Anwar Shahzad · Shiwali Sharma
Saeed A. Siddiqui *Editors*

Biotechnological strategies for the conservation of medicinal and ornamental climbers

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Plants become climbers, in order, it may be presumed, to reach the light, and to expose a large surface of leaves to its action and to that of the free air. This is affected by climbers with wonderfully little expenditure of organized matter, in comparison with trees, which have to support a load of heavy branches by a massive trunk.

– Darwin (1865)

Preface

Climbers (lianas and vines) are one of the most interesting, but much-neglected, groups of plants. They occur in all woody ecosystems of the world. High climbers play an important ecological role in forest ecosystem dynamics and functioning, exhibiting a wonderful example of economy of nature. It allows a plant to attain maximum exposure to sunlight, water, and nutrients with minimum expense in vegetation support. Phylogenetically, climbers are found in over 125 families of flowering plants as well as among several fern groups and even in one significant gymnosperm genus, *Gentum*.

Though a climber is a straggling plant, it plays vital roles in horticulture, medicine, and agriculture. Some climbing species are grown for ornamental purpose also. The most commonly used medicinal climbers, viz., *Abrus precatorious*, *Aristolochia indica*, *Cissus quadriangulairs*, *Coccinia inidca*, *Gloriosa superba*, *Gymnema sylvestre*, *Hemidesmus indicus*, *Tinospora cordifolia*, *Tylophora indica*, and *Decalepis hamiltonii,* play an important role to cure ailments related to skin, cough, fever, headache, diabetes, rheumatism, asthma, dysentery, and poison bites. *Bougainvillea* spp., *Gloriosa superba, Ceropegia* spp*., Allamanda, Passiflora* spp., etc. are some common ornamental climbers.

This book has been written in the vicinity of the books on climbing plant species. As there is no recent book on climbers, the aim of this book is to gather up-to-date information on recent trends of biotechnology and research in light of the surge in the demand for climber-based medicine. The chapters are focused on eight different themes. The book begins with a discussion on the evolution of a climbing habit and their diversification in angiosperms, the second theme highlights the use of some important climbers as medicine, while the rest of the themes (third to eighth) describe biotechnological interventions for conservation and the qualitative and quantitative improvement of climbers (both medicinal and ornamental). Authors have tried to collect the protocols for in vitro propagation and synthetic seed production of most of the studied climbers, including threatened and rare species. During the past few decades, the development and use of molecular markers for the detection and exploitation of DNA polymorphism is one of the most significant progresses in the field of plant biotechnology and their genetic studies. This book has a separate theme on "Molecular marker approaches: quality assessment and authentication for medicinal value." Chapters in this theme provide a general account on various molecular markers and their applications in quality assessments and improvement of medicinal and ornamental climbers.

During preparation of this book, we made our sincere efforts to provide good scientific information on climbers. We hope the book will be useful for researchers in academia, industry, and agriculture planning. We also hope that our earnest endeavor will have a great reception by graduate students and teachers.

As editors, we would like to thank all the authors and coauthors for their timely submissions and cooperation during the compilation of the book. We also gratefully acknowledge permission from many authors and journals to include previously published data. The editors deeply appreciate the time-to-time assistance provided by the Springer book editorial team, especially by Mariska van der Stigchel, whose enthusiastic guidance throughout the period of compilation helped us to complete the task smoothly.

The task of completing this book could not have been accomplished without the patience and understanding of our family members, dear friends, postdocs, and research scientists. Finally, we sincerely acknowledge the blessings from the Almighty God, who provided us the boost for completing this energetic task.

Aligarh, India
6 April 2015

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Part I
Origin, Evolution and Diversification of Climbers

