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Trait Diversity and Essential Oil Yield in Cinnamon: A Half-sib Genetic Study from Central Western Ghats, India

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Abstract: *Cinnamomum zeylanicum*, known as 'true cinnamon,' is an economically significant species valued for its spice and essential oil, particularly its high eugenol content. This study assessed the growth traits, leaf oil yield, eugenol content and reproductive parameters among 15 half-sib families of *C. zeylanicum* from the Central Western Ghats, India, with the objective to identify superior genotypes for genetic improvement. The progeny trial conducted at Bakkal Botanical Garden near Sirsi, Uttara Kannada district of Karnataka. Plant height, girth, branching, leaf count, inflorescence and immature fruit production of two-year-old progenies were recorded. Significant variability was observed in growth traits. Family G11 exhibited superior vegetative growth with maximum plant height (213.33 cm) and leaf production (677.66 leaves/plant), while K16 showed the maximum basal girth (51.46 mm). Leaf oil content ranged between 1.30 and 2.20 per cent (dry weight basis), where J6 achieved the highest oil yield. Eugenol content varied from 55.78 to 89.43 per cent among half-sib families where family S5 recorded the highest concentration. The negative correlation was recorded between total oil yield and eugenol concentration, indicating the importance of strategic balancing in selection breeding. Moreover, reproductive traits also showed variation and family J2 produced the highest number of inflorescence and immature fruits per plant. Study concludes that families such as G11, J6, K16, S5 and J2 can be considered as elite germplasm for future breeding and improvement programs. These findings provide an essential insight for enhancing both yield and quality of cinnamon, contributing to sustainable industry development.

Keywords: Essential oil yield, Eugenol content, Genetic diversity, Progeny evaluation, Western Ghats

Cinnamon (*Cinnamomum verum* Presl., syn. *C. zeylanicum* Blume; Family: Lauraceae) is one of the earliest known and most important tree spices of India. It is both cultivated and wild-harvested for its aromatic bark, leaves and immature fruits, which are widely used as a spice and in traditional medicine (Hanumantha and Vasudeva 2025a, 2025b). The Western Ghats and neighbouring regions of Southern India are believed to be the centre of diversity for the *Cinnamomum* genus (Sasikumar et al., 1999). The Western Ghats and some parts of North Eastern states of India exhibit wide variability in plant species (Joy et al., 1998). Cinnamon leaves find extensive use in spice production, food preparation and essential oil extraction. The leaf oil is particularly rich in eugenol, along with other constituents such as cinnamic aldehyde, benzaldehyde, pinene, phellandrene, methyl eugenol, geraniol and caryophyllene (Joy et al., 1996). Presently, India's total cinnamon cultivation area is approximately 2,800 hectares, India's total cinnamon production is around approximately 5,050 tonnes in that Karnataka's contribution is around approximately 0.2 percent of the national production (Spices Board of India 2022).

Key producers are Indonesia, China, Vietnam and Sri Lanka. Key importers are Mexico, USA, India and Bangladesh. India is a net-importer of cinnamon from countries such as Indonesia, Vietnam, and Sri Lanka as domestic supplies are too small to meet the growing demands of domestic consumption and export demand of value added spices, wherein cinnamon is mixed with other spices (Singh and Singh 2008).

India is a net-importer of cinnamon from countries such for quality and final yield. To further enhance the quality of Ceylon cinnamon, Department of Export Agriculture (DEA) in Sri Lanka introduced two varieties, namely Sri gamunu (SG) and Sri Wijaya (SW), through long-term selection (Wijesinghe and Pathirana 2000). However, farmers do not benefit from these advancements as cinnamon is primarily propagated through seeds. Additional efforts are necessary to select superior genotypes and maintain genetic uniformity. The current methods of vegetative propagation are not efficient enough to meet the demand for planting material. Moreover, farmers are hesitant to adopt vegetatively propagated materials due to unresolved crop management and maintenance issues. In order to address these challenges, a progeny trial was conducted to identify superior genotypes based on their performance.

