Genet Resour Crop Evol (2020) 67:241–255
https://doi.org/10.1007/s10722-019-00820-7

RESEARCH ARTICLE

Taxonomic identity, occurrence of six species of *Salacia* and first report on chromosome numbers of the *Salacia chinensis* L. and *Salacia oblonga* Wall ex Wight and Ern Var. from Western Ghats of Karnataka (India)

Sheetal Ganapati Kamat · R. Vasudeva · Chandrashekar G. Patil

Received: 12 February 2019 / Accepted: 9 August 2019 / Published online: 11 September 2019

Abstract The genus *Salacia* is an important element of the forest flora of the Western Ghats of Karnataka and is well known for its anti-diabetic properties. The region hosts a wide diversity with several taxa. The genus is considered as a taxonomically difficult one due to the complexity and diversity in floral characteristics. The species is still poorly understood with respect to its cytological characteristics. The present study explicates the diversity and distribution of *Salacia* species in the Western Ghats of Karnataka. Here, we also present the first report of the chromosome numbers of the species *Salacia chinensis* L. and *Salacia oblonga* Wall ex Wight and Ern Var. and is different from those of other previously reported *Celastraceae* genera. Conservation status of *Salacia* species of the Western Ghats of Karnataka has also been revised in this study. The diversity of floral morphology, leaf morphology, fruit and seed morphology, stem and root morphology were elaborated along with a dichotomous key to the Western Ghats species. Morphological study in *S. chinensis* L., *S. malabarica* Gamble, *S. oblonga* Wall ex Wight and Ern Var, *S. macrosperma* Wight, *S. reticulata* Wight and *S. gambleana* Whiting and Kaul is done for the first time using descriptor analysis. The paper describes 73 morphological traits that appear to be at least partly genetically controlled and can be used as descriptors of *Salacia* species.

Keywords *Salacia* · Descriptors · Diversity · Conservation · Somatic chromosomes

S. G. Kamat (✉)
Department of Applied Genetics, Karnataka University, Dharwad, India

R. Vasudeva
Department of Forest Biology and Tree Improvement, College of Forestry, University of Agricultural Sciences, Dharwad, Sirsi, India
e-mail: vasukoppa@gmail.com

C. G. Patil
Department of Botany, Karnataka Science College, Dharwad, India
e-mail: patil.cg1970@gmail.com

Introduction

Many drugs listed as traditional medicines were primarily derived from plants. Diverse wild medicinal plants including herbs, lianas and trees or their related parts like leaves, stems, roots, fruits and flowers are used in traditional medicinal systems (Marshall 2011). Although there is no record for exact total number of medicinal plants around the world, about half million plants around the world are considered as medicinal plants and the numbers and share of each country vary (Schippmann et al. 2002). Medicinal plants have favourable future because most of their medical activities have not been explored yet and their medical activities could be vital in the treatment of many diseases (Hassan 2012).

The genus *Salacia* comprises several medicinally important species (*S. chinensis*, *S. oblonga*, *S. malabarica*, *S. macrosperma, S. reticulata* etc.) and is known as Saptrangi in Ayurveda medicine and used as medicine for the treatment of Diabetes. Genus *Salacia* belongs to family Celastraceae. *Salacia* species are widespread in tropical and subtropical regions including North Africa, South America and East Asia, particularly in China (Spivey et al. 2002). The Genus *Salacia* consists of about 131 species in the world (http://www.theplantlist.org/).

In India genus *Salacia* is represented by 21 species, of which 15 species are known to occur in Peninsular India and it is distributed in Karnataka (rare in semi-evergreen forests of Western Ghats), Kerala (coastal forests of Kollam, Western Ghats of Pathanamthitta and Idukki districts) and Sothern Orissa (Ramamurthy and Naithani 2000). Among them, eight species are recorded from Karnataka (Herbarium JCB 2016). To get more evidence about the current variation in Karnataka and other states of India, it will be necessary to establish organised national germplasm collections, and to describe accessions according to a proper descriptor list. The variation that is observed among individuals can be the result of their genetic structure, the effect of the environment and the interface between these factors. Therefore, morphological variation will be due to some degree of genetic variability, but it will also be intertwined with variation caused by various environmental factors. However, in the lack of direct genetic methods, morphological variation of a group of traits is frequently used to determine the population structure of a species (Hughes 2001).

The descriptors of *Salacia* species have not yet been fully defined. It would be very useful to establish a descriptor list for each of the economically important *Salacia* species in order to classify all important and genetically controlled traits. Descriptors are essential for the determination of cultivars and conservation of the germplasm. For this purpose it would be very helpful to have consistent data about the variation within species.

The main objective of this paper was to prepare the list of morphological traits, which could be used in description of the *Salacia* species of Western Ghats of Karnataka, and as selection criteria in genetic breeding. To our knowledge there are no previously published chromosome numbers for the species *S. chinensis* and *S. oblonga.* This paper also provides the first report of the chromosome numbers of these species.

Material and method

Descriptor analysis

The descriptor list is based on the documented observations of the phenotypic variation within various germplasm collections of natural populations of *Salacia* species during the period 2014–2018. It included 6 species collected from different geographical regions of Western Ghats of Karnataka (Table 1).

The assessment of morphological factors was based on the observation of variation of particular trait within individuals (e.g., the shape of leaf apex was determined on 5 or more leave on the same plant) and or within different plant of same species. The observations of variation within the same individual was more frequently used because the number of individuals was limited for same species. The species were identified at the beginning of flowering. Colours were observed when plants are fully exposed to sun. The list of morphological traits that can be used as descriptors for *Salacia* species are given in Table 2.

Somatic chromosome preparation

Somatic chromosomes were examined using root tips collected from seedlings. Mitotic squash preparations were made by pre-treating root tips in with 0.002 M 8-hydroxyquinoline for 2–3 h, a saturated aqueous solution of paradichlorobenzene for 4–5 h fixing was done with freshly prepared Carnoy fluid (ethanol alcohol: glacial acetic acid = 3:1), after washing with distilled water three times hydrolyzed in 1 M HC1 for 8 min at room temperature, and stained with 1% aceto-orcein for 15 min. Then the root tips were heated slightly and squashed on glass slide and were observed under microscope and photographs were taken. The experiment was repeated three times (Xin-Hua et al. 2010).

