

RESEARCH ARTICLE

Genetic Diversity through Morphological Characterisation in Betel Vine (*Piper betle* L.) of Malappuram District, Kerala, India

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The present investigation was carried out to study the diversity of betel vine in Tirur and nearby areas of Malappuram district of Kerala and to characterise the landraces based on morphological features. *Puthukodi*, *Chelan*, *Karinadan* and *Nadan* were the betel vine cultivars recorded from Malappuram District. *Puthukodi* and *Nadan* were the most common cultivars whereas *Chelan* and *Karinadan* were the cultivars conserved by few farmers. Morphological characterisation revealed distinctness of *Karinadan* and *Chelan* from other cultivars. *Karinadan* had dark green leaves with even leaf margin, short petiole, generally ovate lanceolate leaf lamina and high brittleness. The plant growth parameters like plant height and total number of leaves were significantly low in this cultivar. On the other hand, *Chelan* had light green leaves with wavy leaf margin, long petiole, ovate leaf lamina and round leaf base. The plant growth parameters such as plant height and total number of leaves were significantly high in this cultivar, resulting in higher number of leaves per plant. *Nadan*, *Puthukodi* and *Muvattupuzha Local* cultivars had green leaves with even margin and medium brittleness. *Puthukodi* recorded maximum leaf weight per unit area and optimum leaf parameters, making it as the most preferred land race in Malappuram district.

Key Words: Chelan, Karinadan, Muvattupuzha local, Nadan, Puthukodi

Introduction

Betel vine (*Piper betle* L.) is a dioecious, evergreen creeper belonging to the family Piperaceae. It grows in moist tropical and subtropical regions of different countries such as China, Thailand, Philippines, India, Bangladesh, Sri Lanka, etc. It is native to Central and Eastern Malaysia (Chattopadhyay and Maity, 1967). In India, it is cultivated in an approximate area of 45,000 ha as cash crop. Everyday about 15-20 million people in the country consume betel leaves. Sixty six per cent of the total production of betel leaf in India is contributed by West Bengal (Guha, 2006).

Betel vine is an indigenous medicinal plant with glabrous, deep green and heart shaped leaves as economically important part. The betel vine leaves are popularly known as *Paan* and is also known in other names like *Tamalapaku*, *Tambul* and *Vettilai* in different parts of India. *Bangla* had large thin leaves with nine main nerves and ovate lamina with cordate base. Leaf apex was pointed, short and not curved. Petiolar sinus of *Bangla* was more prominent than other varieties. *Desawari* had large thin leaves and cordate lamina with seven to nine nerves.

In Kerala, Tirur and nearby areas of Malappuram district are famous for betel vine cultivation with an area of 183 ha (FIB, 2014). In earlier days *Paan Bazar* in Tirur was an exclusive market for betel leaves. Best quality *Tirur betel vine* leaves are exported to Pakistan via North India and second grade leaves are sold in local markets (Nair, 2010). Presently *Tirur betel* leaves are also exported to Pakistan via Arab countries. Majority of people from Tirur and nearby areas depend on betel vine cultivation and allied sectors for their livelihood. Betel vine landraces from Tirur area possess some special morphological and biochemical characters like unique flavour and aroma because of geographical features, traditional cultural practices, specific genotypes, special soil characters and peculiar climatic features of area of production.

Even though *Tirur betel vine* leaf from Malappuram is a unique agricultural product of the country, studies on the variability of betel vine cultivars in Malappuram district are very scanty. Characterisation of popular betel vine types is a prerequisite to reveal the existing variability within the crop in Malappuram area. Studies on morphological characters are to be undertaken to identify

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the best cultivars for commercial cultivation and to use in both medicine and cosmetic production. Moreover, documentation of unique characters is necessary for the registration of *Tirur betel vine* as a Geographical Indication from Kerala. Presently an approved crop descriptor for betel vine is lacking. In this background, the present study was undertaken to document and characterise the betel vine cultivars of Malappuram district based on morphological characters.

Materials and Methods

The present study was undertaken in the Department of Plant Breeding and Genetics, College of Horticulture, Thrissur during 2012-2014. Experimental material was raised in farmer's field at Tirur, Malappuram which lies on the geographical coordinates of 10°54'0" N and 75°55'0" E with an altitude of two meter above Mean Sea Level (MSL).