Chapter 1
Climbers: Evolution and Diversification in Angiosperm

Shiwali Sharma and Anwar Shahzad

Abstract Climbers are the perfect example of the economy of nature by using maximum utilization of sunlight, water, and nutrients in minimum expanse of vegetation support. During food scarcity, they serve as the best food source for various animals. Climbers are also the best source of medicine, vegetable, and fruit. They cover a broad range of light through both supported (climbing) and unsupported (creeping) individuals. Due to their broad ecological niche (ranging from forest floor to the forest canopy), they provide a greater exposure to different pollinators that favor the ecological specialization. Climbers show a key innovation in angiosperm evolution because of species richness as compared to the non-climbing sister group. Climbers are found among ancestral groups of dicotyledons (such as the Piperales and Austrobaileyales) and monocotyledons (e.g., Dioscoreaceae, Arecaceae, and Araceae). Their phylogenetic breadth from rosids to asterids strongly supports multiple origins of the climbing habit within the angiosperms. Prior to the angiosperms' evolution, variations among climbers pose the hypothesis that climbers of the past had an important role in tropical forests, at least in the Paleozoic era. In contrast, small contribution of climbers to Mesozoic ecosystems might be due to few detailed morphological and anatomical studies capable of identifying fossil lianas, as well as because of inhospitable conditions for growth and fossilization.

Keywords Circumnutation • Creepers • Liana • Tendril • Vine

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1.1 Introduction

Darwin (1865) might be the first who documented his observation toward the movements of tendrils and stems of some cucurbitaceous climbers in an essay. Later on, he studied such movements in other climbers also. Although climbers are one of the important plant groups, unfortunately they are the least studied among all the plant forms till now. These neglected climbers contribute largely to the charms of our landscapes by the manner in which they climb over trees, hedgerows, or rocks. Early morphologists like Dutta (1689) referred the climbers as "weak stemmed plants." Climbers germinate on the soil then grow upward by anchoring or adhering to other plants or any neighboring object by means of some special organs of attachment (Jongkind and Hawthorne 2005; Swaine et al. 2005).

Climbers are found among one third of the plant families (Gentry 1991). They play a significant role in functioning and balancing of forest ecosystem. Evolution of climbers has boosted plant diversification by affecting forest trees in their demography and ecophysiology (Stevens 1987; Perez-Salicrup and Barker 2000; Gianoli 2004). They have a very high canopy-stem ratio that results in a higher biomass production as compared to most of the woody plants (Schnitzer and Bongers 2002).

1.2 Climbing Habitat

Due to rapid growth but suppressed lateral growth and elongated axes, climbers possess very weak and flexible stem; they need rocks or any other man-made structure for support. They have considerable tensile strength that indicate their evolution to resist pulling and twisting. Darwin termed such movement of climbers as "circumnutation." Climbers show a great diversity in their climbing mechanism depending on which they are classified by Adrian Bell (an Australian morphologist) as root climbers, hook climbers, tendril climbers, leaf or stem climbers, or twiners.

1.3 Climbing and Attachment Mechanisms

Climbing plants achieve their objective of climbing on and attaching themselves to host plants by means of different active or passive mechanisms. Some species have active mechanisms for both tasks, while others are passive in one or both of them. Twining plants, as well as those that have tendrils or sensitive stems, possess active mechanisms that permit them to achieve both objectives. Climbers with recurved spines or adventitious roots do not have active climbing mechanisms, but these structures represent an active mechanism for the task of attaching them to the host plant.

Darwin (1865) has categorized the climbing mechanism into the following classes:

1.3.1 Twining Plants

In this mechanism, climbing plants are winding around a support by forming large arcs. Darwin (1865) named this movement as "circumnutation." for example, *Dioscorea* spp. (Dioscoreaceae) and *Ipomoea* spp. (Convolvulaceae).

1.3.2 Leaf Climbers

This type of climbing mechanism is found in leaf bearers. These plants climb on their support with the help of a sensitive petiole that bends and grasps the support after contact, for example *Clematis* spp. (Ranunculaceae) and *Bauhinia* spp. (Caesalpiniaceae).

1.3.3 Tendril Bearers

Tendril bearers differ from twining plant in having their faster and irregular ellipsoidal movement. Such climbers have few long, slender, filiform, sensitive structures known as tendrils for the attachment to the support. Their length may vary from 3.8 cm in *Bignonia unguis* (Bignoniaceae) to 40 cm in *Vitis vinifera* (Vitaceae) (Jaffe and Galston 1968). Tendrils are developed from various structures of the plant body and are discussed under the following categories.