Table 1 *Salacia* species in the Western Ghats: IUCN status and distribution

Sl. no	*Salacia* species	IUCN status	Distribution	Locality
1.	*S. chinensis*	–	Southern India, Sri Lanka	Rare in semi-evergreen forests of Western Ghats Karnataka (Kurse, Karwar)
2.	*S. malabarica*	EN	India, Sri Lanka, China, Malaysia, Java, Philippines	Throughout the evergreen-semi evergreen forests of the Western Ghats
3.	*S. oblonga*	EN	India, Sri Lanka, China, Vietnam, Malaysia, Indonesia	In the rain forest of western Ghats from Konkan southwards to Kerala, Karnataka (Anshi, Belgaum)
4.	*S. macrosperma*	R	Southwest India	In wet forests of Western Ghats
5.	*S. reticulata*	EN	Sri Lanka, Southern region of India	Rare in forests of Western Ghats Karnataka (Karje Udupi)
6.	*S. gambleana*	VU	Southern region of India	Semi-evergreen forests of Western Ghats

EN Endangered, *R* rare, *VU* vulnerable

Result and discussion

Distribution of *Salacia* species in the Western Ghats

In the Western Ghats, most of the *Salacia* species are distributed in semi evergreen to evergreen habitats. Altitude wise *S. chinensis* and *S. malabarica* were exclusively found in higher elevation (1001–1700 m) (Tripathi et al. 2015). *S. chinensis* and *S. macrosperma* are the most widely distributed species in the Western Ghats. Among the six species indigenous in the Western Ghats, *S. chinensis* is an economically important and widely cultivated plant in Southern Western Ghats.

Conservation status

Literature review revealed that *Salacia* species in the Western Ghats have not been evaluated critically for their distribution and conservation and a comprehensive revision on the conservation status of the *Salacia* species appears to be vital. According to Majid et al. (2016), Mastiholi et al. (2018) *S. chinensis* is an endangered plant. However detailed literature survey and the guidelines of IUCN Red List revealed *S. chinensis* is rare in semi-evergreen forests of Western Ghats, *S. macrosperma* is rare in southwest India in wet forests of Western Ghats (Hassan, Kodagu, Shimoga, Uttar kannada) (http://flora-peninsula-indica.ces.iisc.ac.in), *S. malabarica*, *S. oblonga* and *S. reticulata* are endangered species (http://www.bsienvis.nic.in) (Table 1).

Taxonomy

The overall characteristics of the plants of the genus are as follows; scandent or sarmentosa shrub (Dandy 1969; Mabberley 2005) or small tree (Roopa et al. 2017; Ramakrishna et al. 2016). Among the different phylogenic analytical strategies, morphology in all its aspects, from micromorphology to embryology, palynology, seed, fruit, floral, stem and leaf morphology still remains to be the most indispensable tool. Till to date no identification keys have been reported for *Salacia* species across the globe based on morphological features of tree, leaf, stem, flower, fruit and root.

Table 2 The taxonomic and morphological traits that can be used as descriptors of *Salacia* genotypes

Trait	Variation range
Plant appearance/descriptors	
Plant height	Short (≤ 3.0 m); intermediate (3.1–4.5 m); tall (4.6–6.0 m); very tall (> 6.0 m)
Shape of plant	Compact; open
Type of plant	Shrub; climbing shrub; Stout climbing Shrub; strangling shrub; scandent shrub
Flowering season	January–April; February–April; March–April; March–May; May–December; December
Fruiting season	January–April; April–June; May–June; May–August
Leaf descriptors	
Leaf colour	Green; dark green
Leaf shape	Elliptic; oblong elliptic; elliptic oblong; broadly elliptic; oblanceolate
Petiole colour	Light green; green
Colour of leaf vein	Green; reddish green
Orientation of petiole	Horizontal
Colour of young leaf	Light green; green
Leaf blade shape	Narrowly ovate; round; elliptic; ovate
Leaf apex shape	Acute; obtuse; acuminate; abruptly acuminate
Leaf base shape	Obtuse; wedge; round; cuneate; attenuate; acute; entire; crenulate
Leaf edges	Jagged; serrate; smooth; wavy
Leaf margins	Dentate; undulate; entire; serrate; toothed
Leaf venation appearance	Less prominent; prominent
Leaf venation	Pinnate; reticulate
Midrib appearance	Less prominent; prominent
Type of leaf placement	Alternate; opposite
Type of leaf arrangement	Simple opposite; pinnately compound
Leaf upper surface pubescence	Non glossy; glossy
Leaf lower surface pubescence	Non glossy; glossy
Leaf length	In cm
Leaf width	In cm
Stem descriptors	
Angle of branching	Acute; obtuse
Colour of stem cortex	White; cream
Colour of stem exterior	Grey; greenish grey; greenish yellow
Colour of epidermis	Green
Growth habit of stem	Strangling; zigzag
Branching habit	Erect; dichotomous
Stem length	Measured from base to first branching
Stem diameter	Measured at 30 cm above ground level
Inflorescence/flower descriptors	
Inflorescence branching	Branched; unbranched
Type of inflorescence	Raceme; verticil
Anther thecae colour	Orange; yellow
Petal shape	Ovate; broadly ovate; elliptic; ovate acute; oblong
Corolla shape	Stellate; companulate
Flower colour	Green; yellowish green; greenish yellow; greenish white; whitish yellow
Flower odour	Mild; absent