Information regarding betel vine landraces grown in Malappuram district and their special characteristic traits were collected through a preliminary survey conducted in seven Block Panchyaths located in the area of production of *Tirur vettila*. *Puthukodi*, *Chelan*, *Karinadan* and *Nadan* were the betel vine landraces grown in Malappuram district. Among these except *Chelan* all others were female landraces. Planting material of these four types were collected during survey. Planting material of *Muvattupuzha Local* was collected from Ashamanoor, Ernakulum district.

Puthukodi, *Chelan* and *Karinadan* along with *Nadan* (Local check variety) and *Muvattupuzha Local* type from Asamannoor as check variety were raised in farmer's field in Malappuram district during 2013-14. The five betel vine landraces were grown in a Randomized Complete Block Design with four replications. During the experimentation flowering was observed in all cultivars. The five betel vine types were characterized based on morphological characters.

Morphological Characterization

The betel vine types were characterised and evaluated based on morphological characters. Morphological characters were recorded from whole plant, lateral branch and leaf. Growth parameters were recorded from 15 Days After Lowering (DAL) upto 90 DAL at fifteen days interval. Leaf observations were recorded from fourth leaf from the tip of the lateral branch. Observation on days to lateral branching was recorded from the date of

planting. Currently there is no approved descriptor for betel vine and hence the "Descriptor for Black Pepper" (IPGRI, 1995) and guidelines for the conduct of test for distinctiveness, uniformity and stability on black pepper (PPV & FR Authority, 2009) were followed (with suitable modifications) for characterisation of cultivars.

Qualitative Characters

The qualitative characters observed were internodal colour, lateral branch pattern, shoot tip colour, leaf margin, leaf brittleness, leaf colour, leaf lamina shape, leaf base shape and leaf apex shape. All other characters except leaf brittleness were visually observed. Leaf brittleness analyzed by slightly pressing the leaf by hand and the tendency to break was recorded and classified leaf brittleness as low, medium and high.

Quantitative Characters

The quantitative characters observed were plant height, total number of leaves, angle between orthotropic shoot and leaf petiole, days to lateral branching, days between lateral branch emergence, number of lateral branches, number of nodes per lateral branch, number of leaves per lateral branch, leaf length, leaf width, leaf area, total leaf weight, leaf weight per unit area, leaf petiole length and leaf tip angle.

Plant height was recorded in centimeters from the base to tip of the orthotropic shoot. The number of fully opened leaves were counted and expressed in number. Angle between orthotropic shoot and leaf petiole was measured and expressed in degree. Number of days from planting to lateral branching was counted and expressed in days. The days between the emergences of two consecutive lateral branches, number of lateral branches, number of nodes of the selected lateral branches and number of leaves of the selected lateral branches were counted and expressed in number. Leaf length was measured in centimeters from the base of midrib to tip of the leaf. Leaf width was measured in centimeters at the widest portion of leaf. Leaf area was measured by using leaf area meter model-LI-3000 model and expressed in centimeter squares. Leaf weight was measured using analytical laboratory digital weighing balance and expressed in grams. Leaf weight per unit area was calculated using the following formula and expressed in gram per centimeter square. Leaf petiole length was measured in centimeters from the petiole base to the insertion with the leaf lamina. Leaf tip angle was measured and expressed in degree.

$$\text{Leaf weight per unit area} = \frac{\text{Weight of the leaf (g)}}{\text{Area of the leaf (cm}^2\text{)}}$$

Results and Discussion

Status of Cultivation of Betel Vine

The area of cultivation of *Tirur betel vine* in Malappuram district during 2012-13 was 183 ha (FIB, 2014). It was cultivated in seven Block Panchayaths viz., Ponnundam, Parappanangadi, Valanchery, Malappuram, Vengara, Tirur and Kondotty. In these Block Panchayaths most of the farmers were depending on betel vine cultivation for their livelihood. Variation was seen on different morphological characters of *Tirur betel vine* cultivars. Cultivars recorded from Tirur Block Panchayath were *Puthukodi*, *Karinadan*, *Nadan* and *Chelan*. *Puthukodi* was cultivated in larger area compared to other cultivars and exported to Pakistan. Leaves of *Nadan* were mostly preferred in local markets of Kerala. *Karinadan* and *Chelan* cultivars were conserved by few farmers in Malappuram district. Farmers mainly adopted organic method of cultivation.