- *Axillary tendrils*: These are homologous to short axillary branches; examples are found in the Cucurbitaceae and Passifloraceae. In the genus *Gouania* (Rhamnaceae), they may develop at the end of a short axillary branch, which sometimes produces a single leaf.
- *Tendrils opposite the leaves*: This type of tendril is probably homologous to the distal end of the main stem of the plant; consequently, the branches form a sympodial system. Examples of this type are found in the Vitaceae.
- *Tendrils in the inflorescence*: In the climbing Sapindaceae, the tendrils are homologous to the basal lateral branches of the inflorescences. They are present in pairs in the basal flowering portion of the inflorescence. Examples of this type are found in the genera *Paullinia* and *Serjania*.
- *Foliar tendrils*: In many climbing genera of Bignoniaceae, the tendrils are found to replace the terminal leaflet of the leaves. They are simple, trifurcate, or

sometimes are found to be modified into a *Harpidium* or small claw or into small adventitious disks.

- *Tendrils derived from the leaf sheath*: In the Smilacaceae, the tendrils represent a prolongation of the leaf sheath.

1.3.4 Root Climbers

Root climbers are also known as "clinging climbers." These climbers attach to tree trunk with the help of glandular secretion or by growing the irregularities in the host bark (e.g., *Hedera helix*, Araliaceae, and *Parthenocissus tricuspidata*, Vitaceae).

1.3.5 Hook Climbers

Such climbers climb on their support with the help of curved spines, hooks, or thorns (e.g., *Uncaria* spp., Rubiaceae; *Calamus* spp., Arecaceae).

1.4 Types of Climbers

Broadly, climbers are of two types (Table 1.1):

1.4.1 Vine (Herbaceous Climber)

A "vine" is a herbaceous form of climber having a relatively weak and thin stem that grows either in disturbed colony or in high-light habitats. Vines have limited secondary growth. Most of the herbaceous vines are found in family Convolvulaceae (morning glory family) and Cucurbitaceae (gourd family). Some of the vines have parasitic behavior due to their non-chlorophyllous nature. They depend on their host plant for nutrition as well as for support (e.g., *Cassytha* spp. and *Cuscuta* spp.). However, some of the vines show fleshy and succulent nature (e.g., Australian milkweed *Sarcostemma australe*).

1.4.2 Liana (Woody Climber)

A "liana" is a woody form of climber having relatively woody or hard stem as compared to vines due to significant secondary growth. Their roots grow in woodland or forest floor and leaves grow in full sun, covering the canopies of trees. As far as their

Table 1.1 List of some medicinal climbers (vines and lianas)

Botanical name	Family	Common name	Type
Cardiospermum halicacabum L.	Sapindaceae	Balloon vine	Vine
Tinospora cordifolia Willd.	Menispermaceae	Giloy	Liana
Clitoria ternatea L.	Fabaceae	Aparajita	Vine
Gymnema sylvestre R. Br.	Asclepiadaceae	Gurmar	Liana
Wattakaka volubilis (L.f.) Stapf	Asclepiadaceae	Akad bel	Liana
Mucuna pruriens L.	Fabaceae	Kaunch	Liana
Clematis heynei Roxb.	Ranunculaceae	Murhar	Liana
Gloriosa superba L.	Liliaceae	Flame lily	Vine
Pueraria lobata (Willd.)	Fabaceae	Kudzu	Liana
Aristolochia tagala Champ.	Aristolochiaceae	Hooka bel	Vine
Celastrus paniculatus Willd.	Celastraceae	Mal-kangani	Liana
Holostemma annulare (Roxb.) K. Schum.	Asclepiadaceae	Jivanti	Vine
Naravelia zeylanica (L.) DC.	Ranunculaceae	Vatanasini	Liana
Diplocyclos palmatus (L.) C. Jeffrey	Cucurbitaceae	Shivlingi	Vine
Zehneria scabra (L.f.) Sond.	Cucurbitaceae	Musmusa	Vine
Piper nigrum L.	Piperaceae	Black pepper	Liana
Abrus precatorius L.	Fabaceae	Ratti	Liana
Cissus quadrangularis L.	Vitaceae	Hadjod	Vine

occurrence is concerned, lianas are frequently found in wet tropical forests. They assume various forms of growth like tangled, braided, and looping cables. However, both vines and lianas are commonly found in seasonally dry short-tree tropical forests. Nonetheless, in temperate deciduous forests of North America, several lianas are found such as grapes (*Vitis*), poison ivy, poison oak (*Toxicodendron*) and greenbriers (*Smilax*).