Table 2 continued

Trait	Variation range
Flower position	Axial
Sepal shape	Oblong; elliptic; obovate; circular; obtuse; ovate
Calyx lobe	Triangular; minute ovate entire; orbicular ciliate; oblong; entire; obtuse
No. of flower per inflorescence	2–4; 2–8; 3–6; 4–; 8–12
Petal length	In cm
Petal width (cm)	In cm
Number of petals	5; 6
Pedicle length	In mm
Fruit descriptors	
Immature fruit colour	Light green; green; dark green
Mature fruit colour	Light orange; orange; dark orange; red; pinkish red
Stripes in mature fruit	Present; absent
Fruit shape	Round; ovate; ovoid; oblong
Fruit apex shape	Round; obtuse
Fruit surface	Smooth; slightly tuberculate; tuberculate; rugose
Fruit hairiness	Present; absent
Fruit flavour	Moderately sweet; sweet
Fruit peeling	Easy; hard
Skin thickness	Thin; thick
Flesh thickness	Thin; medium
No. of fruits per fructoscence	2; 3
Fruit diameter	In cm
Fruit weight	In gram
Seed descriptors	
Seed colour	Light brown; brown; light orange; cream; grey
Dry seed shape	Round; oblong; flat oblong; ellipsoid; ovoid; oval
No. of seeds per fruit	1; 2 or many; 1–4; 3; 3–4
Seed length	In cm
Seed width	In cm
Seed diameter	In cm
Dry seed weight	In milligram
Root descriptors	
Root shape	Conical–cylindrical; irregular
Colour of root cortex	Brown; yellow
Texture of root epidermis	Smooth; rough
Cortex thickness	Thin; intermediate

Diversity in tree morphology

Shape of the plant for all the six species i.e. *S. chinensis*, *S. malabarica*, *S. oblonga*, *S. macrosperma*, *S. reticulata* and *S. gambleana* was similar, all the six species showed compact plant shape.

Diversity in leaf morphology

Young leaves of four out of six species showed light green colour whereas leaf colour of *S. malabarica* and *S. oblonga* was green colour. Mature leaves were dark green in colour for all six species. Leaf shape of *S. chinensis* was elliptic, *S. malabarica* was oblong

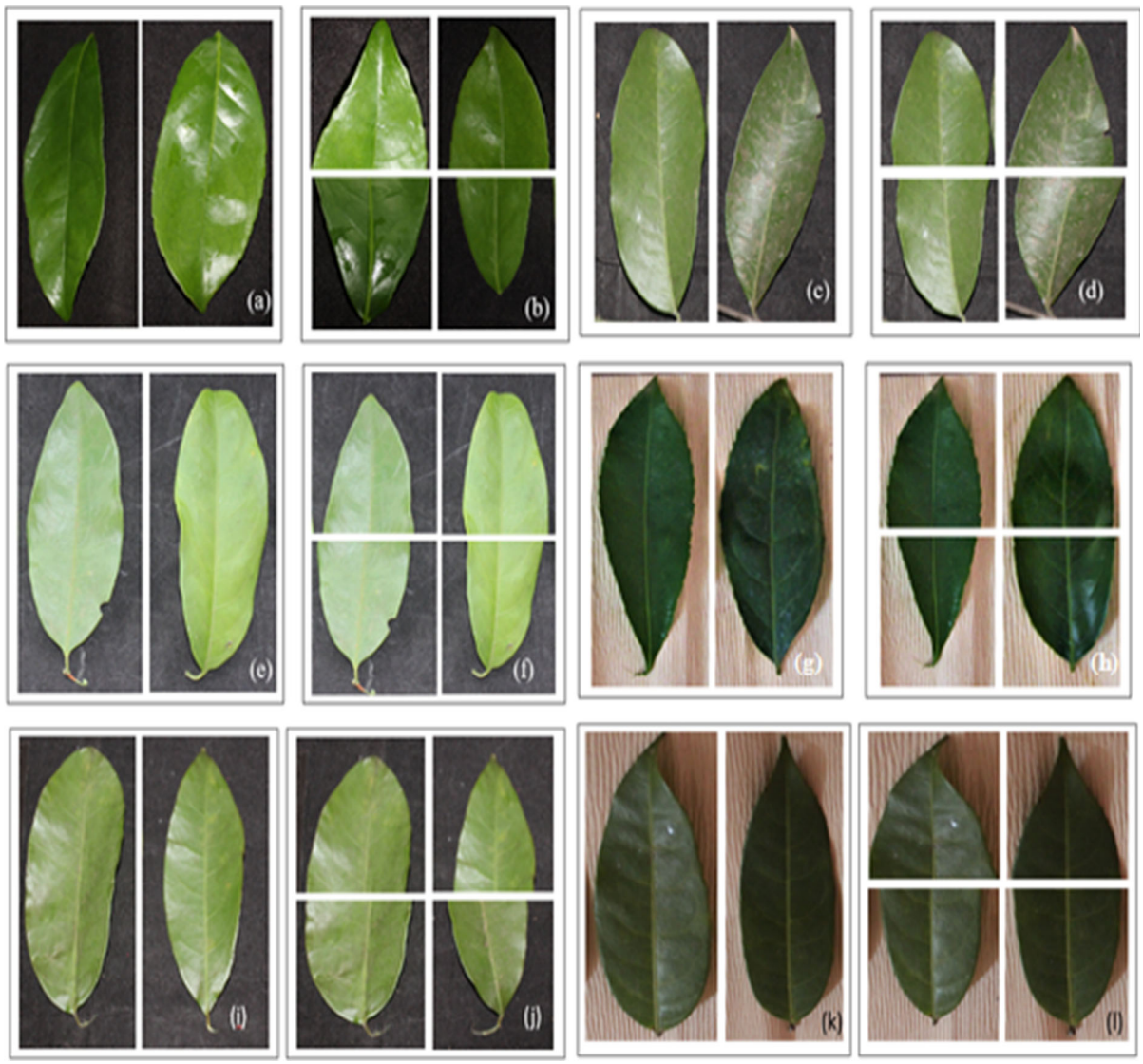

Fig. 1 Variations in leaf apex shape, leaf blade shape and leaf base shape of different species of *Salacia*. **a** Leaf shape, **b** leaf apex and base shape of *S. chinensis*; **c** leaf shape, **d** leaf apex and base shape of *S. malabarica*; **e** leaf shape, **f** leaf apex and base shape of *S. oblonga*, **g** leaf shape, **h** leaf apex and base shape of *S. macrosperma*; **i** leaf shape, **j** leaf apex and base shape of *S. reticulata*; **k** leaf shape, **l** leaf apex and base shape of *S. gambleana*

