Traditional Bulbous Plants

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Contents

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Abstract

Ornamental geophytes with hundreds of species from different genera as well as families grown as bulbous ornamentals hold an important position in world floriculture industry which are used for the production of cut flowers, potted flowering plants, landscaping, etc. For long-term survival, they bear the subterranean storage organs, viz., rhizomes, bulbs, corms, tubers, or tuberous roots, etc., to store food reserves, moisture, and nutrition which are very diverse in their structures. Market saturation with traditional plants and flowers has stimulated an increased interest in novelties through new crops and varieties. Researchers from many countries are thus evaluating and exploring their indigenous flora as a source of potential ornamentals. The rational exploration, evaluation, conservation of these natural resources, and their utility in breeding programs through traditional and advanced breeding options are essential. Exploration of natural resources and their utilization in commercial production is important for germplasm enhancement and breeding in search for new or advanced traits for major geophytes as well as introduction of new geophyte in the global market. Introduction and breeding may also facilitate the commercial production through new production centers with diverse climates in new regions as well as shaping market trends as well as development and accomplishment of consumer demand. These introductions will open doors for the advanced agrotechniques, cultivars, postharvest technologies, and marketing policies.

The globalization of the production and marketing chains in tune with the demand will benefit the researchers who have been engaged for years but also new researchers.

Keywords

Traditional · Bulbous · Breeding

Hundreds of species grown as bulbous ornamental crops commonly known as ornamental geophytes are used for the production of cut flowers, potted flowering plants, or in landscaping. Mostly they are monocots with few dicots and belong to different families as well as genera. They commonly have subterranean storage organs that are very diverse and may consist of bulbs, corms, rhizomes, tuberous roots or tubers, *etc*., the main function of which is to store food reserves, moisture, and nutrition to ensure long-term survival of the species (De Hertogh and Le Nard 1993a). Out of total production of flower bulbs, 90% is accounted by only six genera, namely, *Tulipa, Lilium, Gladiolus, Narcissus, Iris,* and *Hyacinthus* (De Hertogh and Le Nard 1993a, b). These ornamental geophytes hold an important position in floriculture around the world. Few of them are discussed hereunder with their breeding perspectives.

9.1 Agapanthus

Agapanthus is herbaceous perennial that is cultivated as an ornamental plant because of its spectacular blue-violet to white spherical flowers. It is a very good cut flower and also mass planting of agapanthus flowers makes a wonderful display for mild climate, whereas the dwarf types are especially good as pot plant because restricted roots growth induces heavier flowering. The dried seed heads can be used in flower arrangements. *Agapanthus* not only consist ornamental value but medicinal too. *A. praecox* is an evergreen species with medicinal and ornamental uses. Some species of *Agapanthus* are commonly known as lily of the Nile.

9.1.1 Botany and Distribution

The genus *Agapanthus* was established by Charles Louis in 1788 in Sertum Anglicum, based on specimens he saw in London. With a long history of taxonomic confusion, finally the genus Agapanthus is placed in family Amaryllidaceae, as morphologically it is considered closely related to the Amaryllidaceae on account of its umbellate inflorescences, but is regarded as sufficiently different in the absence of amaryllid alkaloid compounds. It is the only genus in the subfamily Agapanthoideae. The strap type leaves of agapanthus are leathery and arranged in two opposite rows and having length up to 60 cm. The leaves are attractive even when the plant is not in flowering condition. As it is geophytes, it has underground rhizomes. It is a tender herbaceous perennial plant grows in upright clumps from fleshy rhizomes that produce short tuberous roots. Flower clusters are borne on sturdy, erect stems held well above the foliage. Each single terminal inflorescence consists of numerous tubular to bell-shaped flowers, each with six parts. There are 20 to 100 flowers in each rounded umbel, depending on variety and species. The individual flower looks like a miniature lily flower, that is, beautiful six tepals (three sepals and three petals) are present. The flower color varies from different shades of violet blue to white.

9.1.2 Origin, Domestication, and Spread

They are cultivated throughout warm areas of the world. They can especially be spotted throughout northern California. Boundaries of *Agapanthus* species are not clear in the genus, and in spite of having been intensively studied, the number of species recognized by different authorities varies from 6 to 10. Despite the common name of Lily of the Nile, they are not native to the Nile River basin of north-eastern Africa and all of the species are native to southern Africa (South Africa, Lesotho, Swaziland, Mozambique) though some have become naturalized in scattered places around the world (Australia, Great Britain, Mexico, Ethiopia, Jamaica, *etc.*). They range from the Cape Peninsula to the mountain ranges just south of the Limpopo River in Limpopo Province (Duncan 1998).

