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RESEARCH PAPER

Progeny variation for leaf morphometric traits of *Cinnamomum zeylanicum* Blume. in Uttara Kannada district, Karnataka

M. NIHARIKA AND *M. HANUMANTHA

Department of Forest Products and Utilization, College of Forestry, Sirsi -581 401
University of Agricultural Sciences, Dharwad - 580 005, India
*E-mail: hanumantha1975@gmail.com

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Abstract: *Cinnamomum zeylanicum* Blume, commonly referred to as Ceylon cinnamon or Dalchini, is renowned for its various culinary uses. Cinnamon leaves are widely used as spice and for the extraction of an essential oil rich in eugenol, which found wide applications in perfume and flavouring industries. *Cinnamomum* is genetically diverse and wide variations are observed for different traits. Due to its cross pollination behavior, an enormous diversity in Cinnamon has been produced. A two-year-old *Cinnamomum zeylanicum* field trial progenies in Kanagod village, Sirsi Taluk, Uttara Kannada, were evaluated for leaf morphometric traits from September 2022 to June 2023. Among the different progenies, progenies of G11, G16, K13 and S4 exhibited a distinct deep pink/purple leaf flush, while green was the most common leaf colour. Progenies of G2 and K18 only exhibited purple and light purple and indicating the production of new variants. Four leaf shapes namely ovate (26.67%), elliptic (26.67%), ovate-elliptic (26.66%) and ovate-lanceolate (20%) were recorded; but majority of the progenies exhibited an acuminate leaf tip shape (53.33%) followed by acute leaf tip shape (26.67%) and sub-acute type (20.00%); but all the progenies exhibited entire margin type. Maximum leaf length was recorded in M21 progenies (15.01 cm) and maximum leaf width for progenies of J4 (6.37 cm); but the progenies of M21 recorded the highest leaf area (69.03 cm^2). Progenies from the Manchale source, M21 showed the highest biomass, with a fresh weight of 1847.78 g/plant and a dry weight of 1099.97 g/plant followed by M8 (with fresh weight of 1838.15 g/plant and 1073.93 g/plant, respectively).

Key words: Cinnamon, Family, Morphometric traits, Progeny, Uttara Kannada

Introduction

Cinnamomum zeylanicum Blume. also known as true cinnamon, ceylon cinnamon or dalchini belongs to the family Lauraceae and includes about 300 genera and 2500 species. It is native to Sri Lanka and Malabar coast of India. It has received increased attention in recent years due to the vast amount of scientific evidence supporting its possible therapeutic and medical benefits (Zare *et al*., 2019). Approximately 65-70 per cent of the world's production of Ceylon cinnamon is produced in Sri Lanka (Anon, 2018). In addition to flourishing in Naga hills and coastal hills of Assam and Karnataka respectively, the genus *Cinnamomum* demonstrates a strong center of diversity particularly within Western Ghats and the surrounding areas of South India (Sasikumar *et al*., 1999). The cinnamon flower is naturally pollinated through cross-pollination, which the botanists refer as protogynous dichogamy. Flower opens at twice, first it opens as female flower with a stigma and immature male components that enable it to pollinate with another male bloom. The female flower then shuts in approximately four hours. The identical flower blooms the following day as an active male flower that distributes pollen. Considerable genetic variation in the offspring produced by this pollination activity is represented in the chemical characteristics, yield and yield-related morphological features (Liyanage *et al*., 2020). Hence, before creating any selection procedure to find superior trees and use them to increase the yield, it is crucial to understand the scope of variation. Morphological features are used as indicators to determine extent of variation in species. The genus *Cinnamomum* has the most variable qualitative and quantitative leaf attributes (Krishnamoorthy *et al*., 1992). Interactions of genotype and environmental factors play a role in generating such wide variations, when planted in varied environments (Lizawati *et al*., 2018).One of the selection strategies used in tree development programs is progeny evalation, in which superior trees are chosen based on their respective progeny performances at a young age by giving progenies of selected genotypes identical environmental (growing) conditions. It is commonly known that those picked through this process have superior genetic traits. Therefore, progeny performance in progeny trials is typically used to grade plus trees (Vasav *et al*., 2011).Testing of progenies enables researchers to understand how effectively they perform in field conditions. Due to diverse agro-ecological conditions present in Western Ghats, coastal areas and plains, finding suitable genotypes over Karnataka is of highest importance.Cinnamon leaf morphometric traits are important markers that can be adopted for measuring the magnitude of the genetic diversity (Lizawati *et al.,* 2018). By understanding and evaluating morphometric parameters of leaf could help in the taxonomical classification and differentiation of closely related species and verities of Cinnamon (Bandusekara *et al.,* 2020) and also helpful in indirect selection of high yielding plant (Wijesinghe and Gunarathna, 2001). The big leaves and large round leaves had high bark yield. Furthermore, bark oil quality (higher per cent of Cinnamaldehyde) is higher in the tree of inwardly curved leaves and high-quality leaf oil is obtained from the small round leaves.