Shrubs are distinguished from vines by having rigid stems capable of maintaining themselves erect. Nevertheless, this distinction is not always easy to make, because there are intermediate forms between lianas and shrubs that have a tendency to climb or support themselves on nearby objects. These intermediate forms are known as "clambering," "scrambling," or "scandent plants." They spread their branches on the other plants for getting support, for example, raspberries (*Rubus*). Few climbers are secondary hemiepiphytes. Such climbers initially rooted in the soil then grow as a vine and finally grow as an epiphyte with no attachment with the soil.

Climbing plants occur in numerous ecosystems, but are more abundant in low-elevation tropical forests than in any other habitat. Lianas have about 25 % of species diversity (Gentry and Dodson 1987; Schnitzer and Bongers 2002) and 10–45 % of woody stem density (Gentry 1991). According to Gentry (1991), climbing plants in temperate forests represent an average 7 % of the local flora, while in tropical forests this number reaches to 20 %. Lianas are characteristic of tropical forests, where at least 50 % of the trees contain lianas. These can constitute a significant portion of the biomass of the forest, since their crowns can be as large as that of the tree that supports them. In some moist forests or rain forests in continental tropical areas, lianas can represent up to 40 % of the plant species present in the ecosystem (Jacobs 1988), so that some of these forests are known locally as liana forests.

Abiotic factors like elevation, rainfall and seasonality, and soil fertility have a significant effect on the abundance and distribution of different forms of climbers (vines and lianas). According to Uhl et al. (1997), availability of support has more pronounced effect on their abundance than nutrients or light availability. But Laurance et al. (2001) and DeWalt and Chave (2004) suggested that vine density and basal area may also be more in fertile soils. In contrast, liana density is more in dry season and low in annual rainfall area (Parthasarathy et al. 2004). Deep root system and efficient vascular system provide a competitive advantage to the lianas over other life-form for successful resistance in seasonally dry areas (Schnitzer 2005). As far as the species richness is concerned, steady rise in species richness is found with annual rainfall increase, while steady decrease is noticed as the average length of dry season increased (Clinebell et al. 1995). Similar to the trees, diversity of vine species is maintained in the tropical forests by edaphic specialization (Wright 2002).

Ghosh et al. (1975) reported a preliminary checklist of phanerogamic climbers of the Indian Botanic Garden, Calcutta. The Indian Botanic Garden with its 273 acres of land abounds with 15,000 plants distributed in 2,500 species. They have recorded 102 genera of the flowering climbers spread over 151 species. Out of 151 recorded species, 76.1 % are exclusively cultivated taxa, 11.9 % taxa grew in wild state, and 12.5 % taxa are both cultivated and wild. In this garden, only 13 species of monocotyledonous climbers are grown of which only one is an orchidaceous climber, known as *Vanilla planifolia*.

1.5 General Taxonomy of Climbing Plants

More than 110 vascular plant families are comprised of vines and lianas. Among the dicotyledons, family Cucurbitaceae and Convolvulaceae have numerous herbaceous climbing genera and species. However, woody lianas are also found in these families, while Malpighiaceae, Bignoniaceae, Menispermaceae, and Vitaceae have more lianas than vines. Family Apocynaceae has more lianas (e.g., *Mandevilla*) whereas family Asclepiadaceae has both vines and lianas (e.g., *Ceropegia*, *Sarcostemma*, *Araujia*, *Cynanchum*, *Matelea*, *Decalepis* spp., *Tylophora*). However, the legume families exceptionally have many common vines and lianas. In legume families, climbers have evolved repeatedly.

As far as the monocot families are concerned, only a few climbers are found, for example, *Vanilla* (family Orchidaceae); many aroids (family Araceae); yams, *Dioscorea* (family Dioscoreaceae), climbing palms (family Arecaceae); *Smilax* (family Smilacaceae); *Gloriosa* (family Colchicaceae); *Semele androgyna* (family Ruscaceae); certain species of the genus *Asparagus* (family Asparagaceae); certain grasses, e.g., the climbing bamboo in the genus *Chusquea* (family Poaceae); some liliaceous bulbs, e.g., *Bowiea volubilis* (family Hyacinthaceae); and *Dichelostemma volubile* (family Alliaceae).

Among living gymnosperms, few species of *Gnetum* and *Ephedra* are woody climbers. While in ferns and fern allies, several genera have vine species such as *Hymenophyllum*, *Lygodium*, *Dicranopteris*, and *Selaginella*. Table 1.2 shows a list of some climbers with their respective families.

