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RESEARCH PAPER

Assessment of variation for leaf parameters among different sources of *Terminalia arjuna* (Roxb.) Wight &Arn. in Uttara Kannada district of Western Ghats

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Abstract: *Terminalia arjuna* is one of the medicinally important native tree species of India and Sri Lanka and well known for its superlative cardio-protective properties. As bark is the most economical part of the tree, only a handful of information is available on leaves, but leaves act as good morphological markers to assess morphometric superiority of the trees. Present investigation was carried out to study variation of quantitative and qualitative parameters of leaf in four different girth classes (G_1: 0-50 cm, G_2: 50-100 cm, G_3: 100-150 cm and G_4: >150 cm) of four different sources of Uttara Kannada district {Hosakambi (S_1), Manchikeri (S_2), Yellapura (S_3), and Mundgod (S_4)}. Significant variation was observed in quantitative leaf parameters *i.e.,* leaf length, leaf width and leaf area; among the sources highest leaf length (15.10 cm), leaf width (4.80 cm) and leaf area (70.90 cm^2) was recorded for the trees of Hosakambi source (S_1). Among the girth classes, highest leaf length (17.00 cm), leaf width (5.10 cm) and leaf area (81.70 cm^2) was recorded for leaves of G_1 girth class. Significant variation was observed in qualitative leaf parameters *i.e.,* leaf shape, leaf tip shape and leaf margin. Among the sources, more oblong (38.33%) and elliptical (38.33%) shaped leaves; more leaves with crenate-serrate margin (76.67%) were recorded in Mundgod source (S_4). Whereas, Hosakambi (S_1) source recorded more number of leaves with sub-acute leaf tip (56.67%). Overall, among the sources and girth classes, more number of trees exhibited elliptical shaped leaves (38.00%), more number of leaves with crenate-serrate (72.00%) margin and higher proportion of sub-acute (53.00%) leaf tip shapes. The current study revealed that the leaf parameters are reliable morphological characters to study the source variation.

Keywords: Diversity, Morphological markers, Source variation, Qualitative, Quantitative

Introduction

Terminalia arjuna **(**Roxb.) Wight & Arn**.** commonly known as Arjuna is a member of Combretaceae family. It is a large (30 m) deciduous tree, native to India and Sri Lanka. It has been introduced to the tropical and subtropical regions of the world as an ornamental and avenue tree and reported to be planted in numerous African nations and now it has been naturalized in these nations. Although the extent of its dispersion is unknown exactly, Arjuna is found to be widely distributed in Southern Asia, Himalayas, Madagascar, Australia, and the tropical and subtropical regions of Africa. *T. arjuna* is primarily found to be distributed along riverbanks and streams of moist deciduous and evergreen forests of all states through out the India (Zhang *et al*., 2019).

Arjuna thrives well at an altitude of 0-1200 m with an annual rainfall of 75-190 cm and fertile soil with pH of 6.5-7.0. The tree has buttressed trunk and superficial, shallow root system spreads along river banks or stream banks. The tree has large spreading crown produces drooping branches. Bark is whitish grey or pinkish-green in colour, thick and smooth. Leaves of the tree are simple and sub-opposite, 10-15 cm in length and 4-7 cm broad; Leaves are oblong or elliptic oblong, glabrous, apex obtuse or sub-acute, base is rounded or sometimes sub-cordate and veins are reticulated. Leaves sprout usually during the period of February-April. Petiole is short, sericeous with two glands at petiole apex. Inflorescence is short axillary spikes or small terminal panicles, 9.0-13.0 cm long with 2.5-6.0 cm long branches. Flowers are simple, small, panicled, regular, polygamous, white, creamy or greenish-white, it usually flowers during months from May to June. Fruits are about 2.2 - 5.0 cm in size, woody drupes, usually having five wings, and fruiting occurs from January to March. Seeds are orthodox and viable up to one year. The trees are usually found in moist deciduous to evergreen forests of India. The tree listed as near threatened (NT) under IUCN (Kelly, 2002).