Hence, it is necessary to understand the extent of morphological variation within the species and among the different progenies before formulating any selection programme to identify superior trees and to apply them for increasing the yield. Cinnamon shows great variations in Karnataka in terms of leaf morphometric traits (Hanumantha, 2020; Hanumantha *et al.,* 2020). However, there were less documented data regarding the leaf morphometric traits of Cinnamon progenies. Hence the current study was undertaken to determine the variation of leaf morphometric traits of Cinnamon among thirty different progenies collected from different sources of Karnataka.

Material and methods

The present study was carried out during 2022-23 at Kangod (farmers field), Sirsi, Uttara Kannada. Thirty progenies from elite plus tree families, as identified and established by Hanumantha (2020) in farmers' fields at Kanagod village were evaluated for their leaf traits. The original sources of these progenies were Gejjehalli (Hangal taluk of Haveri District), Jaddigade (Sirsi taluk of Uttar Kannada), Kankodlu (Yellapura taluk of Uttar Kannada), Manchale (Sagar taluk of Shivamogga) and Siddapura (Taluk of Uttar Kannada). Ten fully matured leaves from every 5th leaf from the branches of each progeny were collected and used for measuring the leaf parameters (Hanumantha *et al*., 2020; Bandusekara *et al*., 2020).

Results and discussion

The results revealed significant variation among the thirty progenies was reported for qualitative characteristics of the leaves (Table 2). A wide range of leaf flush shadeswere observed ranging between green topurple. Notably, only four progenies (G11, G16, K13, S4) exhibited a deep pink or purple colour; while the rest exhibited colours ranging from green to medium pink. For leaf colour, green leaf color was most prevalent amongst the progenies followed by dark green. Only the G3 and M9 progenies showed a light green leaf colour. No variability was observed for leaf margin among the progenies; all plants exhibited an entire leaf margin. Furthermore, the progenies from G2 showed petioles with a purple colour, while those from K18 showed petioles of a lighter purple shade. The remaining 28 progenies recorded green petioles. Among the thirty progenies, four different leaf shapes were observed (Fig 1), with the following distribution: ovate (26.67%), elliptic (26.67%), ovate-elliptic (26.66%) and ovate-lanceolate (20.00%). The majority of cinnamon progenies had leaf tip shape of acuminate (53.33%), followed by the acute (26.67%) and the

