season, semihardwood cutting treated with combination of 1000ppm IBA+ 2000ppm NAA as well as 2000ppm IBA+2000ppm NAA resulted in 8.5 number of leaves per cutting.
- Even though success of vegetative propagation through stem cuttings was found to be very low, hardwood cutting treated 2000ppm IBA + 2000ppm NAA in rainy season showed an establishment rate of 3.3 %. The cuttings recorded mean leaf length of 11.4 cm and width of 1.45 cm after 180 days of planting and numbers of primary and secondary roots were found to be 6.00 and 17.00 respectively. The mean length of primary and secondary root was recorded as 5.32 cm and 3.70 cm respectively. The fresh weight of root was obtained as 1.12 g.

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EVALUATION OF CURRY LEAF ACCESSIONS (*Murraya koenigii* L.) FOR YIELD AND QUALITY

by

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ABSTRACT OF THE THESIS

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ABSTRACT

Curry leaf (*Murraya koenigii* L.) is an important perennial herbal spice widely used for culinary purpose in India for centuries and the leaves valued for its characteristics flavour and aroma. Leaves possess medicinal and neutraceutical properties due to the presence of vitamins, minerals and phytochemicals. In Kerala, cultivation is limited to landraces which are often reported to be low in quality. Identification of promising types with high yield and quality will pave way for promoting large scale cultivation in Kerala. The present study entitled "Evaluation of curry leaf (*Murraya koenigii* L.) accessions for yield and quality" was undertaken with objectives of morphological and biochemical characterization of available accessions and standardization of vegetative propagation.

accessions of curry leaf maintained by the Department of Vegetable Science, College of Horticulture, Vellanikkara along with the released variety Suvasini were used as the experimental material. Among the accessions, wide variability was recorded for fifteen quantitative and five qualitative morphological characters studied. Cluster analysis was performed and superior accessions were selected and those were subjected to biochemical analysis.

Among the accessions, 76 % were having green midrib and petiole whereas 24 % with light red pink. Leaf colour was found as dark green in 19 % of accessions and the remaining accessions were green in colour. Only two leaflet shape were noticed with 19 % having lanceolate shape. The plant height varied from 2.23 m (MK 107) to 5.21m (MK 103) whereas branching height ranged from 31.25 cm (MK 125) to 67.51 cm (MK 122). Accession MK 118 recorded highest canopy spread in N-S direction (4.57 m) while MK 142 recorded in E-W direction (4.78 m). Considerable variability was observed in number of primary, secondary and tertiary branches and more than 40 numbers of tertiary branches were recorded in five accessions namely MK 107, MK 118, MK 126, MK 142 and MK

160. The leaf length ranged from 14.71 cm (MK 122) to 21.81 cm (MK 126) whereas maximum number of leaflets (22 leaflets) were observed in three accessions viz., MK 126, MK 142 and Suvasini with the largest leaf area of 66.46 cm^2 in MK 142. Curry leaf was harvested at four months interval from June to March. Harvesting during June- July months in the rainy season recorded the highest leaf yield per plant. Leaf yield of more than 5 kg per plant was obtained in four accessions namely, MK 107, MK 126, MK 142 and MK 160. Aroma and flavour are the important parameters in curry leaf and based on sensory evaluation, eight accessions were identified as superior with a mean sensory score of above 7, with the highest score of 7.40 and 7.33 for flavour and aroma in MK 126.

Correlation analysis revealed significant and positive correlation of yield with number of primary, secondary and tertiary branches, canopy spread in N-S and E-W direction, number of leaflets, and leaf area. Based on cluster analysis, all the thirty accessions under the study were grouped into twelve clusters and ten accessions from superior clusters were selected for biochemical analysis.

Oil recovery was higher in dry leaves than in fresh whereas antioxidant activity and beta carotene content were higher in fresh leaves. Highest essential oil recovery was recorded in dried samples of accession MK 186 (1.09 %) and maximum content of crude fibre was recorded in two accessions namely MK 118 (11.61 %) and MK 186 (11.65 %). Accession MK 126 recorded the highest content of carbohydrate (15.99 %) and protein (6.00 %). Highest content of total phenol (0.31 %) and antioxidant capacity (3.45) was recorded in MK 105. The beta carotene content was found higher (> 8.80 mg $100g^{-1}$) in three accessions namely, MK 105, MK 142 and MK 186. Considering yield and quality MK 142 and MK 126 were identified as most promising types followed by MK 105 and MK 186.

Standardization of vegetative propagation was done in Suvasini with softwood, semihardwood and hardwood types of cuttings, two growth regulators (IBA and NAA) at different concentrations of 1000ppm, 2000ppm and their combinations during rainy, winter and summer season. Even though success rate of vegetative propagation through stem cuttings was very low, hardwood cuttings treated with highest concentration of growth regulator (2000ppm IBA+2000ppm NAA) resulted in 3.3 % of establishment during rainy season.