Arjuna is one of the most versatile medicinal plants having a wide spectrum of biological activity. The bark of *arjuna* consist of properties like, anti-dysentric, antipyretic, astringent, cardiotonic, lithotriptic, anticoagulant, hypolipidemi, antimicrobial and Antiuremic agent. Many useful phytoconstituents have also been isolated from Terminalia arjuna which include triterpenoids for cardio vascular properties, tannins and flavonoids for its anticancer, antimicrobial properties and soon. The powder of the bark acts as a diuretic in cirrhosis of liver and gives relief in symptomatic hypertension. Its leaves have been shown to have analgesic and anti-inflammatory properties (Mandal *et al.,* 2013; Hanumantha *et al.,* 2020)

Source is defined as “the area or place from which plant materials or samples are collected for study or research”. Leaves act as good morphological markers to assess the diversity status of trees and leaf size and shapes can be used as a gauge of the environmental factors that affect plant growth such as soil type, topography, and climate (Zobel and Talbert, 1984). The current investigation was carried out to study variation of leaf traits of *arjuna* in different sources of Uttara Kannada.

Material and methods

Uttara Kannada is a large district with a geographical area of 10,291 km^2 has a rich biodiversity of flora and fauna. It is located in the Central Western Ghats between 13°55' to 15° 32' N latitude and 74° 05' to 75° 05' E longitude. The average rainfall is about 250 to 350 mm and the mean annual temperature is ranging from 25° C to 30° C. Uttara Kannada district has twelve taluks with five perineal rivers and more than 75 per cent of forest cover.

Sixty trees in four different girth classes *viz*.,G_1: 0-50 cm, G_2: 50-100 cm, G_3: 100-150 cm and G_4: >150 cm, were selected from four different sources *viz*., Hosakambi (S_1), Manchikeri (S_2), Yellapura (S_3), and Mundagod (S_4), of Uttara Kannada district (Fig. 1). These four sources are located along the river banks, streams, and ravines. Among the four sources, S_1 falls nearer to coastal region with alluvial loamy soil, S_2 and S_3 in moist region with alluvial black cotton soils, where as S_4 falls under dry region with lateritic black loamy soils. Ten mature leaves were collected from each tree for the assessment. Quantitative (leaf length, leaf width, leaf area and petiole length) and qualitative leaf parameters (leaf shape, leaf tip shapes and leaf margin) were recorded for ten leaves in each tree and averaged. Statistical analysis of the data was done by two factors ANOVA (Hanumantha and Vasudeva, 2022)

Results and discussion

Variation for quantitative leaf parameters

The Table 1 shows that the leaf parameters were significantly varies with respect to the sources and the girth classes. Among the four sources highest leaf length (15.10 cm), leaf width (4.80 cm) and leaf area (70.90 cm^2) was recorded for the leaves of Hosakambi (S_1) source and the lowest leaf length (13.60 cm), leaf width (4.00 cm) and leaf area (52.50 cm^2) recorded for Mundgod (S_4) source. Reduction in the leaf parameters (leaf length, leaf width and leaf area) along the altitude gradient was observed; Hosakambi (msl 17 m) source recorded the highest leaf attributes followed by Manchikeri (537 m), Yeallapura (541 m) and Mundagod (msl 564 m).

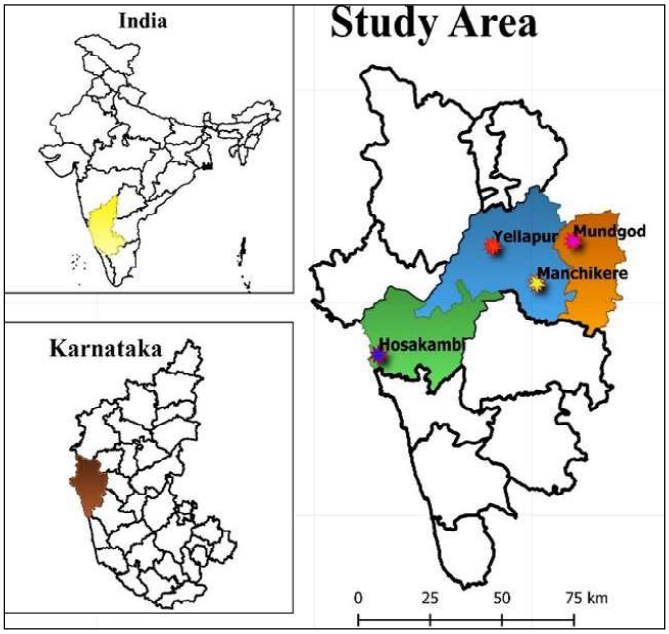

Fig. 1. Map showing study area

Table 1. Variation for quantitative leaf parameters among the sources and the girth classes of *Terminalia arjuna*