1.6 Some General Properties of Climbing Plants

The following are the features that have evolved repeatedly for the climbing life-form to be successful:

- Rapid shoot growth and long internode.
- Circumnutation and thigmotropism movements are the characteristic of climbers.
- Development and expansion of leaf remain slow until circumnutation.
- Climbers have the least stem and leaf area ratio as compared to the erect plants.
- As far as the histology of stem is concerned, soft and hard tissues are alternate to each other.
- They possess very wide vessesls to carry more water up the stem.
  - Table 1.3 shows some useful characters used to diagnose climbing habit.

1.7 Role of Climbers in Ecosystem

The role of climbers in extant ecosystems outstrips our knowledge of their biological characteristics, their distributions, or even their biological diversity. Recent reviews of the role of climbers in forest ecosystems (Putz and Mooney 1991; Schnitzer and Bongers 2002; Wright et al. 2004; Phillips et al. 2005) have highlighted the abundance, competitive abilities, and contribution to disturbance regimes. Today, climbing plants typically contribute 2–15 % of the leaf biomass and about 5 % of the wood biomass to forests (Fearnside et al. 1999; Gerwing and Farias 2000; Clark et al. 2008). In climber-rich areas, they can contribute as much as 40 % of the estimated total biomass (Hegarty and Caballé 1991; Perez-Salicrup et al. 2001).

Climbers represent a perfect example of economy of nature by using maximum utilization of sunlight, water, and nutrients in minimum expense of vegetation support. Climbers (woody lianas and herbaceous vines) accomplish this balancing act, high vegetative biomass perched atop low woody biomass, through structural dependence on other upright organisms or structures. Through their structural parasitism, they are able to invest large amounts of photosynthetic products into vegeta-

Table 1.2 List of some climbers with their respective families

S. No.	Families/plants
1	**Annonaceae**
	Desmos viridiflora (Bedd.) Safford
	Uvaria narum (Dunal) Wall. ex Wight & Arn.
2	**Apocynaceae**
	Aganosma cymosa (Roxb.) G. Don var. *cymosa*
	Aganosma cymosa (Roxb.) G. Don var. *elegans* Hook. f.
	Aganosma cymosa (Roxb.) G. Don var. *lanceolata* Hook. f.
	Anodendron paniculatum A. DC.
	Carissa carandas L
	Carissa gangetica Stapf
	Carissa paucinervia A. DC.
	Carissa salicina Lam.
	Carissa spinarum L.
	Ellertonia rheedii Wight
	Ichnocarpus frutescens (L.) R. Br.
	Ichnocarpus ovatifolius A. DC.
3	**Araceae**
	Rhaphidophora laciniata (Burm.f.) Merr.
4	**Aristolochiaceae**
	Aristolochia indica L.
	Aristolochia tagala Cham.
5	**Asclepiadaceae**
	Cosmostigma racemosum (Roxb.) Wight
	Cryptolepis buchanani Roemer & Schultes
	Cynanchum callialatum Buch.-Ham. ex Wight & Arn.
	Decalepis hamiltonii Wight & Arn.
	Gymnema hirsutum Wight & Arn.
	Gymnema montanum (Roxb.) Hook. f. var. beddomei Hook. f.
	Gymnema sylvestre (Retz.) R.Br.ex Roemer & Schultes
	Gymnema tingens (Roxb.) Wight & Arn.
	Hemidesmus indicus (L.) R. Br. var. indicus
	Hemidesmus indicus (L.) R. Br. var. pubescens (Wight & Arn.) Hook. f.
	Marsdenia brunoniana Wt. & Arn.
	Marsdenia tenacissima (Roxb.) Moon
	Pergularia daemia (Forssk.) Chiov.
	Sarcostemma acidum (Roxb.) Voigt
	Secamone emetica (Roxb.) R. Br. ex Schultes
	Tylophora capparidifolia Wight & Arn.
	Tylophora indica (Burm.f) Merr.
	Wattakaka volubilis (L.f.) T. Cooke

(continued)

Table 1.2 (continued)