elliptic, *S. oblonga* was elliptic oblong, *S. macrosperma* was broadly elliptic, *S. reticulata* was elliptic oblong and leaf shape of *S. gambleana* oblanceolate. Leaf apex shape was acute for *S. chinensis* and *S. gambleana*, acute to obtuse for *S. malabarica* and *S. oblonga*, acuminate for *S. macrosperma* was abruptly acuminate for *S. reticulata*. Leaf base shape was obtuse to wedge for *S. chinensis*, round to wedge for *S. malabarica*, cuneate for *S. oblonga*, entire to crenulated for *S. macrosperma*, acute for *S. reticulata* and attenuate for *S. gambleana*. Leaf blade shape of four out of six species was elliptic whereas *S. chinensis* leaf blade shape observed was narrowly ovate to round and *S. gambleana* leaf shape observed was ovate. Leaf margin was dentate for *S. chinensis*, entire to undulate for *S. malabarica* and *S. gambleana*, undulate to serrate for *S. oblonga*, serrate for *S. macrosperma* and toothed for *S. reticulata*. Leaf length was maximum in *S. malabarica* (15 cm) and lowest in *S. macrosperma* (10 cm). *S. malabarica* showed the highest leaf width

(7 cm) whereas *S. gambleana* showed the lowest leaf width (4 cm). Petiole length was maximum in *S. oblonga* (1.2 cm) and the lowest in *S. reticulata* (0.3 cm). *S. malabarica* showed the highest leaf blade length (5 cm) whereas *S. gambleana* showed the lowest (2.2 cm) (Fig. 1).

Diversity in stem morphology

Colour of the stem exterior of four out of six species was grey, whereas it was greenish grey for *S. chinensis* and greenish yellow for *S. oblonga*. Colour of the stem cortex of five out of six species was cream whereas colour of the stem cortex of *S. reticulata* was white. All six species showed acute branching and strangling stem. Five species showed green colour epidermis whereas *S. reticulata* showed white colour epidermis. Maximum stem length was in *S. malabarica* and *S. oblonga* (8 m) and minimum in *S. chinensis* (4 m). Maximum stem diameter was in *S. malabarica* (35 cm) and minimum in *S. chinensis* (20 cm).

Fig. 2 Pictorial depiction of flowers of different species of *Salacia*. **a** *S. chinensis*, **b** *S. malabarica*, **c** *S. oblonga* **d** *S. macrosperma* **e** *S. reticulata* **f** *S. gambleana*

Diversity in flower morphology

Type of inflorescence of four out of six species was verticil whereas it was raceme for *S. oblonga* and *S. gambleana*. Corolla shape of five out of six species was stellate whereas it was companulate for *S. oblonga*. Flower colour was greenish yellow for *S. malabarica* and *S. oblonga,* yellowish green for *S. chinensis*, green for *S. macrosperma*, greenish white or greenish yellow for *S. reticulata* and whitish yellow for *S. gambleana*. Sepal shape observed was oblong to obovate for *S. chinensis*, elliptic for *S. malabarica,* circular to oblong for *S. oblonga,* ovate for *S. macrosperma* and *S. reticluata* and oblong to obtuse for *S. gambleana*. Anther thecae colour was orange for five out of six species and yellow for *S. oblonga*. Calyx lobe was triangular for *S. chinensis*, minute ovate and entire for *S. malabarica*, orbicular ciliate for *S. oblonga*, oblong for *S. macrosperma* and *S. reticulata* and obtuse for *S. gambleana* (Fig. 2).

Fig. 3 Picture representing fruit clustering habit of different species of *Salacia*. **a** *S. chinensis*, **b** *S. malabarica*, **c** *S. oblonga*, **d** *S. macrosperma,* **e** *S. reticulata*, **f** *S. gambleana*

Diversity in fruit morphology

Immature fruit colour of four out of six species was green. Immature fruit colour of *S. malabarica* and *S. oblonga* was light green and dark green respectively. Mature fruit colour was red for *S. chinensis*, dark orange for *S. malabarica*, orange for *S. oblonga*, orange red for *S. macrosperma*, pinkish red for *S reticulata* and light orange for *S. gambleana*. Fruit shape was round for *S. reticulata* and *S. oblonga*, round to ovate for *S. chinensis*, ovoid for *S. malabarica*, ovate for *S. macrosperma* and oblong for *S. gambleana*. Fruit apex shape was round for *S. malabarica, S. oblonga* and *S. reticulata*, obtuse for *S. chinensis*, *S. macrosperma* and *S. gambleana*. Fruit surface was smooth for *S. chinensis* and *S. macrosperma*, tuberculate for *S. oblonga* and *S. reticulata*, slightly tuberculate for *S. malabarica* and rugose for *S. gambleana*. Fruit mesocarp colour observed was pale yellow for *S. chinensis*, light orange for *S. malabarica* and *S. gambleana*, white for *S. oblonga* and for *S. macrosperma* and *S. reticulata* was green and light yellow respectively. Fruit diameter was maximum in *S. oblonga* (5 cm) and minimum in *S. chinensis* 1 cm (Fig. 3).

Diversity in seed morphology

Dry seed shape of *S. chinensis* was round, *S. malabarica* was oblong, *S. oblonga* was ellipsoid, seed shape of *S. macrosperma* was ovoid seed shape of *S. reticulata* and *S. gambleana* was oval and flat oblong respectively. Seed colour of S. *chinensis* was brown, *S. malabarica* was light orange, *S. oblonga* was cream, seed colour of *S. macrosperma* and *S. reticulata* was grey and seed colour of *S. gambleana* was light brown. Seed length and seed width was maximum in *S. gambleana*, i.e., 2 cm and 1 cm respectively, and seed length and seed width was lowest in *S. chinensis,* i.e., 0.6 cm and 0.5 cm respectively. Seed weight was maximum in *S. gambleana* (1.8 g) and minimum in *S. reticulata* (150 mg).