Source	Girth class (cm)	Leaf length(cm)	Leaf width (cm)	Leaf area (cm^2)	Petiole length (cm)
Hosakambi(S_1)	G_1	17.00	5.10	81.70	0.70
	G_2	15.20	4.90	74.70	0.70
	G_3	15.10	4.70	66.50	0.60
	G_4	13.20	4.60	60.80	0.70
	Source mean	15.10	4.80	70.90	0.70
Manchikeri(S_2)	G_1	15.60	4.10	59.00	0.60
	G_2	14.80	4.30	57.80	0.60
	G_3	13.50	3.90	54.90	0.50
	G_4	12.90	3.90	50.10	0.50
	Source Mean	14.20	4.10	55.50	0.60
Yellapura(S_3)	G_1	15.30	4.10	63.90	0.60
	G_2	14.30	4.60	56.60	0.60
	G_3	13.70	3.90	46.30	0.60
	G_4	13.70	3.70	43.50	0.60
	Source Mean	14.30	4.10	52.60	0.60
Mundgod(S_4)	G_1	14.70	5.20	64.00	0.70
	G_2	13.70	4.00	56.30	0.60
	G_3	13.50	3.90	46.40	0.60
	G_4	12.60	3.10	43.30	0.50
	Source Mean	13.60	4.00	52.50	0.60
S.Em ±	Source (S)	0.23	0.13	2.01	0.03
	Girth class (G)	0.23	0.13	2.01	0.03
	S × G	0.46	0.26	4.11	0.05
C.D@5%	Source (S)	0.64	0.36	5.74	0.07
	Girth class (G)	0.64	0.36	5.74	0.07
	S × G	N.S.	0.712	N.S.	N.S.

*Girth classes (G) - G_1: 0-50 cm, G_2: 50-100 cm, G_3: 100-150 cm and G_4: >150 cm

Similarly, Wani and Singh (2016) studied the variation for leaf attributes in *Terminalia arjuna*; they reported that reduction in the leaf attributes along the altitude gradient; leaf size was more in Achanakmar which has the lowest altitude followed by Chhapparwa and Lamini. Phenotypic variation of leaf size among the sources was due to genetic factor or environmental factors.

Highest leaf length (17.00 cm) was recorded in the G_1 followed by G_2 (15.20 cm), G_3 (15.10 cm) and the lowest (12.60 cm) leaf length was recorded for the G_4 girth class. Maximum leaf width (5.20 cm) and leaf area (81.70 cm^2) was recorded for leaves of G_1 girth class; whereas, lowest leaf width (3.10 cm) and leaf area (43.30 cm^2) was recorded for the G_4 girth classes and the trend is similar in all the four sources. Higher petiole length (0.7 cm) recorded for Hosakambi (S_1) and other three sources recorded same petiole length (0.6 cm). Among the girth classes petiole length varied from 0.5 to 0.7 cm; G_3 and G_4 girth class of the Mundgod (S_4) and Manchikeri (S_2) sources showed the lowest petiole length (0.5 cm), whereas, G_1 and G_2 girth class of all the sources showed the higher (0.7 cm) petiole length (Table 1).

Similarly, reduction of leaf area with tree height and girth was reported in *Eucalyptus regnans* (England and Attiwill, 2006). The reduction in leaf area with age/girth was mainly to overcome the physiological process mainly the transpiration.

Variation for leaf qualitative parameters

Variation for qualitative leaf characters like leaf shape, leaf margin and leaf tip shape were recorded among the sources and girth classes and it was inferred that *Terminalia arjuna* leaves showed three different shapes *i.e.,* oblong, elliptical and oblanceolate. Among the sources, the Mundgod (S_4) exhibited more oblong (38.33%) and elliptical (38.33%) shaped leaves. Higher (31.67%) number of oblanceolate shaped leaves was recorded in Yellapura (S_3) source (Table 2). In overall, among the sources and girth classes, more number of trees exhibited elliptical shaped leaves (38.00%) followed by oblong (34.00%) and oblanceolate (28.00%) shaped leaves (Fig.2).