S. No.	Families/plants
6	**Basellaceae**
	Basella alba L.
7	**Caesalpiniaceae**
	Caesalpinia crista L.
	Caesalpinia cucullata Roxb.
	Pterolobium hexapetalum (Roth) Sant. & Wagh
8	**Capparaceae**
	Capparis brevispina DC.
	Capparis divaricata Lam.
	Capparis sepiaria L. *var. sepiaria*
	Capparis sepiaria L. *var. retusella* Thwaites
	Capparis shevaroyensis Sund.-Ragh.
	Capparis zeylanica L.
	Maerua oblongifolia (Forsk.) A. Rich.
9	**Celastraceae**
	Celastrus paniculatus Willd.
	Loeseneriella obtusifolia (Roxb.) A.C. Smith
	Maytenus heyneana (Roth) Raju & Babu
	Maytenus royleanus (Wallich ex M. Lawson) M.A. Rau
	Reissantia indica (Willd.) Halle
	Salacia chinensis L.
	Salacia oblonga Wall. ex Wight & Arn.
10	**Combretaceae**
	Combretum acuminatum Lam.
	Combretum albidum G. Don
11	**Convolvulaceae**
	Argyreia cuneata (Willd.) Ker
	Argyreia elliptica (Roth) Choisy
	Argyreia involucrata Clarke
	Argyreia kleiniana (Roem. & Schultes) Raizada
	Argyreia pilosa Arn.
	Argyreia sericea Dalz.
	Ipomoea asarifolia (Desr.) Roem. & Schultes
	Ipomoea campanulata L.
	Ipomoea eriocarpa R. Br.
	Ipomoea quamoclit L.
	Ipomoea staphylina Roem & Schultes
	Merremia vitifolia (Burm. f.) Hall. f.
	Rivea hypocrateriformis (Desr.) Choisy
12	**Cucurbitaceae**
	Coccinia grandis (L.) J. Voigt
	Gymnopetalum cochinchinense Kurz

(continued)

Table 1.2 (continued)

S. No.	Families/plants
	Kedrostis courtallensis (Arn.) Jeffrey
	Trichosanthes anaimalaiensis Bedd.
13	**Dioscoreaceae**
	Dioscorea oppositifolia L.
	Dioscorea pentaphylla L.
	Dioscorea tomentosa J. Koenig ex Sprengel
14	**Elaeagnaceae**
	Elaeagnus indica Servettaz
15	**Euphorbiaceae**
	Phyllanthus reticulatus Poir
	Tragia involucrata L.
	Tragia plukenetii R. Smith
16	**Gnetaceae**
	Gnetum ula Brongn.
17	**Liliaceae**
	Asparagus racemosus Willd.
18	**Linaceae**
	Hugonia mystax L.
19	**Malpighiaceae**
	Hiptage benghalensis (L.) Kurz
20	**Menispermaceae**
	Anamirta cocculus (L.) Wight & Arn.
	Cissampelos pareira L. *var. hirsuta* (DC.) Forman
	Cocculus hirsutus (L.) Diels
	Cocculus pendulus (Forst.) Diels
	Cyclea peltata (Lam.) Hook.f. & Thoms.
	Diploclisia glaucescens (Blume) Diels
	Pachygone ovata (Poir.) Miers ex Hook.
	Stephania japonica (Thunb.) Miers
	Tinospora cordifolia (Willd.) Hook.f. & Thoms.
21	**Mimosaceae**
	Acacia caesia (L.) Willd.
	Acacia canescens Grah.
	Acacia intsia Willd. var. intsia
	Acacia pennata (L.) Willd
	Acacia sinuata (Lour.) Merr.
	Acacia torta (Roxb.) Craib
	Entada pursaetha DC.
	Mimosa intsia L.
22	**Moraceae**
	Plecospermum spinosum Trecul.

(continued)

Table 1.2 (continued)

S. No.	Families/plants
23	**Myrsinaceae**
	Embelia basaal (Roem. ex Schultes) A. DC.
	Embelia ribes Burm.f.
24	**Nyctaginaceae**
	Pisonia aculeata L.
25	**Oleaceae**
	Jasminum auriculatum Vahl
	Jasminum azoricum L. var. azoricum
	Jasminum cuspidatum Rottl.
	Jasminum malabaricum Wight
	Jasminum multiflorum (Burm. f.) Andr.
	Jasminum sessiliflorum Vahl
	Jasminum trichotomum Heyne ex Roth
	Jasminum angustifolium (L.) Willd.