Diversity in root morphology

Four species showed irregular shape of roots, whereas shape of root of *S. chinensis* and *S. oblonga* was conical–cylindrical. Colour of root cortex of *S. malabarica*, *S. macrosperma*, *and S. reticulata* was yellow *S. chinensis*, *S. oblonga* and *S. gambleana* was brown. For all six species texture of root epidermis and cortex thickness was rough and intermediate, respectively.

Key to the *Salacia* species of the Western Ghats

Morphological characters among the *Salacia* species of the Western Ghats were evaluated systematically to construct an identification key, which will be a valuable tool for identification of the Western Ghats species in the field.

Group I

1a Plant height tall—2
1b Plant height very tall—2
2 Shape of the plant compact—3
3a Type of the plant climbing shrub—4
4a Flowering and fruiting season December–April—*S. chinensis*
4b Flowering and fruiting season February–June—*S. malabarica*
3b Type of the plant shrub—5
5a Flowering season March–August—*S. oblonga*
5b Flowering and fruiting season January–June—*S. macrosperma*
3c Type of the plant scandent shrub—6
6a Flowering and fruiting season February–August—*S. reticulata*
6b Flowering and fruiting season March–August—*S. gambleana*

Group II

1 Type of leaf placement opposite—2
2 Type of leaf arrangement pinnately compound—3
3 Colour of leaf vein green—4
4 Orientation of petiole horizontal—5
5 Midrib appearance prominent—6
6 Leaf upper surface pubescence glossy—7
7 Leaf lower surface pubescence non glossy—8
8 Leaf venation reticulate—9
9 Leaf venation appearance prominent—10
10 Petiole colour green—11
11 mature leaf colour dark green—12
12a Colour of young leaf light green—13
13 Leaf shape elliptic, leaf apex acute, base obtuse, edge jagged, margins dentate—14

14a Leaf blade shape narrowly ovate or round, leaf length 5–11 cm, leaf width 3–5 cm—*S. chinensis*
14b Leaf blade shape elliptic—15
15a Leaf shape broadly elliptic, apex acuminate, base entire/crenulated, edge wavy, margins serrate, leaf length 4–12 cm, leaf width 2–6 cm—*S. macrosperma*
15b Leaf shape elliptic oblong, apex abruptly acuminate, base acute, edge jagged, margins toothed, leaf length 6–12 cm, leaf width 3–6 cm—*S. reticulata*
14c Leaf blade shape ovate—16
16 Leaf shape oblanceolate, apex acute, base attenuate, edge smooth, margins entire, leaf length 6–12 cm, leaf width 3–4 cm e—*S. gambleana*
12b Colour of young leaf green—17
17b Leaf shape oblong elliptic, apex obtuse, base round/wedge, edge smooth, margins entire–leaf length 8–16 cm, leaf width 5–7 cm—*S. malabarica*
17b Leaf shape elliptic oblong, apex acute/obtuse, base cuneate, edge wavy, undulate/serrate leaf length 6–14 cm, leaf width 3–5 cm—*S. oblonga*

Group III

1 Growth habit of stem strangling—2
2 Angle of branching acute—3
3 Colour of epidermis green—4
4a Colour of stem exterior greenish grey—5
5 Branching habit erect—6
6a Colour of stem cortex cream, stem length 4 m, stem diameter 20 cm—*S. chinensis*
6b Colour of stem cortex cream, stem length 5 m, stem diameter 23 cm—*S. gambleana*
4b Colour of stem exterior grey—7
7 Colour of stem cortex cream—8
8 Branching habit dichotomous—9
9a Stem length 8 m, stem diameter 35 cm—*S. malabarica*
9b Stem length more than 5 m, stem diameter 22 cm—*S. macrosperma*
9c Colour of stem cortex white, stem length 6 m, stem diameter 24 cm—*S. reticulata*
4c Colour of stem exterior greenish yellow—10
10 Colour of stem cortex cream, stem length 8 m, stem diameter 32 cm—*S. oblonga*

Group IV

1 Inflorescence branching unbranched—2
2 Flower position axial—3
3 Corolla shape stellate—4
4 Anther thecae colour orange—5
5a Type of inflorescence verticil—6
6a Number of flowers per inflorescence 3–6, flower colour yellowish green, petal shape broadly ovate, sepal shape oblong or obovate and calyx lobe triangular—*S. chinensis*
6b Number of flowers per inflorescence 8–12, flower colour greenish yellow, petal shape elliptic, sepal shape elliptic and calyx lobe minute ovate entire—*S. malabarica*
6c Number of flowers per inflorescence 4–6, flower colour green, petal shape ovate acute, sepal shape ovate and calyx lobe oblong—*S. macrosperma*
6d Number of flowers per inflorescence 2–8, flower colour green, petal shape ovate, sepal shape ovate and calyx lobe obtuse—*S. reticulata*
5b Type of inflorescence raceme—7
7a Anther thecae colour orange, number of flowers per inflorescence 2–4, flower colour greenish yellow, petal shape ovate, sepal shape circular oblong and calyx lobe orbicular ciliate, pedicle sessile—*S. oblonga*
7b Anther thecae colour orange, number of flowers per inflorescence 2–4, flower colour whitish yellow, petal shape oblong, sepal shape oblong/obtuse and calyx lobe obtuse—*S. gambleana*

Group V

1 fruit hairiness absent—2
2 fruit flavour moderately sweet—3
3 Strips in mature fruits absent—4
4a Number of fruits per fructoscence 2—5
5a Immature fruit colour light green—6
6 Mature fruit colour dark orange, fruit shape ovoid, fruit apex shape round, surface slightly tuberculate—*S. oblonga*
5b Immature fruit colour green—7
7a Fruit apex shape obtuse—8
8a Mature fruit colour red, fruit shape round/ovate, surface smooth, fruit diameter more than 3 cm—*S. chinensis*
8b Mature fruit colour light orange, fruit shape oblong, surface rugose, fruit diameter 4 cm—*S. gambleana*
8c Mature fruit colour orange/red, fruit shape ovate, surface smooth, fruit diameter 1.7 cm—*S. macrosperma*
7b Fruit apex shape round—9