Morphological Characterisation

Qualitative Characters

The qualitative characters of each landrace are presented in Table 1.

Internodal Colour

Orthotropic shoot and lateral branch expressed variability for internodal colour. Green internode with purple colour at nodal region was observed in *Nadan*, *Puthukodi*, and *Muvattupuzha Local*. *Chelan* showed internodal colour of light green with purple tinge whereas *Karinadan* showed uniform purple-green colour for internode. Internodal colour of lateral branch varied before and after spike formation. Purple pigmentation was present in all cultivars before spike formation. Purple colour with light green broken stripes was observed in lateral branches (without spike) of *Karinadan*, *Puthukodi*, *Nadan* and *Muvattupuzha Local* whereas *Chelan* showed light purple with light green broken stripes at internodal region. Purple pigmentation was absent in lateral branches with spikes in all landraces. Pinkish colouration in the stem of the betel vine was reported by Chaveerach *et al.* (2006).

Table 1. Qualitative morphological characters of betel vine cultivars of Malappuram district during 2013-14

Sl. No.	Morphological characters		Betel vine cultivars				
			<i>Puthukodi</i>	<i>Chelan</i>	<i>Karinadan</i>	<i>Nadan</i>	<i>Muvattupuzha Local</i>
1	Internodal colour	Orthotropic shoot	Green with purple colour at nodal region	Light green with purple tinge	Uniform purple green colour	Green with purple colour at nodal region	Green with purple colour at nodal region
		Lateral branch	With spike	Green	Light green	Green	Green
		Without spike	Purple colour with light green broken stripes	Light purple with light green broken stripes	Purple colour with light green broken stripes	Purple colour with light green broken stripes	Purple colour with light green broken stripes
2	Lateral branch pattern		Hanging	Semi-erect	Hanging	Mostly hanging, rarely horizontal	Mostly hanging, rarely horizontal
3	Shoot tip colour		Dark purple colour with broken green stripes	Light purple with light green broken stripes	Dark purple colour with broken green stripes	Dark purple colour with broken green stripes	Dark purple colour with broken green stripes
4	Leaf margin		Even	Wavy	Even	Even	Even
5	Leaf brittleness		Medium	Low	High	Medium	Medium
6	Leaf colour		Green	Light green	Dark green	Green	Green
7	Leaf lamina shape		Mostly ovate elliptic, rarely ovate lanceolate	Ovate	Mostly ovate lanceolate, rarely ovate elliptic	Mostly ovate lanceolate, rarely cordate	Mostly ovate elliptic, rarely cordate
8	Leaf base shape		Cordate	Mostly round, rarely acute	Cordate	Mostly cordate, rarely round	Mostly cordate, rarely round
9	Leaf apex shape		Aristulate	Aristulate	Accuminate	Accuminate	Apiculate

Variations in the internodal colour could be used as a morphological marker in cultivar identification.

Lateral Branch Pattern

Three types of lateral branching pattern namely hanging, horizontal and semierect were shown by the betel vine cultivars. Hanging lateral branches were mainly seen in betel vine cultivars whereas, semi-erect lateral branches were the unique character of *Chelan*. *Nadan* and *Muvattupuzha Local* rarely produced horizontal lateral branches.

Shoot Tip Colour

All cultivars showed purple pigmentation at shoot tip. *Chelan* had light-purple with light-green broken stripes for shoot tip whereas all other cultivars showed dark purple colour with green broken stripes (Figure 1). Colour of shoot tips of *Tirur betel vine* cultivars was same as that in *Muvattupuzha Local*. An experiment conducted by Sreedevi et al. (2005) on black pepper recorded light purple for young orthotropic shoot tip.

Leaf Characters

Two types of leaf margins (even/entire and wavy) were found in betel vine cultivars. All cultivars, including check cultivar, *Muvattupuzha Local* showed even leaf margin except *Chelan* which produced wavy leaf margin (Figure

2). *Tirur betel vine* cultivars and *Muvattupuzha Local* showed same pattern in leaf margin. Similar findings were reported by Pariari and Imam (2012a).

Leaf brittleness varied among cultivars. Highly brittle leaves were produced by *Karinadan* and low brittle leaves by *Chelan*. Medium brittle leaves, which have more market preference were produced by *Puthukodi*, *Nadan* and *Muvattupuzha Local*. High brittleness of leaves in *Karinadan* and low brittleness of leaves in *Chelan* would have reduced their marketability.