Only two types of leaf margin *i.e.,* entire and crenate-serrate (leaf margin between the crenate and serrate) were reported

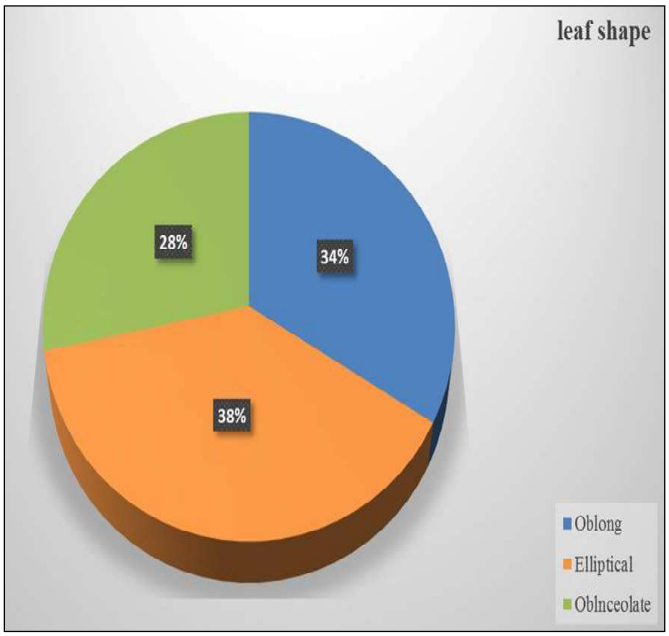

Fig. 2. Leaf shape variation in *Terminalia arjuna*

Table 2. Variation for qualitative leaf parameters among the different sources and the girth classes of *Terminalia arjuna*

Sources	Girth class	Leaf shape			Leaf margin		Leaf tip shape	
		Oblong	Elliptical	Oblnceolate	Entire	Crenate-serrate	Obtuse	Sub-acute
Hosakambi(S_1)	G_1	10.00	10.00	5.00	8.33	16.67	8.33	16.67
	G_2	8.33	8.33	8.33	8.33	16.67	16.67	8.33
	G_3	5.00	11.67	8.33	3.33	21.67	10.00	15.00
	G_4	8.33	8.33	8.33	8.33	16.67	8.33	16.67
	Σ(Sum)	31.60	38.33	30.00	30.00	70.00	43.33	56.67
Manchikeri(S_2)	G_1	6.67	10.00	8.33	5.00	20.00	10.00	15.00
	G_2	10.00	8.33	6.67	3.33	21.67	13.33	11.67
	G_3	8.33	8.33	8.33	11.67	13.33	15.00	10.00
	G_4	10.00	10.00	5.00	11.67	13.33	11.67	13.33
	Σ(Sum)	35.00	36.67	28.33	31.67	68.33	50.0	50.00
Yellapura(S_3)	G_1	8.33	10.00	6.67	8.33	16.67	13.33	11.67
	G_2	5.00	11.67	8.33	5.00	20.00	13.33	11.67
	G_3	8.33	8.33	8.33	6.67	18.33	11.67	13.33
	G_4	8.33	8.33	8.33	5.0	20.0	8.33	16.67
	Σ(Sum)	30.00	38.33	31.67	25.00	75.00	46.67	53.33
Mundgod(S_4)	G_1	11.67	10.00	3.33	6.67	18.33	18.33	6.67
	G_2	8.33	10.00	6.6	8.33	16.67	8.33	16.67
	G_3	8.33	11.67	5.00	5.00	20.00	13.3	11.67
	G_4	10.00	6.67	8.33	3.33	21.67	10.00	15.00
	Σ(Sum)	38.33	38.33	23.33	23.33	76.67	50.00	50.00
Mean		8.44	9.48	7.08	6.88	18.13	19.00	21.00
S.D.		1.77	1.46	1.67	2.78	2.78	14.93	16.44
C.V. (%)		20.9	15.4	23.5	40.40	15.30	26.10	23.60

*Girth classes (G) - G_1: 0-50 cm, G_2: 50-100 cm, G_3: 100-150 cm and G_4: >150 cm