9 Mature fruit colour pinkish red, fruit shape round, surface tuberculate, fruit diameter 5 cm—*S. reticulata*
4b Number of fruits per fructoscence 3—10
10 Immature fruit colour dark green—11
11 Mature fruit colour orange, fruit shape round, fruit apex shape round, surface tuberculate, fruit diameter 5 cm, pedicle sessile—*S. oblonga*

Group VI

1a Seed colour grey—2
2 Seed width 0.6–0.65–3
3 Seed diameter 0.8–0.9—4
4a Dry seed shape ovoid, seed length 0.95 cm, dry seed weight 300 mg, number of seeds per fruit 3—*S. macrosperma*
4b Dry seed shape oval, seed length 0.7 cm, dry seed weight 150 mg, number seeds per fruit 1–4—*S. reticulata*
1b Seed colour light brown—5
5 Dry seed shape flat oblong, seed length 2 cm, seed width and diameter 1 cm, dry seed weight 700 mg, number of seeds per fruit 2 or many—*S. gambleana*
1c Seed colour brown—6
6 Dry seed shape round, seed length 0.6 cm, seed width 0.5 cm and diameter 0.75 cm, dry seed weight 380 mg, number of seeds per fruit 1—*S. chinensis*
1d Seed colour light orange—7
7 Dry seed shape oblong, seed length 1.5 cm, seed width 0.9 cm and diameter 1 cm, dry seed weight 1 g, number of seeds per fruit 4—*S. malabarica*
1e Seed colour cream—8
8 Dry seed shape ellipsoid, seed length 1.5 cm, seed width 0.95 cm and diameter 1.6 cm, dry seed weight 1.2 g, number of seeds per fruit 3–4—*S. oblonga*

Group VII

1a Root shape conical–cylindrical—2
2 Colour of root cortex–brown—3
3 Texture of root epidermis rough, cortex thickness intermediate—*S. chinensis*, *S. oblonga*
1b Root shape irregular—4
4a Colour of root cortex yellow—5
5 Texture of root epidermis rough, cortex thickness intermediate—*S. malabarica*, *S. macrosperma*, *S. reticulata*
4b Colour of root cortex brown—6
6 Texture of root epidermis rough, cortex thickness intermediate—*S. gambleana*

Western Ghats *Salacia* species

Salacia chinensis L.

Evergreen tree up to 4 m high; climbing/strangling shrub, branching habit erect.

Leaves: elliptic, leaf blade shape narrowly ovate/round, leaf apex shape acute, leaf base shape obtuse/wedge, leaf edges jagged/serrated, margins dentate, 5–11 × 3–5 cm.

Flowers: inflorescence verticil, 3–6 flowers on axillary fascicles, petal 0.37 × 0.3 cm, pedicle 0.4–0.6 cm long, flower colour yellowish green, petals broadly ovate, sepal shape oblong or obovate, sepal length up to 0.1 cm, anther thecae colour orange, calyx lobe triangular.

Fruits: immature fruit colour green, red when ripening, fruit 1 cm in diameter, fruit shape round/ovate, apex shape obtuse, fruit surface smooth, pericarp thin, flesh thickness thin.

Seeds: one seeded, colour brown, round shape, 0.6 × 0.5 cm.

Flowering season: December

Fruiting season: January–April

Field identification characters

- Leaves elliptic in shape, 5–11 cm long
- Flower yellowish green, 3–6 flowers on axillary fascicles
- Fruit orange when ripening, one seeded

Salacia malabarica Gamble

Evergreen tree up to 8 m high; climbing shrub, branching habit dichotomous.

Leaves: oblong elliptic, leaf blade shape elliptic, leaf apex shape acute/obtuse, leaf base shape round/wedge, leaf edges smooth, margins entire/undulate, 8–16 × 5–11 cm.

Flowers: inflorescence verticil, 8-12 flowers on axillary fascicles, petal 0.25 × 0.15 cm, pedicle 0.8–1.5 cm long, flower colour greenish yellow, petal

elliptic, sepal shape elliptic, sepal length up to 2 mm, anther thecae colour orange, calyx lobe minute ovate entire.

Fruits: immature fruit colour light green, dark orange when ripening, fruit 3 cm in diameter, fruit shape ovoid, apex shape round, fruit surface slightly tuberculate, pericarp thick, flesh thickness medium.

Seeds: 4 seeded, colour light orange, oblong shape, 1.5 × 0.9 cm.

Flowering season: February–April

Fruiting season: April–June

Field identification characters

- Leaves oblong elliptic in shape, 8–16 cm long, branching habit dichotomous
- Flower greenish yellow, 8–12 flowers on axillary fascicles
- Fruit dark orange when ripening, 4 seeded

Salacia oblonga Wall ex Wight and Ern Var.

Evergreen tree up to 8 m high; shrub, branching habit erect.

Leaves: elliptic oblong, leaf blade shape elliptic, leaf apex shape acute/obtuse, leaf base shape cuneate, leaf edges wavy, margins undulate/serrate, 6–14 × 3–5 cm.

Flowers: inflorescence raceme, 2–4 flowers on axillary fascicles, petal 0.25 × 0.2 cm, pedicle sessile, flower colour greenish yellow, petal ovate, sepal shape circular, oblong, sepal length up to 1.5 mm, anther thecae colour yellow, calyx lobe orbicular ciliate.

Fruits: immature fruit colour dark green, orange when ripening, fruit 5 cm in diameter, fruit shape round, apex shape round, fruit surface tuberculate, pericarp thick, flesh thickness medium.

Seeds: 3–4 seeded, colour cream, ellipsoid shape, 1.5 × 0.95 cm.

Flowering season: March–May

Fruiting season: May–August

Field identification characters

- Leaves elliptic oblong in shape, 6–14 cm long
- Flower greenish yellow, 2–4 flowers on axillary fascicles
- Fruit orange when ripening, fruit surface tuberculate, 3–4 seeded

Salacia macrosperma Wight

Evergreen tree up to 5.5 m high; stout climbing shrub, branching habit dichotomous.