Light-green leaves were the unique character of *Chelan* whereas dark-green leaves were the character of *Karinadan*. The remaining three cultivars viz., *Puthukodi*, *Nadan* and *Muvattupuzha Local* produced green leaves. Light-green leaves and very dark-green leaves generally have less consumer preference. The dorsal surface of leaf lamina of all cultivars showed slight anthocyanin pigmentation along main veins and at the point of insertion of petiole with leaf lamina.

Leaf lamina shape varied with different cultivars in plagiotropic shoots. Four types of leaf lamina namely ovate, cordate, ovate-elliptic and ovate-lanceolate were seen in leaves from the lateral branches of the cultivars. Mostly ovate elliptic leaves were observed in *Puthukodi* and *Muvattupuzha Local*. *Karinadan* and *Nadan* mostly

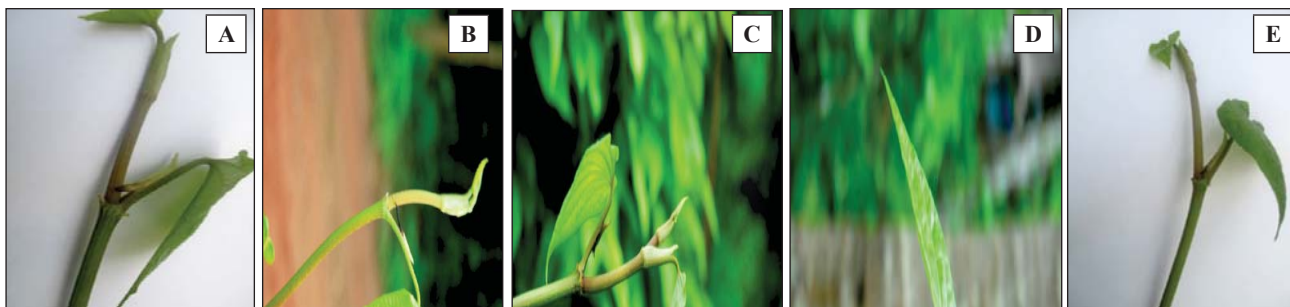


Fig. 1. Shoot tip colour in betel vine: (A) *Puthukodi*, (B) *Chelan*, (C) *Karinadan*, (D) *Nadan*, and (E) *Muvattupuzha Local*

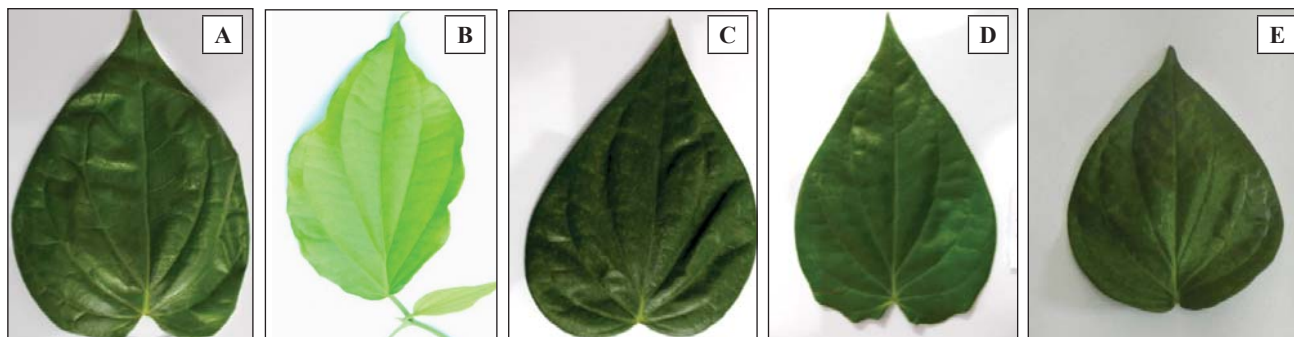


Fig. 2. Leaf margin types in betel vine: (A) *Puthukodi*, (B) *Chelan*, (C) *Karinadan*, (D) *Nadan*, and (E) *Muvattupuzha Local*

produced ovate-lanceolate leaf. *Chelan* was unique in the group to produce ovate leaf lamina. Chaveerach *et al.* (2006) observed ovate lamina for betel vine leaves whereas Pariari and Imam (2012a) observed cordate leaf lamina in plagiotropic shoots.