MATERIAL AND METHODS

The present study was undertaken during 2021-22 at the Bakkal Botanical Garden, near Sirsi, Uttara Kannada district, which is located in the Central Western Ghats between 13° 55' to 15° 32' N latitude and 74° 05' to 75° 05' E longitude with a geographic area of 10,291 km^2. The study area consists of germplasm conservation site in Bakkal Botanical Garden near Hulekal, Sirsi and it consists of 15 half sib progenies of different families with three replications in each family. The experiment was in RCBD with three replications. Sources of half sib progenies of *Cinnamomum zyalanicum* were Jaddigadde of Sirsi forest range (J2 and J6), Gejjehalli of Hangal forest range, G4, G11, G16 and G24), Kankodlu of Yellapura forest range (K5, K10, K13, K16 and K18) and local of Siddapura forest range (S1, S4, S5 and S9).

Plant height was measured by, from ground level up to the top of the plant. Girth at collar region of the plant was measured at the collar region with a digital caliper, whereas in the case of two stems, the observation was taken from both stems and the average value was calculated. Number of branches and of number of leaves per plant were manually counted and recorded. The inflorescence and immature fruits per plant were also manually counted. Similarly, total fresh weight of leaves per plant was estimated by calculating the mean fresh weight of ten sampled leaves by multiplying it with total number of leaves. The fresh weight of leaves of fruits per plant was estimated by calculating mean fruit fresh weight of ten samples by multiplying it with total number of fruits per plant. The data were subjected to a one-way analysis of variance (ANOVA) using the online statistical software OPSTAT Sheoran et al. (1998).

The leaf essential oil was extracted at the 28 months after transplanting (May, 2022). About 100-150 g of fresh leaves were collected from selected progenies and stored in the room temaparature (Shade dried) and oil extraction was done by water distillation as quoted by Hanumantha (2020).

$$\text{Essential oil (\%)} = \frac{\text{Volume of oil}}{\text{Weight of sample}} \times 100$$

The collected leaf samples were subjected to RP-HPCL at K2VR Analytical Research Pvt. Ltd., Bangaluru, Karnataka for eugenol content assessment.

RESULTS AND DISCUSSION

Variation in growth attributes: There was significant variation among the fifteen half-sib progenies of *Cinnamomum zyalanicum* for growth parameters namely girth, number of leaves and number of branches per plant at 28 months after planting (MAP), however, height was non-significant (Table 1). The highest girth of 51.46 mm was in K16 family and was lowest in the K18 (20.69 mm). The greater number of leaves (677.66 per plant) were observed in G11 and lesser number of leaves in K18 (175.33). The greater mean number of branches per plant (50.33) were also in G11 and was lowest in K5 family (14.00 per plant). These variations may be due to the genetic variations and environmental factors. The coefficient of variation) was ranged from 21.22 % (girth) to 34.17 % (number of leaves). Wang et al. (2017) also reported variation in seven months old seedling growth of *Cinnamomum camphor* and the range of variation for basal diameter was 0.1 to 2.35 cm whereas height varied from 23 to 130 cm. Hanumantha (2020)

Table 1. Variation in growth parameters (among the selected progenies of *C. zeylanicum* at 28 months after planting (Mean ± SE)

Family code	Plant height (cm)	Girth at collar region (mm)	No. of branches/plant	No. of leaves/plant
J2	168.33±23.33	40.46±4.03	33.33±5.69	380.66±34.35
J6	165.00±18.02	31.64±3.71	31.00±4.16	423.66±77.02
G4	213.00±9.074	39.04±3.52	36.66±6.38	375.66±88.00
G11	213.33±21.66	42.03±3.67	50.33±1.20	677.66±86.19
G16	147.33±28.26	22.20±1.47	24.00±3.21	240.33±67.99
G24	137.00±38.55	25.99±1.67	34.33±7.12	191.66±70.96
K5	147.33±31.97	35.03±1.57	14.00±1.15	430.33±25.49
K10	187.33±6.48	31.89±4.25	28.66±6.43	368.33±52.27
K13	210.33±30.38	36.97±7.48	29.66±6.36	318.33±44.19
K16	184.00±10.69	51.46±6.39	38.00±6.08	444.00±42.00
K18	112.33±4.48	20.69±3.26	31.33±8.64	175.33±14.83
S1	171.33±6.83	38.85±5.43	44.33±8.66	665.33±194.65
S4	164.00±11.01	37.44±3.16	51.00±7.50	533.00±76.51
S5	162.33±21.69	31.37±4.45	47.66±5.04	334.66±38.40
S9	185.33±5.23	29.97±2.21	33.66±4.63	320.00±5.77
CD (p=0.05)	NS	12.25	17.84	225.19
CV (%)	21.36	21.22	30.14	34.17