Leaves: broadly elliptic, leaf blade shape elliptic, leaf apex shape acuminate, leaf base shape entire/crenulate, leaf edges wavy, margins serrate, 4–12 × 2–6 cm.

Flowers: inflorescence verticil, 4–6 flowers on axillary fascicles, petal 0.3 × 0.2 cm, pedicle 0.5–7 cm, flower colour green, petal ovate acute, sepal shape ovate, sepal length up to 1.5 mm, anther thecae colour orange, calyx lobe oblong.

Fruits: immature fruit colour green, orange red when ripening, fruit up to 2 cm in diameter, fruit shape ovate, apex shape obtuse, fruit surface smooth, pericarp thin and flesh thickness thin.

Seeds: 3 seeded, colour grey, ovoid shape, 0.95 × 0.65 cm.

Flowering season: January–April

Fruiting season: April–June

Field identification characters

- Leaves broadly elliptic in shape, 4–12 cm long, branching habit dichotomous
- Flower green, 4–6 flowers on axillary fascicles
- Fruit orange red when ripening, 3 seeded

Salacia reticulata Wight

Evergreen tree up to 6 m high; strangling woody shrub, branching habit dichotomous.

Leaves: elliptic oblong, leaf blade shape elliptic, leaf apex shape abruptly acuminate, leaf base shape acute, leaf edges jagged, margins toothed, 6–12 × 3–6 cm.

Flowers: inflorescence verticil, 2–8 flowers on axillary fascicles, petal 0.3 × 0.2 cm, pedicle 0.4–5 cm, flower colour greenish white/greenish yellow, petal ovate, sepal shape ovate, sepal length up to 1 mm, anther thecae colour orange, calyx lobe entire.

Fruits: immature fruit colour green, pinkish red when ripening, fruit up to 6 cm in diameter, fruit shape round, apex shape round, fruit surface tuberculate, pericarp thick, flesh thickness medium.

Seeds: 1–4 seeded, colour grey, oval shape, 0.7 × 0.6 cm, branching habit dichotomous

Flowering season: February–April

Fruiting season: April–August

Table 3 Species studied of *Salacia* and their chromosome number

Sl. no.	Species	Chromosome number
1.	*Salacia chinensis*	2n = 28
2.	*Salacia oblonga*	2n = 28

Field identification characters

- Leaves elliptic oblong in shape, 6–12 cm long
- Flower greenish white/greenish yellow, 2–8 flowers on axillary fascicles
- Fruit pinkish red when ripening, fruit surface tuberculate, 1–4 seeded

Salacia gambleana Whiting and Kaul

Evergreen tree up to 5 m high; scandent shrub, branching habit erect.

Leaves: oblanceolate, leaf blade shape ovate, leaf apex shape acute, leaf base shape attenuate, leaf edges smooth, margins entire/undulate, 6–12 × 3–4 cm.

Flowers: inflorescence raceme, 2–4 flowers on axillary fascicles, petal 0.3 × 0.15 cm, pedicle 0.4–5 cm, flower colour whitish green, petal oblong,

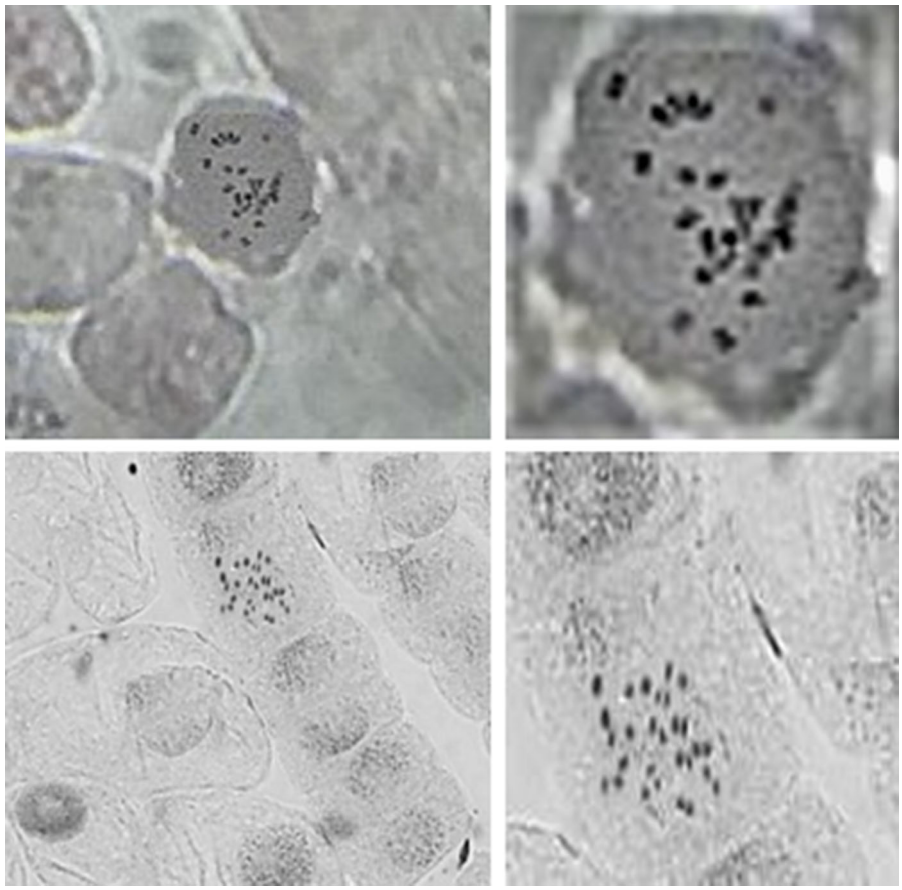

Fig. 4 Somatic chromosomes at mitotic metaphase in the **a**, **b** *Salacia chinensis* 2n = 28 and **c**, **d** *Salacia oblonga* 2n = 28

sepal shape oblong/obtuse, sepal length up to 1.5 mm, anther thecae colour orange, calyx lobe obtuse.

Fruits: immature fruit colour green, light orange when ripening, fruit up to 4 cm in diameter, fruit shape oblong, apex shape obtuse, fruit surface rugose, pericarp thick, flesh thickness medium.