Table 1.3 Characters used to diagnose climbing habit and supporting exemplar literature (Taken from Burnham (2009) with permission)

Characters in climber	Example and/or rationale reference
Long internodes	Ray (1986), Galtier (1988), Dubuisson et al. (2003), Dunn et al. (2006), DiMichele et al. (2006)
Small stem diameter to length ratio.	Dunn et al. (2006), Harris et al. (2007), Ichihashi et al. (2009)
Small stem diameter relative to supported foliage	Galtier (1988), Selaya and Anten (2008)
Delayed apical foliage expansion and/or dense glandular trichomes	Baxter (1949), Hegarty (1991), Putz and Holbrook (1991), Krings et al. (2003), Ichihashi et al. (2009)
Adventitious roots	Gentry (1991), Hegarty (1991), Speck (1994)
Large petiole bases relative to stem diameter	Tomescu et al. (2001), Dunn et al. (2006)
Hooks, spines, or grappling structures	Menninger (1970), Hegarty (1991), Teramura et al.(1991)
Heterophylly	Batenburg (1981), Lee and Richards (1991), Krings and Kerp (2000), Krings et al. (2001, 2003)
Anomalous wood anatomy: successive cambia; excessive parenchyma; multiple vascular tissue cycles	Taylor and Millay (1981), Carlquist (1991), Ewers et al. (1991), Caballé (1993), Mosbrugger and Roth (1996)
Structural anatomy inconsistent with self-support	Li and Taylor (1998), Li et al. (1994), Speck (1994)
Taxonomic affinities to other climber taxa.	Gianoli (2004)
Direct observation of climber wrapped on larger individuals in "snapshot" deposits	Opluštil et al. (2007, 2009)

tive growth, reproductive propagules, and continuously meristematic tissues. Compared to other upright growth habits, like trees and shrubs, climbers invest large amounts of photosynthetic products in woody structural tissues. For climbers, the potential for vegetative proliferation is thus high, leading to large and potentially isolated populations that may contribute to speciation if broad geographic distributions are dissected. They contribute sustainability to canopy closure after tree fall and help to stabilize the microclimate underneath. Lianas in particular add considerably to forest plant diversity and provide valuably habitat and connections among tree canopies that enable arboreal animals to traverse the treetops. Climbers constitute a large and important sector of ornamental horticulture. Some play a vital role in medicine and agriculture. Many climbers combinedly serve both the purposes. In spite of numerous roles climbers play in ecosystem, as medicines, in horticulture, and agriculture, little attention has been paid to them; they are scanty treated in literature. Only a few studies are carried out on climbers.

1.8 Climber Evolution

Angiosperms, with approximately 300,000 species, appear to be the most successful and dominant group of land plants and have undergone an outstanding diversification compared to other plant groups (Stebbins 1981; Crane et al. 1995; Magallón and Castillo 2009). The evolutionary success of certain lineages within angiosperms has been related to a number of plant features, including life history traits, growth habits, specialized organs, and physiological pathways (Quezada and Gianoli 2011). Although taxa diversification cannot be evaluated in ecological timescale, it is considered that genetic differentiation among populations may be a surrogate for speciation (Grant 1981; Avise 2000; Levin 2000).

Hunter (1998) suggested that the proliferation of species (key innovation) can be used for evolutionary success of a particular taxonomic group than other related groups. Key innovation hypothesis involve as traits that allow a clade to exploit a previously unused or underutilized resource (Simpson 1953). This hypothesis is used for the comparison of species richness in two sister groups (i.e., related groups of equivalent age) having or lacking the particular trait (Barraclough et al. 1998).

Climbers exhibit in a broad range of ecological niche that attracts more pollinators for their diverse specialization (Gentry 1991). Gianoli (2004) studied the phylogenetic relationships, growth habit, and species richness of 48 pairs of sister groups that belong to 45 angiospermic plant families and found that in 38 pairs, the climbing taxa were more diverse than their non-climbing sister groups. Similar to the climbers, epiphytic genera (orchid and non-orchids) have more species diversity than terrestrial genera.