assessed the 90 *C. zeylanicum* progenies and reported significant variation in plant height at 24 MAT and attained mean height of 73.12 cm. Such observation was also reported by Swarnapali and Subasinghe (2004)

Variation in leaf oil and eugenol content: Wide variation was recorded in leaf oil among the selected 15 progenies from different half-sib families of *Cinnamomum zyalanicum*. Oil content (v/w dry weight basis) ranged from 1.30 to 2.20 per cent with 9.7 per cent CV (Fig. 1). The maximum leaf oil content (2.20%) was recorded in family J6, followed by S4 (2.10%) and it was least (1.30%) in G24 family (Table 2). The variation in leaf oil content is attributed due to genetic factors. Apart from genotypic variation, plant protection and climatic factors also contribute to variations in leaf oil content (Kaul et al., 1996, Bakkali et al., 2008). Hanumantha (2020) reported leaf oil content of 1.28 to 1.60 per cent variation in *C. zeylanicum*. Ariyarathne et al. (2018) also assessed variability in amount of leaf oil using different *Cinnamomum* species. Further, as per Joy et al. (1998) and Krishnamoorthy et al. (1992), the leaf oil variation was reported to be 0.39 to 3.16 per cent. Considering cinnamon leaf eugenol, it is widely used in perfumery industries which possess antimicrobial and antifungal properties. In this study, a notable variation in eugenol content was recorded among the selected 15 progenies and it varied from 55.78 to 89.43 per cent (Table 2). The highest eugenol content was recorded in S5 (89.43%), K16 (88.57%) and G24 (87.43%) families and it was lowest in J6 (59.29%). Variation in eugenol content in leaf oil sample may be attributed by genetic effect, since these genotypes are grown in uniform environmental condition. Such variation for eugenol content was also reported by Hanumantha (2020) in *Cinnamomum zeylanicum* leaf oil (73.60 to 95.80 %) at Western Ghats of Karnataka, Chalchat and Valade (2000) reported 80.53 to 93.67 per cent variation in Odakkalli accessions of Kerala, Schmidt et al. (2006) recorded 74.90 to 76.74 per cent variation from Sri Lanka population, and Paranagama et al. (2001) reported 73.27 per cent eugenol content in cinnamon leaf from the Brazil.

There was strong negative association was observed between total leaf oil and eugenol content (R^2 = 0.630). This inverse relationship could be attributed to the compositional complexity of cinnamon leaf oil, which, apart from eugenol, also contains other constituents such as cinnamaldehyde, linalool and camphene. As the overall oil yield increases, the relative proportion of eugenol may decline due to the increased presence of these other compounds. Eugenol is one of the commercially valuable constituents of cinnamon oil, such a negative association should be carefully considered in selection and breeding program. These findings highlight the need for a balanced approach when selecting genotypes for higher oil yield to ensure that the concentration of key compounds like eugenol is not compromised.

Variation in reproductive attributes: The immature fruits of *C. zeylanicum* are a valuable commercial product with high market demand and price. Surprisingly, this characteristic has not been considered for selection in any previous studies. The large coefficient of variation was observed in total inflorescence per plant (125.42), followed by fruit weight per plant (113.94) and lowest was in immature fruit per plant (115.77). The maximum inflorescence (16.66 no./plant) and immature fruit (6.00 per plant) was in J2 family (Table 3). Hanumantha (2020) observe , four parameters *i.e.* fruit