Seeds: 2 or many seeded, colour light brown, flat oblong shape, 2 × 1 cm.

Flowering season: March–May

Fruiting season: June–August

Field identification characters

- Leaves oblanceolate in shape, 6–12 cm long
- Inflorescence raceme, flower greenish whitish green, 2–4 flowers on axillary fascicles
- Fruit light orange when ripening, fruit surface rugose, 2 or many seeded

Somatic chromosome numbers

The first aspect to be noted about *Salacia* chromosomes is that they are not a very good material for analysis because they are very small and difficult to spread, especially the somatic ones. Moreover, the dense cytoplasm, especially in somatic cells, turns chromosome counting a rather difficult task. Chromosome counts are listed in Table 3 and chromosome complements are illustrated in Fig. 4. In *Celastraceae* the base chromosome number includes x = 8, 9, 10, 12, 14, 15, 17 and 23. In *Celastraceae* the polyploidy appears to be relatively common (Kubitzki 2004). In this study *S. chinesis* and *S. oblonga* were determined as having 2n = 28 chromosomes (Fig. 4), although in some preparations absolute counts proved difficult. This is the first report on the chromosome number in the genus *Salacia*. However, attempts were made to study the karyomorphology in the taxon but because of the stringency of chromosomes it was not possible. This count is in agreement with Mangenot and Mangenot (1957) somatic count of *Salacia lucida* Oliv. is 2n = 28.

Conclusions

Salacia species are important components of the flora of the Western Ghats and also an economically important group. The study of descriptor analysis indicates that Western Ghats of Karnataka is a good source of diversity for *Salacia*. However, the collection surveys indicated that even though many species exist, the population density is dangerously low and is reduced to one or two trees due to the fact that seeds fail to produce seedlings because of numerous physiological and environmental factors making multiplication, maintenance and survival of these species very difficult. Field surveys revealed that 6 species are indigenous to the Western Ghats of Karnataka out of which *S. macrosperma* is rare to the region. Though the root product of *Salacia* is available in local markets, the awareness of *Salacia* as a tree is very rare. In this study, descriptors of fruit, leaf, root, stem, seed and tree morphology for six species of *Salacia* has been discussed in detail. It is also important to determine the chromosome numbers of other *Salacia* species including these two species with wide distribution in order to reveal the diversity of the chromosome numbers and ploidy levels in the genus *Salacia*.

Acknowledgements This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Compliance with ethical standards

Conflict of interest The authors declared that they have no competing interests.

References

Dandy JE (1969) (275). 4662. *Salacia* Linnaeus, Mant.159, 293. Oct 1771. [CELAST.] T.: *S. chinensis* Linnaeus. [J. D. Hooker in Bentham and Hooker, Gen. Pl.1: 370. 1862; Loesener in EnglerandPrantl, Nat. Pflanzenfam.3 (5): 228. 1893; et op. cit. ed. 2. 20b: 217. 1942; R.H.S. Dict. Gard. 4: 1849. 1951]. Taxon 18:468

Flora of Peninsular India (2018) Indian Institute of Science. http://flora-peninsula-indica.ces.iisc.ac.in

Hassan BAR (2012) Medicinal plants (importance and uses). Parmaceut Anal Acta 3:10

Herbarium JCB (2016) Flora of Karnataka. Indian Institute of Science. http://florakarnataka.ces.iisc.ac.in

Hughes JB (2001) Population diversity, overview. In: Levin SA (ed) Encyclopedia of biodiversity. Academic Press, San Diego

Kubitzki K (2004) The families and generas of vascular plants, vol 6. Springer, Berlin, p 32

Mabberley DJ (2005) The plant-book: a portable dictionary of the vascular plants. Cambridge University Press, Cambridge

Mabberley DJ (2005) Mabberley's plant-book: a portable dictionary of plants, their classification and uses: 3rd edn. Cambridge University press

Majid BN, Sampath KKK, Prakash HS, Geetha N (2016) Rapid mass propagation of *Salacia chinensis* L. an endangered valuable medicinal plant through direct organogenesis. INDJST 9(4):1–8

Mangenot S, Mangenot G (1957) Nombres chromosomiques nouveaux chez diverses Dicotylédones et Monocotylédones d'Afrique occidentale. Bulletin du Jardin botanique de l'État a Bruxelles 27(4):639–654

Marshall E (2011) Health and wealth from medicinal aromatic plants. FAO, Rome

Mastiholi L, Shetty GR, Souravi K, Rajeshekharan PE (2018) Invitro conservation studies in *Salacia chinensis* L. a threatened medicinal plant. J Pharmacogn Phytochem 3:78–81

Ramakrishna D, Tidke AS, Shinomol GK, Kiran S, Ravishankar GA (2016) *Salacia* sps.: asource of herbal drug for several human diseases and disorders. Int J Pharm Sci Rev Res 7(3):122–133

Ramamurthy K, Naithani BD (2000) Hippocrateaceae. In: Singh NP et al. (ed.), Fl. India, vol 5, pp 138–162

Roopa G, Mdhusudhan MC, Majid BN, Sampath Kumar KK, Prakash HS, Geetha N (2017) Diversity of fungal endophytes from *Salacia* species in Western Ghats of Karnataka India. Res J Pharm Biol Chem Sci 8(2):549–555

Schippmann U, Leaman DJ, Cunningham A (2002) Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues. In: Biodiversity and the ecosystem approach in agriculture, forestry and fisheries

Spivey AC, Weston M, Woodhead S (2002) ChemInform abstract: celastraceae sesquiterpenoids: biological activity and synthesis. Chem Soc Rev 31:43–59

State wise distribution of endemic and threatened plant taxa of India http://www.bsienvis.nic.in

The Plant List (2013) Version 1.1. Published on the internet; http://www.theplantlist.org/. Accessed 1st January

Tripathi JS, Yadav MK (2015) Ethno medicinal plants with antidiabetic activity: a review. IJPSR 6(11):4570–4578

Xin-Hua Z, Jaime A, Da Silva T, Ma GH (2010) Karyotype analysis of *Santalum album* L. Caryologia 63(2):142–148