Generally three types leaf base were seen in betel vine cultivars. Cordate base was the most common type except in *Chelan*. In other qualitative characters, *Chelan* was found different from other cultivars with respect to leaf base also. Generally, *Chelan* produced distinguishable round leaf base and only very rarely, it produced acute leaf base. Other cultivars like *Puthukodi*, *Karinadan*, *Nadan* and *Muvattupuzha Local*, mostly produced cordate leaf base. However, *Nadan* and *Muvattupuzha Local* sometime also exhibit round leaf base. Chaveerach *et al.* (2006) found cordate base in *P. betle*. In black pepper, Sanchu (2000) reported cordate and round leaf bases.

Leaf apex shape varied slightly among cultivars. Three types of leaf apex namely acuminate, apiculate and aristulate were seen in leaves from the lateral branches of the cultivars. Leaf apex of *Nadan* and *Karinadan* was acuminate while aristulate leaf apex was observed in *Chelan* and *Puthukodi*. *Muvattupuzha Local* had apiculate leaf apex. However, slight variations from these cited shapes of leaf apex were also observed. Repeated studies are required to confirm leaf apex shape in each cultivar.

Number of lateral veins varied in cultivars. *Chelan* showed four lateral veins all others recorded six lateral veins in leaf. According to Singh (1994), *Bangla* cultivar had large thin leaves with nine main nerves. Colour of

stipule or prophyll is light green in *Chelan* whereas all others showed violet tinge in stipule.

Quantitative Characters

The quantitative characters of each landrace are presented in Table 2.

Plant Height

Chelan showed significantly high value for plant height at all stages of crop growth; might be due to higher growth rate. *Karinadan* recorded lower plant height at all stages. At 90 DAL, all cultivars recorded a plant height of more than 260 cms. A study conducted by Pariari and Imam (2012a) revealed a vine length of 145.37 cm.

Total Number of Leaves

Faster growth rate in *Chelan* as evidenced by highest plant height, led to highest (280.35 per vine) total number of leaves at 90 DAL. On the other hand *Karinadan*, produced lowest leaf number (175.68 per vine). The work conducted by Pariari and Imam (2012a) showed higher annual leaf yield of 58.56 leaves per vine in *Simurali Deshi*. The number of leaves per vine at 90 DAL in *Tirur betel vine* cultivars ranged from 175.68 – 280.35. In the present study, method of trailing adopted in *Koottakodi* system would have resulted in higher leaf number per vine than the annual leaf yield (58.56 leaves per vine) in *Simurali Sanchi* recorded in 'bareja' system by Pariari and Imam (2012a).

Lateral Branch Characters

As in the case of plant height and total number of leaves, number of lateral branches in *Chelan* recorded significantly high values. This would be due to faster

Table 2. Quantitative characters of betel vine cultivars

Sl. No.	Morphological characters	<i>Puthukodi</i>	<i>Chelan</i>	<i>Karinadan</i>	<i>Nadan</i>	<i>Muvattupuzha Local</i>
1	Days to lateral branching	134.00 ^{ab}	80.75 ^c	151.25 ^a	85.00 ^c	127.50 ^b
2	Days between lateral branch emergence	18.23 ^c	9.35 ^d	26.35 ^a	18.03 ^c	21.78 ^b
3	Angle between orthotropic shoot and leaf petiole (degree)	49.85 ^c	77.95 ^a	49.12 ^c	59.92 ^b	57.55 ^b
		(narrow)	(wide)	(narrow)	(narrow)	(narrow)
4	Leaf length (cm)	17.70 ^c	14.78 ^d	19.48 ^a	19.23 ^b	15.25 ^d
		(long)	(medium)	(long)	(long)	(medium)
5	Leaf width (cm)	12.63 ^c	11.50 ^d	14.40 ^a	13.80 ^b	11.75 ^d
		(medium)	(medium)	(broad)	(broad)	(medium)
6	Leaf area (cm ²)	156.13 ^d	134.25 ^e	196.23 ^a	184.08 ^b	164.25 ^c
		(medium)	(low)	(high)	(high)	(medium)
8	Leaf weight (g)	4.78 ^a	2.82 ^c	4.85 ^a	4.53 ^a	3.95 ^b
7	Leaf weight per unit area (g/cm ²)	0.028 ^a	0.021 ^d	0.025 ^b	0.022 ^c	0.022 ^c
8	Leaf petiole length (cm)	2.93 ^c	4.85 ^a	2.75 ^c	3.30 ^b	3.35 ^b
		(short)	(long)	(short)	(medium)	(medium)
9	Leaf tip angle (degree)	35.20 ^c	38.90 ^b	51.62 ^a	42.62 ^b	40.95 ^b
		(narrow)	(narrow)	(wide)	(medium)	(medium)