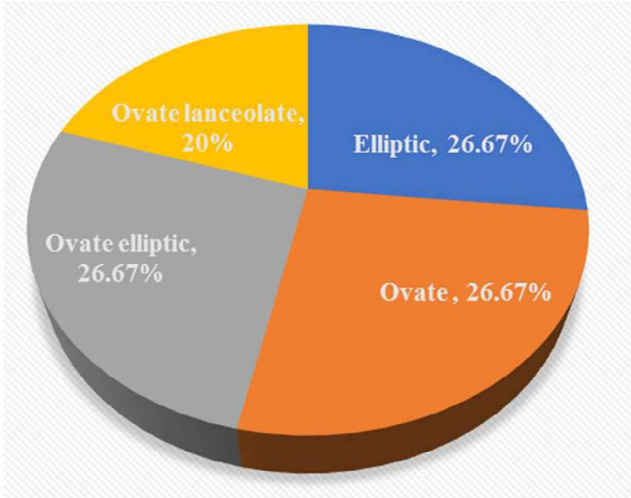

Fig 1. Variation in leaf shape among different progenies of *C. zeylanicum*

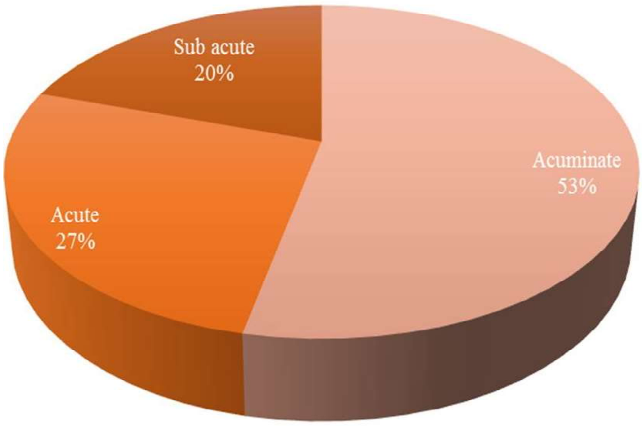

Fig 2. Variation in leaf tip shape among different progenies of *C. zeylanicum*

Table 1. Observations on leaf parameters were recorded according to the following works

Leaf parameters	Procedure/ descriptors used	Refrence
Leaf length and Leaf width (cm)	Measured for ten leaves in each progeny using a measuring scale and averaged.	Sourav Manoharan and Hanumantha (2023) Hanumantha *et al*. (2020); Bandusekara *et al*. (2020)
Leaf area (cm^2)	Measured using the leaf area meter (LI-COR-LI-3000C model) for ten leaves and averaged.	
Leaf weight (g)	Measured using weighing balance and averaged	
Leafflush colour	Green, Light pink /Purple, Medium pink/Purple, Deep pink /Purple and Very deep pink /Purple	Sourav Manoharan and Hanumantha (2023) Krishnamoorthy *et al*. (1999) Hanumantha *et al*. (2020)
Petiole colour	Green, Light purple/Pink and Purple/Pink	
Leaf colour	Pale/ Light green, Green and Dark green	
Leaf shape	Elliptic, Ovate, Ovate-elliptic and Ovate-lanceolate	
Leaf tip/apex shape	Sub-Acute, Acuminate and Acute	
Leaf margin serration	Entire and Wavy	

Table 2. Variation for qualitative leaf characters among half-sib progenies of *C. zeylanicum*

Progeny I. D	Leaf characteristics					
	Leaf flush colour	Leaf colour	Petiole colour	Leaf Shape	Leaf tip shape	Leaf margin
G1	2	3	Green	Elliptic	Sub-Acute	Entire
G2	3	3	Purple	Ovate	Acute	Entire
G3	2	1	Green	Elliptic	Acute	Entire
G4	2	2	Green	Ovate-Elliptic	Acuminate	Entire
G5	2	2	Green	Elliptic	Acute	Entire
G11	4	2	Green	Ovate-Elliptic	Acuminate	Entire
G16	4	3	Green	Ovate	Acute	Entire
G23	2	2	Green	Elliptic	Acuminate	Entire
G24	3	3	Green	Ovate-Elliptic	Acute	Entire
G25	2	3	Green	Elliptic	Acuminate	Entire
J2	3	2	Green	Elliptic	Acuminate	Entire
J4	3	2	Green	Ovate-Elliptic	Acuminate	Entire
J6	2	2	Green	Elliptic	Acuminate	Entire
J7	2	2	Green	Ovate	Acute	Entire
J18	3	2	Green	Ovate-Lanceolate	Acute	Entire
K3	1	2	Green	Ovate-Elliptic	Sub-Acute	Entire
K5	2	3	Green	Ovate-Elliptic	Sub-Acute	Entire
K10	2	3	Green	Ovate-Lanceolate	Acuminate	Entire
K13	4	3	Green	Ovate	Acuminate	Entire
K16	3	3	Green	Ovate	Sub-Acute	Entire
K18	2	2	Light Purple	Ovate-Lanceolate	Acuminate	Entire
K20	1	3	Green	Ovate-Lanceolate	Acuminate	Entire
M6	3	2	Green	Ovate-Elliptic	Sub-Acute	Entire
M8	2	2	Green	Ovate	Acuminate	Entire
M9	3	1	Green	Ovate	Sub-Acute	Entire
M21	1	3	Green	Ovate-Lanceolate	Acuminate	Entire
S1	3	2	Green	Ovate-Lanceolate	Acuminate	Entire
S4	4	2	Green	Ovate-Elliptic	Acuminate	Entire
S5	2	2	Green	Elliptic	Acute	Entire
S9	2	3	Green	Ovate	Acuminate	Entire
Mean	2.4	2.41				
S Em±	0.25	0.37				
C.D@ 5 %	0.70	1.04				
C.V (%)	18.02	26.29				