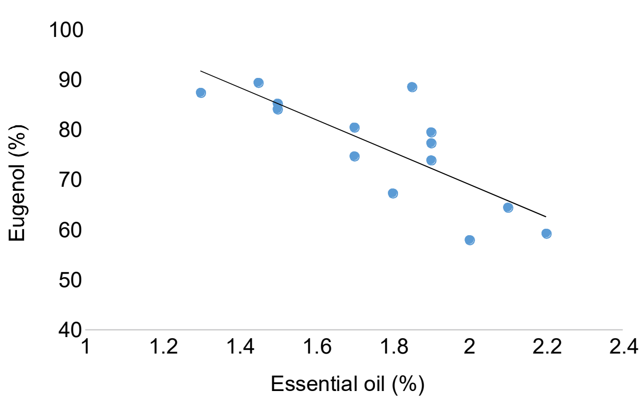

Fig. 1. Correlation between leaf oil (%) and eugenol content (%) in *C. zyalanicum*

Table 2. Variation in leaf oil and eugenol content among the selected progenies of *C. zeylanicum* at 28 months after planting

Family I.D.	Leaf oil content (%)	Eugenol (%)
J2	1.70	80.49
J6	2.20	59.29
G4	1.70	74.73
G11	2.00	58.00
G16	1.50	84.12
G24	1.30	87.43
K5	1.50	85.27
K10	1.90	73.93
K13	1.90	79.53
K16	1.85	88.57
K18	1.80	67.33
S1	1.90	77.35
S4	2.10	64.48
S5	1.45	89.43
S9	No data	No data
CV (%)	9.78	19.44

Table 3. Variation in reproductive parameters among the selected progenies of *C. zeylanicum* at 28 months after planting (Mean ± SE)

Family code	Inflorescence/plant (numbers)	Immature fruits/ plant (numbers)	Fruit weight/ plant (g)
J2	16.66±5.45	6.00±2.08	0.23±0.08
J6	3.33±2.02	2.00±1.00	0.21±0.11
H29	5.33±2.90	5.33±2.90	0.157±0.10
H36	15.66±9.90	4.00±2.08	0.27±0.14
H41	0.33±0.33	4.66±4.66	0.00±0.00
H49	5.66±5.66	1.66±1.66	0.03±0.03
K5	3.33±3.33	0.66±0.66	--
K10	8.00±6.02	4.33±2.40	--
K13	1.33±1.33	1.66±1.66	--
K16	11.33±6.96	2.33±1.20	0.11±0.07
K18	4.00±2.08	3.00±1.73	0.09±0.09
S1	13.33±6.88	3.66±2.02	0.16±0.09
S4	10.00±7.02	3.66±0.33	0.23±0.01
S5	4.33±2.33	2.33±1.20	0.15±0.07
S9	3.33±1.76	2.33±1.45	0.14±0.09

bearing density of individual trees, the number of immature fruits per foot of inflorescence and the fresh/dry weight of immature fruits per tree were examined to identify the best individuals. Among the trees assessed, Siddapura exhibited the highest mean fruit bearing density (2.80). The tree from Jaddigadde displayed the highest coefficient of variation for fruit bearing density (42.89%). The number of immature fruits per foot of inflorescence also varied among the selected mother trees which ranged from 10 to 135 fruits. The tree identified as G6 produced the maximum number of immature fruits (135). Additionally, Gejjehalli had the highest mean number of fruits per foot of inflorescence (88.32), indicating that it is a suitable source for selecting trees with high production of immature fruits. Krishnamoorthy et al. (2001) evaluated yield and quality parameters of ten *Cinnamomum cassia* accessions and reported significantly higher coefficient of variation for fruit yield per tree (107.11 per cent).

CONCLUSION

Variation in growth traits, leaf oil and eugenol content, and reproductive attributes among half-sib progenies of *C. zeylanicum*. Half-sib families like G11, J6, K16, S5 and J2 demonstrated superior performance in various economic traits, indicating these are ideal candidates for future breeding and improvement programs. The negative correlation between oil yield and eugenol content highlights the need for a balanced selection approach to optimize both quantity and quality. Furthermore, the study identified potential in immature fruit production, an often-overlooked trait with commercial relevance. These findings provide a valuable foundation for selecting elite genotypes aimed at enhancing cinnamon's economic value, ensuring sustainable production and supporting both spice and essential oil industries in India.

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