Climbers are found among ancestral groups of angiosperms such as the Piperales and Austrobaileyales and among monocotyledons (e.g., Dioscoreaceae, Arecaceae, and Araceae) and are commonly represented in both major groups of rosids and asterids. This phylogenetic breadth strongly supports multiple origins of the climbing habit within angiosperms and supports the idea that a significant advantage is conferred on plants that are able to transition from self-supporting to assisted support. Within flowering plants alone, Caballé (1993) estimated that between 5,000 and 10,000 species of climbers exist today. In spite of this angiosperm-centered view of climbers, substantial evidence has accumulated, in isolated reports on the fossil record, of diverse climbers prior to the Cretaceous radiation of angiosperms. According to the report of Burnham (2009), the Fossil Record of Climbers (FRC) indicates more than 1,100 climbing plants from the Paleozoic to the Quaternary. Prior to the angiosperms' evolution, variations among climbers pose the hypothesis that the climbers of the past had a similarly important role in tropical forests, at least in the Paleozoic. The extinct Paleozoic pteridosperms, in particular, appear to have employed a range of morphologies and strategies as diverse as those of angiosperms today. The apparently small contribution of climbers to Mesozoic ecosystems, in contrast, may be a result of relatively few detailed morphological and anatomical studies capable of identifying fossil lianas, as well as unusually inhospitable conditions for growth and fossilization. The importance of climbers in ancient ecosystems is underlined to encourage greater recognition of life-form diversity in the past.

Burnham (2009) located a total of 1,175 individual climbing plants from the fossil record and reported an overview of fossil records. This number is substantially lower than the number potentially available; however, the records give a first good picture of the fossil history of climbing plants. Although considerable effort was made to locate evidence from the Paleozoic and Mesozoic, with less effort placed on the many records from the Cenozoic, the database still includes 44 % (516/1,175) of its records from the Cenozoic. The Cenozoic record is strongly dominated by angiosperms (90 %; 464/516) with only ferns accounting for the remainder. The Mesozoic record is astonishingly scant with only 73 records found cumulatively from the Triassic, Jurassic, and Cretaceous. The large majority of the Mesozoic records are Late Cretaceous climbers (71 %), which are largely angiosperm species.

The Paleozoic climbing plant record, almost equal in record number to the Cenozoic, includes several major plant groups. Six broad phylogenetic groups are recognized among climbers during the Paleozoic: Sphenophyllales, Filicales, Lyginopteridales, Mariopteridales, Medullosales, Callistophytales, and (rarely) Gigantopteridales. The seed ferns represent the largest group, encompassing the Lyginopteridales, Medullosales, Mariopteridales, and Callistophytales, all entirely extinct. However, contribution by pteridophyte climbers is also significant. Gigantopterids are included, but climbing habit in these plants is inferred from interpretations of high leaf biomass supported on thin stems, interpretations that have been made from incomplete material (Li and Taylor 1998, 1999; Wang 1999; Rees 2002); the clear demonstration of climbing hooks on some species strongly supports a habit that was not self-supporting (Halle 1929; Li and Taylor 1998; Hilton et al. 2004).

1.9 How Long Ago Were Climbing Plants Common in Forest Ecosystems?

It is clear that climbing plants were abundant enough to be fossilized and subsequently recovered as early as the mid-Mississippian (Visean ~335 Myr). Several genera of lyginopterid pteridosperms (*Lyginopteris*, *Rhetinangium*, *Sphenopteris*) include species whose first appearance is in the mid to late Mississippian. Significantly, they occur in similar-age sediments in deposits from the Czech Republic, Scotland, and Arkansas, USA. In France and Scotland, remains of presumed climbing pteridophytes and pteridosperms are also found in Visean age sediments (Galtier et al. 1993). So, climbers were abundant and diverse even in the early Carboniferous.

Climbing plants were important in Paleozoic forests as early as the Pennsylvanian (ca. 315 Myr), and possibly even earlier, although their ecological abundance is still unclear (Galtier 1997; Dunn et al. 2006). The first climbing plants were present as soon as upright supports (trees) were present to climb upon. Climber species evolved within sphenophylls, filicaleans, and pteridosperms, and in each group, many species can be documented as climbing, indicating that ancient climbers were, in fact, quite diverse. Although quantitative data on species richness are difficult to compare with that from modern forested communities, it appears that following the high Carboniferous diversity, a period of scarcity existed in the climber community, in species, and in individuals. The Mesozoic low species diversity and abundance of climbers stands in stark contrast to the preceding Paleozoic and subsequent Cenozoic (Burnham 2009).

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