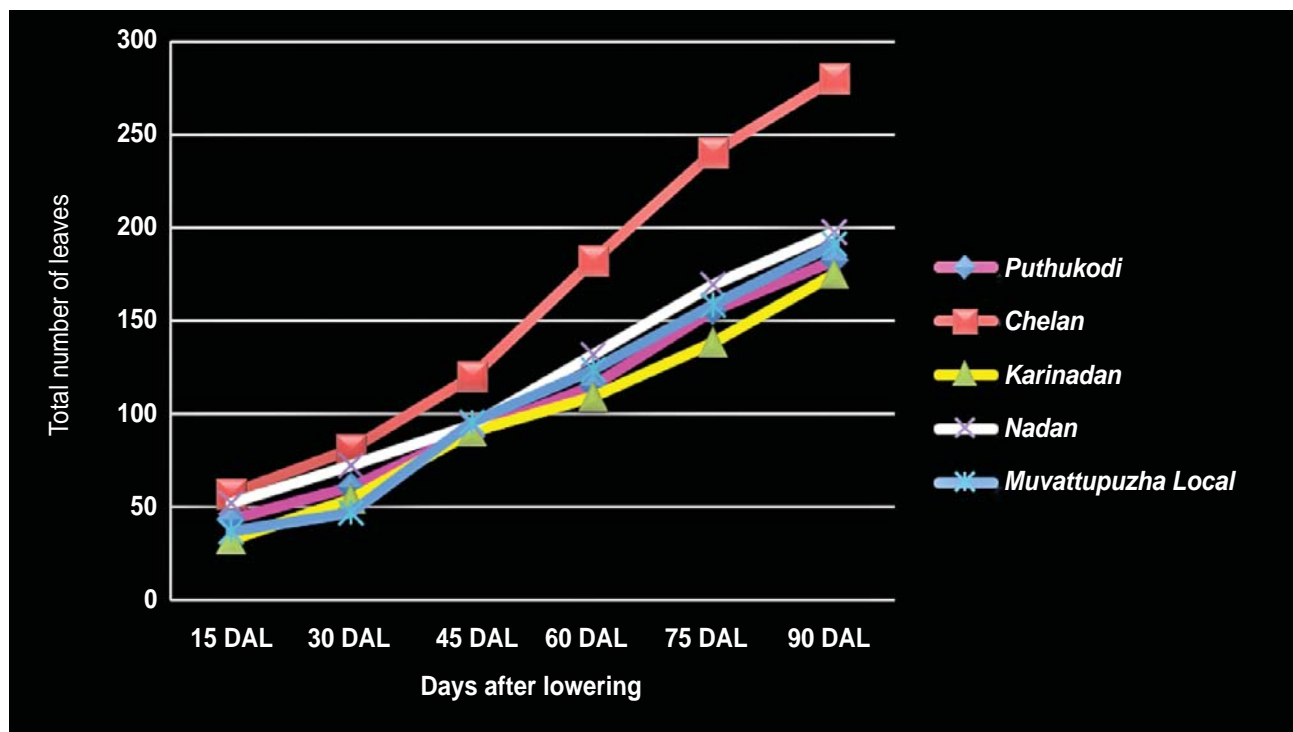


Fig. 3. Total number of leaves at different growth stages in betel vine cultivars of Malappuram district during 2013-2014

growth rate in this cultivar. *Karinadan* recorded less number of lateral branches as in other characters. *Chelan* recorded 16.88 lateral branches while *Karinadan* recorded 10.88 lateral branches at 90 DAL. *Muvattupuzha Local* recorded lower number of lateral branches than *Nadan* and more number than *Puthukodi*.