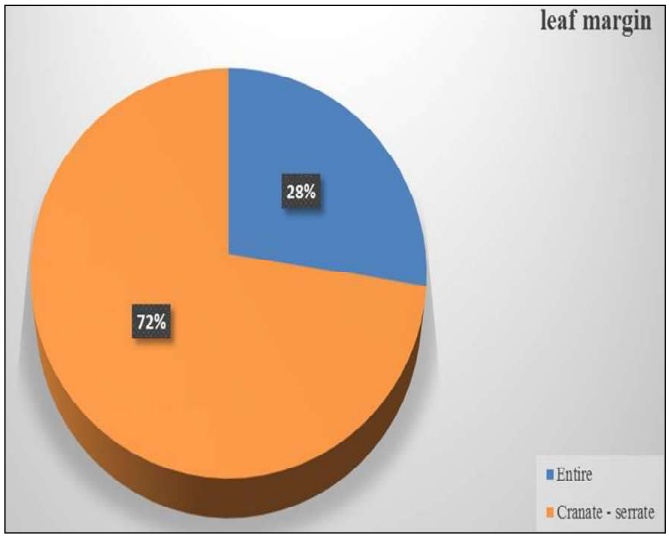

Fig. 3. Leaf margin variation in *Terminalia arjuna*

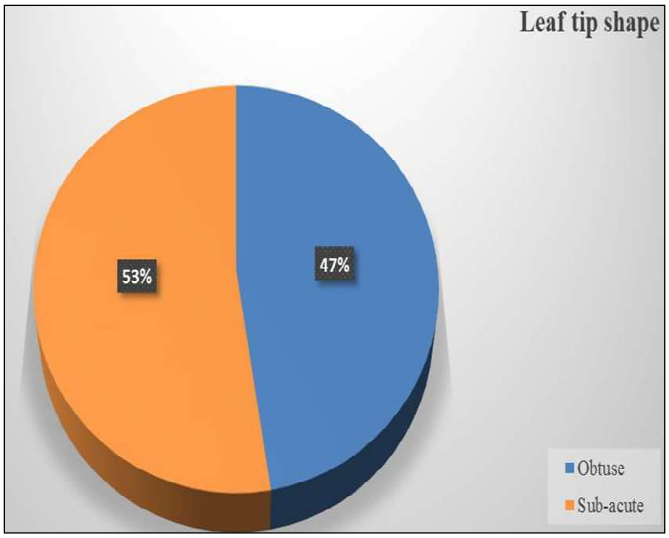

Fig .4. Leaf tip shape variation in *Terminalia arjuna*

from this study. Table 2 represents the variation for leaf margins among the sources; More crenate-serrate (76.67%) margined leaves were recorded from Mundgod (S_4) source, whereas more entire (31.67%) margin leaves were recorded in Manchikeri (S_2) source. In overall, among the sources and girth classes, more crenate-serrate (72.00%) margin leaves were recorded and less leaves with entire (28.00%) margin leaves (Fig. 3).

Among the sources and girth classes two types of leaf tip shapes were recorded *i.e.,*obtuse and sub-acute, whereas, among sources Hosakambi (S_1) source exhibits more sub-acute tip shapes (56.67%) followed by Yellapura (S_3), Manchikeri (S_2) and Mundgod (S_4). Higher numbers of obtuse tip shaped leaves were recorded in Mundgod (50.00%) and Manchikeri (50.00%) source compared to other sources. Over all among the sources and girth classes, sub-acute leaves represented in higher proportion (53.00%) as compared to the obtuse (47.00%) (Fig. 4).

Similarly, Desai and Chanda (2014) studied the variation for leaf shapes of *T. arjuna* in Rajkot, Gujrat; they reported more number of leaves with crenate- serrate margin, sub-acute leaf tip shape/apex and oblong leaf shape compared to entire margin, obtuse tip shape and elliptical and oblanceolate leaves respectively. Similar study was carried out by Gurevitch (1992) on *Achillea lanulosa* and they reported that the variations in leaf parameters were mainly attributed due to environmental factors (rainfall, temperature, altitude, *etc*.).

Conclusion

Terminalia arjuna is one of the important tree species of Western Ghats and it is extensively harvested for its bark; but only limited studies were carried out on different aspects of this species. Uttara Kannada district exhibits wide variation in *Terminalia arjuna* population with respect to different growth parameters. Variation in leaf parameters among trees/sources can be used as good morphological markers to analyse the variation and to identify the superior source and trees within sources. Hence, the present study was undertaken to study the variation in quantitative and qualitative leaf parameters among the four different sources and girth classes. Wide variation was noticed for both quantitative and qualitative parameters among girth classes and sources. Among the different sources, higher leaf area was recorded in Hosakambi (70.90 cm^2) followed by Manchikeri (55.50 cm^2), Yellapura (52.60 cm^2) and Mundgod (52.50 cm^2). Among the girth classes higher leaf size was recorded for the G_1 girth class (81.70 cm^2) followed by G_2 (74.70 cm^2), G_3 (66.50 cm^2) and the lowest leaf area for G_4 (43.30 cm^2). Variation for qualitative leaf parameters like leaf shape, leaf tip shape and leaf margin was reported, Elliptical shape (38.00%), crenate-serrate leaf margin (72.00%) and sub-acute leaf tip shape/apex (53.00%) were predominantly found among all the selected trees. The variation reported between sources and girth classes can be utilized for selection of source with the superior trees, which can be further utilized for mass multiplication or breeding programmes.

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