Leaf flush colour: 1=Green 2=Light Purple 3=Medium Purple 4= Purple 5= Dark PurpleLeaf colour= 1=Light green 2= Green 3=Dark Greens

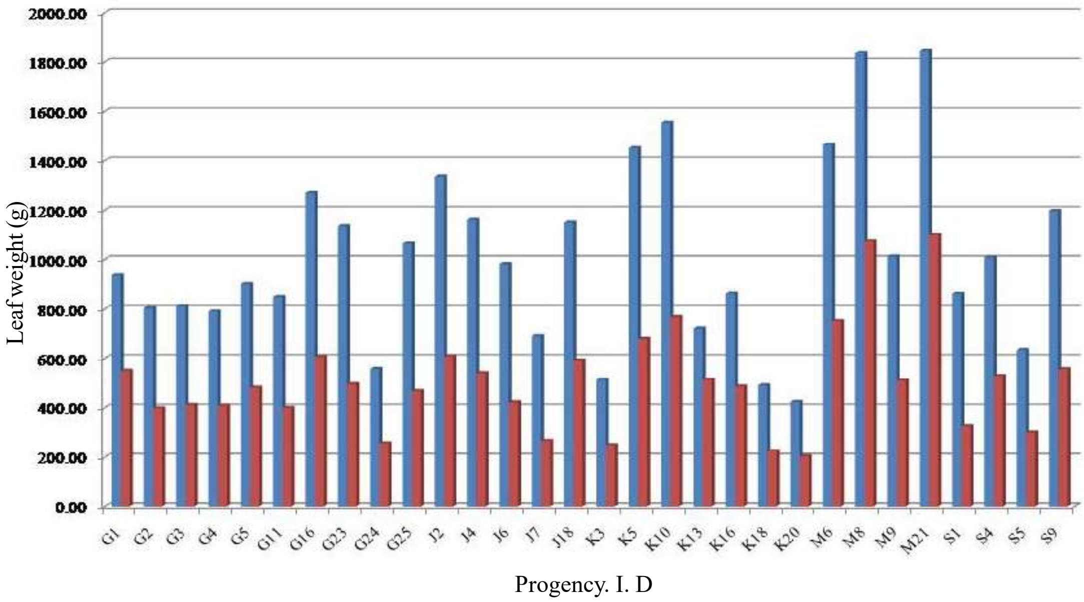

Fig 3. Variation for leaf biomass among different progenies of *C. zeylanicum*

Table 3. Variation for quantitative leaf characters among half-sib progenies of *C. zeylanicum*

ProgenyI. D	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Fresh leaf biomass after 9 months(g)	Dry leaf biomass after 9 months(g)
G1	13.55	5.44	62.95	936.55	550.57
G2	13.84	5.55	63.14	804.48	398.48
G3	12.80	5.59	57.78	811.66	411.80
G4	11.57	5.41	46.60	790.61	409.20
G5	11.74	5.12	47.66	901.77	482.10
G11	12.07	5.93	52.04	847.61	400.21
G16	11.41	5.25	45.27	1271.22	606.17
G23	12.08	4.41	52.32	1136.13	495.79
G24	13.08	4.87	61.47	556.82	255.96
G25	10.68	5.03	42.76	1065.31	468.11
J2	13.12	6.04	60.48	1337.48	608.00
J4	12.36	6.37	58.55	1161.71	540.35
J6	11.58	5.40	45.42	982.19	422.43
J7	12.59	5.55	57.48	690.94	265.64
J18	12.96	5.30	58.26	1150.83	591.57
K3	11.07	4.28	44.44	513.65	248.58
K5	11.30	5.41	50.39	1452.74	678.91
K10	12.85	4.98	51.83	1555.22	768.26
K13	11.28	4.81	43.01	720.63	513.54
K16	11.56	5.49	48.77	861.47	486.97
K18	10.21	4.50	36.86	490.98	224.11
K20	9.71	4.70	36.06	423.77	203.54
M6	13.26	5.68	60.80	1466.52	751.98
M8	14.37	5.95	66.21	1838.15	1073.93
M9	11.66	5.19	46.46	1012.46	509.58
M21	15.01	5.83	69.03	1847.78	1099.97
S1	13.38	5.12	61.81	860.68	326.69
S4	12.62	5.54	56.97	1008.67	528.24
S5	10.38	5.01	40.47	633.75	301.72
S9	13.89	5.53	64.43	1197.64	556.01
Mean	12.27	5.31	52.99	1010.98	505.95
SEm ±	0.64	0.27	3.96	142.16	71.48
C.D @ 5 %	1.79	0.75	11.03	403.47	202.88
C.V (%)	16.57	16.10	23.61	24.36	24.47