As in the case of other growth parameters, *Chelan* produced highest number of nodes per lateral branch (43.95) and *Karinadan* produced lowest number of nodes per lateral branch (26.28) at 90 DAL (Fig. 3). *Nadan* and *Muvattupuzha Local* produced almost same number of nodes per lateral branch during the same period of crop growth.

The data on number of leaves per lateral branch and number of nodes per lateral branch were same because from each node only one leaf was produced. Number of leaves per lateral branch increased in tune to increase in days after vine lowering. At all growth stages *Chelan* produced more number of leaves while *Karinadan* produced less number of leaves.

Leaves from lateral branches have more market value and are locally called as 'Kanni vettilla'. So, days to lateral branching are important with regard to production of marketable leaves. More days for the emergence of lateral branch would result in less leaf

yield. Among the cultivars, *Karinadan* with slow rate of vine growth, took more number of days (151.25) for the commencement of lateral branch. This cultivar had expressed less number of total leaves also. *Chelan* with more plant height at all stages, showed early emergence of first lateral branch, and higher number of leaves at all growth stages.

Emergence of two consecutive lateral branches occurred very fast in *Chelan* as compared with other cultivars. *Chelan* with more plant height and less number of days in lateral branching, showed lesser days (9.35) between lateral branch emergence, indicating a faster growth rate. *Karinadan* with less plant height and more number of days in lateral branching took more days (26.35) between emergence of two lateral branches.

The angle between orthotropic shoot and leaf petiole is an important character in distinguishing different subtypes of *Piper* species. Except *Chelan*, which produced wide angle, all other cultivars showed narrow angle between orthotropic shoot and leaf petiole. The wide angle in *Chelan* resulted in spreading nature of leaves. Krishnamurthy et al. (2010) suggested that in black pepper, the leaf angle should be more at the bottom compared to top to help in filtering of more light to the bottom canopy.

Leaf Characters

Leaf length varied significantly among cultivars with highest leaf length (19.48 cm) in *Karinadan*. On the other hand lowest leaf length (14.78 cm) was observed in *Chelan*. In general, *Karinadan*, *Nadan* and *Puthukodi* showed long leaves. Pariari and Imam (2012a) also observed variation in leaf length between 14.75–16.73 cm among six cultivars namely *Ghanagette*, *Simurali Sanchi*, *Simurali Jhal*, CARI-2, CARI-6 and *Sanchi*.

The trend exhibited for leaf length was seen in leaf width also. Leaf width was more in *Karinadan* (14.40 cm) and less (11.50 cm) in *Chelan*. *Puthukodi* showed a leaf width of 12.63 cm. Optimum leaf length and leaf width are always preferred by traders to reduce handling difficulties.

Among the cultivars, maximum leaf area was recorded in *Karinadan* (196.23 cm²) and minimum in *Chelan* (134.25 cm²). The bigger leaves as well as small leaves of these cultivars would have added to their low acceptance in the market. *Muvattupuzha Local* (164.25 cm²) and *Puthukodi* (156.13) recorded medium leaf area. Pariari and Imam (2012b) reported leaf area from 114.17 to 129.00 cm² for betel vine cultivars grown with different sources of organic manures.

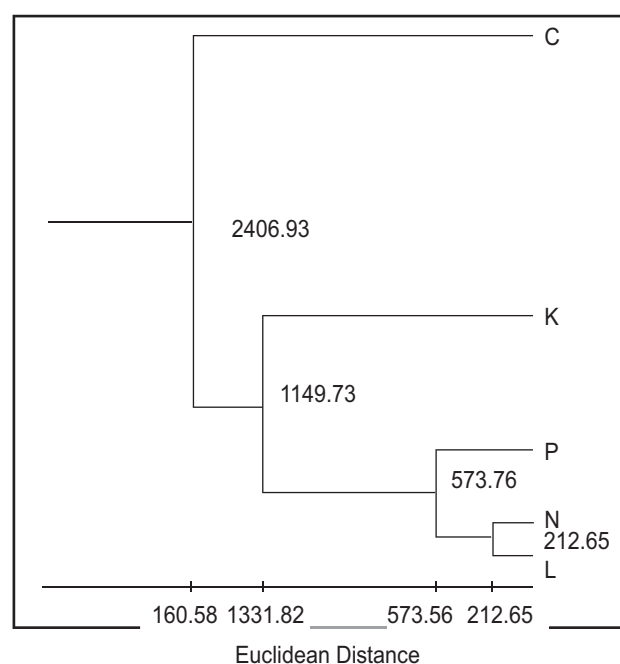
Leaf weight is an important criteria, deciding the market potential of betel leaf. *Karinadan* and *Puthukodi* produced leaves having maximum fresh weight while *Chelan* produced thin leaves with low weight. Pariari and Imam (2012b) reported a leaf weight of 3.64 gm for *Simurali Sanchi* which was close to the fresh leaf weight of *Muvattupuzha Local* (3.95 gm). The high fresh weight of leaves recorded in *Puthukodi*, would have been a reason for its high consumer acceptance. Leaf fresh weight per unit area ranged from 0.022–0.028 g/cm² with maximum in *Puthukodi* and minimum in *Chelan*. Pariari and Imam (2012b), in their field experiment, observed maximum fresh weight of 328.83 g for 100 leaves. Leaf weight is considered as an important parameter in the betel vine markets (Sumanasena *et al.*, 2005). High fresh leaf weight might be one of the reasons for the high export potential of *Puthukodi* and on the other hand low fresh leaf weight and small leaf size are some of the probable reasons for less preference for leaves of *Chelan*.

Petiole length was significantly less in *Karinadan* and *Puthukodi*, significantly high in *Chelan*. Reddy (1996) reported 5.2–6.6 cm lengthy leaf petioles among the cultivars.

Narrow leaf tip angle (35.20°) was seen in *Puthukodi* and *Chelan*. *Nadan* and *Muvattupuzha Local* showed medium leaf tip angle. Leaf tip angle in *Karinadan* was wide. Leaf tip angle determines the shape of leaf apex, and may act as morphological character for cultivar identification.

Diversity Analysis

The results of diversity analysis are presented in a dendrogram (Fig. 4) which illustrates the relationship between five landraces under study. The distance between two clusters or two cultivars is the measure of degree of diversification, greater the distance between two clusters, greater the divergence and *vice versa*. The dendrogram constructed, with Euclidean distance, based on morphological characters revealed that *Chelan* cultivar was distinct from other cultivars. *Chelan* showed 2406.93 Euclidean distance from cluster containing *Karinadan*, *Puthukodi*, *Nadan* and *Muvattupuzha Local*. *Karinadan* formed distinct cluster with a distance of 1149.73 from the cluster containing *Puthukodi*, *Nadan* and *Muvattupuzha Local*. It was interesting to note that *Muvattupuzha Local* and *Nadan* collected from different geographical locations, having almost similar morphological characters, proved their relatedness by



C – *Chelan*, K – *Karinadan*, P – *Puthukodi*, N – *Nadan*, L – *Muvattupuha Local*

Fig. 4. Dendrogram of taxonomic relationship of betel vine cultivars of Malappuram district during 2013-14

being in a single cluster with lowest Euclidean distance of 212.65. The cultivars from different clusters are generally opted for hybridization purpose and hence *Karinadan* and *Chelan* can be used for hybridization with the objective of combining their superior characters.

Conclusions

The study revealed that the *Chelan* is a very distinct, easily distinguishable among all the cultivar in Malappuram district in its leaf character with ovate, wavy, light-green leaves having round base. The internodes of orthotropic shoots are light-green in colour with purple tinge. The lateral branches are semi-erect. However, *Puthukodi*, *Nadan* and *Muvattupuzha Local* are morphologically quite similar to some extent showing green internode with purple colour at nodal region in orthotropic shoots, purple shoot tip, even leaf margin, medium leaf brittleness and green leaves. The shoot tip showed dark purple colour with green broken stripes in tender stem.

Chelan showed more vegetative growth with lesser days to lateral branch initiation and lesser days between two consecutive lateral branch emergence. However, leaves in this cultivar were small with less leaf length, less leaf width, less leaf area, less leaf weight per unit area and more petiole length reducing the market demand of the leaves. *Karinadan* showed less vegetative growth with more days to lateral branch emergence. The leaves are bigger in size with more leaf length, more leaf width, larger leaf area and short petiole. *Puthukodi* is identified as the most accepted landrace among farmers due to its optimum morphological characters suitable for cultivation, consumer preference and export.

Conflict of Interest

The authors declare that they have no conflict of interest.

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