sub-acute type (20.00%) (Fig 2). Significant variationsfor progenies regarding leaf length, width, leaf area, fresh and dry leaf biomass was noticed (Table 3). Coefficient of variation found highest for dry leaf biomass (24.47%) followed by fresh leaf biomass (24.36%). Leaf length also exhibited a wide range of variation, with the shortest length observed in K20 (9.71 cm) and the longest in M21 (15.01 cm). Similarly, leaf width showed variability, ranging from 4.28 cm in K3 to 6.37 cm in J4. Leaf area of M21progeny showed the highest with 69.03 cm^2 and the lowest was shown in K20 (36.06 cm^2). Fresh and dry weight per plant of cinnamon progenies were calculated for biomass accumulation at 9 months measurements period. The results indicated that progenies originating from the Manchale source M21 exhibited the highest biomass, with a remarkable fresh weight and dry weight of 1847.78 g and 1099.97 g respectively (Fig 3). Both with respect to of fresh weight (423.77 g) and dry weight (203.54 g), the offspring of Kankodlu (K20) had the lowest biomass.

Numerous authors have documented these variations in progeny, highlighting their significance.Variation in leaf

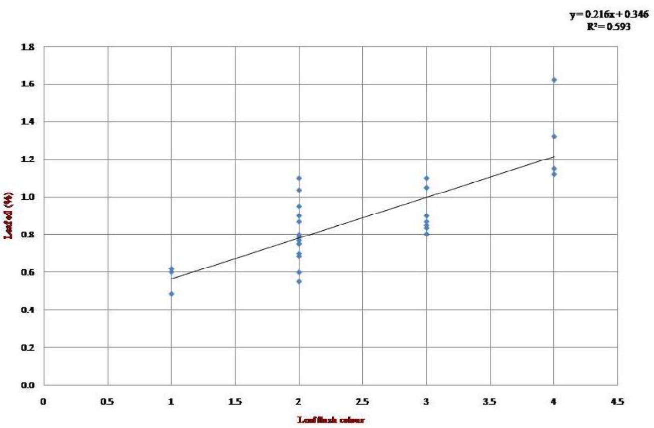

Fig 4. Association between leaf flush colour and per cent leaf oil

qualitative parameters was analyzed by Dattappa (2022) among various half-sib progenies of *C. zeylanicum*, leaf flush colour diverged among the families, with G4, G16 and K13 families recorded a medium purple and S4 exhibiting a purple coloration, while K18 exhibited a green flush color. In contrast, J6, G4, G24 and S1 observed a light green leaf color, while K13 was characterized by its dark green foliage. All the progenies of cinnamon showed the entire leaf margin and showed leaf petiole with green colour. They also reported highest leaf area in the K13 family (59.52 cm^2) followed by the J2 (59.07 cm^2); while the S5 family had lowest leaf area (37.21 cm^2). The leaf fresh weight per plant was ranged from 470.16 g in G24 to 2649.67 g in G11 family.

C. zeylanicum progenies were assessed for leaf morphological traits by Liyanage *et al.* (2020). Among the leaf shapes, elliptic, narrowly elliptic, ovate, oval and ovate-lanceolate types were prevalent among both Sri Wijaya (SW) and Sri Gemunu (SG) progenies. Additionally, obtuse, acuminate, long acuminate, narrowly acuminate and acuminate with broad acumen leaf apex types were common across the progenies.Hanumantha (2020) reported variation for flush colour in cinnamon; they reported that majority of cinnamon progenies exhibited light purple leaves (50.94%), followed by medium purple (28.30%). However, almost all of progenies (85.00 %) had dark green leaves, while (14.15%) had green leaves. There was minimal variation in leaf petiole color, with only two progenies differing in petiole color; progenies K2 and G2featured purple petioles and the remaining progenies had green petioles. Majority of progenies, having leaf with elliptic shape (51.89%) and leaf tip with sub-acute shape (69.81%). Notably, only the G2 progeny had oblong-shaped leaves, setting it apart from the others. All progenies of cinnamon observed with entire leaf margin. About 239 cinnamon plants were assessed by (Krishnamoorthy *et al.*, 1988) and observed that around 55 per cent of these plants had green flushes, while the rest exhibited flushes with different shades of purple. Genetic control has been identified as the underlying factor influencing the differences in colour of leaf flush, leaf and leaf petiole. Studies conducted by Kaul *et al.* (1996) and Bakkali *et al.* (2008) concluded that the deep pink leaf flush colour has been linked to higher leaf oil yield in Cinnamon. A study by Wang *et al.* (2017) recorded leaf area exhibited significant variability, ranging from a maximum of approximately 17,727.424 mm^2 to a minimum of about 454.354 mm^2. Leaf length varied between 43.204 mm to 114.543 mm and width of leaf from15.55 mm to 41.34 mm in Camphor.Specific leaf characteristics were documented by Krishnamoorthy *et al.* (1996)for two cinnamon varieties. An average leaf length of 13.40 cm was recorded in Navashree variety and a breadth of 4.69 cm. In contrast, the Nithyashree variety measured an average length of 15.40 cm and breadth of 5.70 cm.Hanumantha (2020) reported significant variation for leaf area and biomass among top two year old 15 containerized progenies. Leaf area varied from 959 cm^2 (G4) to 1480 cm^2 (S1) with a mean leaf area of 1219 cm^2 Among the different progenies, K13, K16, S1 and S4 recorded more than 1400 cm^2 leaf area per plant as compared to other progenies. Mean fresh weight and dry weight of progenies was 106.16 g and 47.47 g respectively at 24 months. Coefficient of variation for all the biomass parameters varied from 9.05 to 21.14 per cent. Among all the progenies, K13, S1, S3, S4 and S9 performed well with higher biomass as compared to other progenies.

The effective display of leaves in a canopy is crucial for plant functioning because it determines the efficiency of the photosynthetic conversion of available light to assimilate and thus influences the potential growth of plants. Morphological characters are markers that can be adopted to measure the magnitude of diversity in plants based on the phenotypic character (Lizawati *et al.*, 2018). Leaf characteristics are highly variable in the genus *Cinnamomum* and this variation is seen both at species and sub species levels. Morphological characters can be used to recognize and describe species level similarities. Studying morphology of leaves helps in identifying and describing the plant correctly. Flush colour of the leaves is indicative of higher oil content in cinnamon (Hanumantha *et al.,* 2020; Krishnamoorthy *et al.,* 1992; Joy *et al.,* 1998). Of all the characters of cinnamon, leaves are the most variable. Krishnamoorthy *et al.* (1988) and Gopalam (1997) reported higher bark oil (29% more) in purple coloured leaves plants.

Differences in leaf characteristics among cinnamon trees can serve as useful indicators for identifying suitable genotypes. These variations can be employed as indirect selection criteria to choose superior trees with higher oil content and increased biomass The colour of the leaf flush is a reliable marker for higher essential oil production (Fig 4), facilitating the rapid domestication process through indirect selection of trees with superior oil yield (Hanumantha, 2020).The research suggested that when creating Distinctness, Uniformity and Stability (DUS) traits for identification, one can include characteristics like colour of leaf and leafflush as well as other parameters like leaf shape, leaf margin and leaf petiole. Given that, the leaf is avital economic trait of cinnamon, it is essential to identify genetic sources with a maximum leaf area and actively promote their cultivation.

Conclusion

Leaf characteristics are highly variable in the genus *Cinnamomum* and this variation is seen both at species and sub species levels. Morphological characters can be used to recognize and describe species level similarities. Studying morphology of leaves helps in identifying and describing the plant correctly. Considerable variation was noted in leaf characteristics among the selected progenies of *Cinnamomum zeylanicum*, with four distinct morphotypes related to leaf shapes (elliptic, ovate, ovate elliptic and ovate lanceolate) and four types of leaf tip shapes (acuminate, acute, and sub-acute), with acuminate tip shape being the most prevalent. Among the progenies, only two (G2 from Gejjehalli and K18 from Kankodlu sources) exhibited purple and light purple petiole coloration, while the rest displayed green petioles. Progenies of M21 showed superiority in all the quantitative leaf parameters; hence further work on these families helps in improvement of thespecies. The color of the leaf flush is regarded as an indicator of greater essential oil content and can be effectively utilized as a marker for indirectly selecting trees with superior oil production.

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