9.1.3 Plant Genetic Resources

Agapanthus is gaining more and more horticultural interest and large numbers of new cultivars are being introduced (Duncan 1985). All the species in *Agapanthus* have same chromosome number, that is, 2n=2x=30. When all species in a genus have the same chromosome number, differences in nuclear DNA content have proven to be very effective in delimiting intrageneric divisions in a number of taxa (Ohri 1998). *Agapanthus* is a genus of six species *viz*. *A. africanus, A. campanulatus, A. caulescens, A. coddii, A. inapertus,* and *A. praecox* (Zonneveld and Duncan 2003). On the basis of DNA content and pollen characters, Zonneveld and Duncan divided six species into two groups each with three species. The first group with lilac pollen, purple leaf base, deciduous growth, and DNA content below 24.5 pg contains *A. campanulatus*, *A. caulescens,* and *A. coddii*. The second group has yellow/brown pollen, green or purple leaf bases, a deciduous or evergreen growth habit, and a DNA content of 25.2–31.6 pg and includes *A. inapertus*, *A. praecox,* and *A. africanus* with *A. walshii* as a separate subspecies.

9.1.4 Conservation

An efficient *in vitro* technique for the rapid multiplication of *A. praecox* (medicinal plant) from shoot-tips cultured on MS medium containing BA (22.2 μM), IAA (2.9 μM), and TDZ (4.5 μM) combinations induced high number of shoots accompanied by *ex vitro* rooting (Baskaran and Van Staden 2013). The protocol developed is economically cheaper and can be applied for large-scale micropropagation for germplasm conservation and genetic transformation of *A. praecox*. Some studies also show successful regeneration of diploid and tetraploid from protoplast of *Agapanthus* (Nakano et al. 2003).

9.2 Canna

Canna is a plant of tropical or subtropical origin. *Canna*, the solitary genus, belongs to family Cannaceae which is one of the monocot families that is easy to recognize. The generic name has been derived from the Greek word "*Kanna*" meaning a reed, referring to its herbaceous stem (Everett 1980). It is commonly known by the names like Indian Shot, Achira, and African arrowroot, *etc*. Records that go back to 2500 B.C. in Peru show that the people were using the rhizomes of C*anna indica* (Gade 1966). *Canna* was also described in the writings of many botanists that came prior to Linnaeus and was listed in many gardens under different names. Although Cannas were previously considered as simple foliage plants, during the last two centuries, cultivation and improvement transformed them into attractive ornamental flowering plants. The flowers of *Canna* are mainly red, orange, and yellow and these majestic flowers provide a bold effect in the garden. It can beautify any wasteland or rugged part or any neglected look of garden, so it is versatile in nature.

Botany

Canna is perennial plant with rhizomes. Leaves are alternate and big, arranged spirally with a sheathing base and no ligulae. Leaves usually green and sometimes stained purple or bronze or variegated with clear midrib and numerous lateral veins. The inflorescence is terminal. Flowers are big and showy with range of colors like red, pink, yellow, or orange. The flower has three sepals and is variously interpreted as having staminodes functioning as petals or petals and staminodes (tepals), one is smaller than the other two. The ovary is inferior with three carpels. The fruit is hard and has a warty surface divided to three parts in which seeds are present. Seeds are hard and shiny black in color and globose to ovoid in shape. Plant height varies according to their species and cultivars. The fleshy, stubby, and horizontal rhizomes are rich in starch and edible. Various morphological, cytological, and taxonomical characteristics of family Cannaceae are closely related to other members of Zingiberales like Musaceae, Strelitziaceae, Lowiaceae, Heliconiaceae, Zingiberaceae, Costaceae, and Marantaceae (Cronquist 1981).

9.2.1 Origin, Domestication, and Spread

Canna species are native of South and North America, and with the course of time, they have been introduced in Asian paleotropics and subsequently evolved into native varieties. Charles de l'Ecluse, who first described and sketched *C. indica*, indicated this origin and stated that it was given the name *indica*, not because the plant is from India, in Asia, but because this species was originally transported from America and at that time, one described the tropical areas of that part of the globe as the Western Indies. From their original habitats, the species were introduced into Europe, beginning with *C. indica* in 1596 by Gerard. This was followed by *C. glauca*, whose exact year of introduction is not known but which was illustrated by Piso in 1648 (Baker 1893). The transformation of Canna from wild to cultivated condition is prevailed historically. The pan-tropical distribution of *Canna* species is most possibly the effect of human dispersal (Prince and Parks 2001). The transportation of Canna from their native place may have been the reason for occurrence of beautiful ornamental plant in Europe, Asia, and Africa (Maas-van de Kamer and Maas 2008). The first species of *Canna* introduced to Europe was *C. indica* L., which was imported from the East Indies, though the species originated from the America. Although canna has seen mostly in cultivation, it has naturalized in many parts and has been noted as weedy with the potential to be invasive and difficult to remove.

9.2.2 Plant Genetic Resources

Canna indica has become naturalized in many tropical areas around the world. The canna cultivars now in use are a tremendous improvement over the original botanical species. The most grown species of canna are *C. discolor*, *C. edulis*, *C. flaccida*, *C. glauca* var. rubra-lutea, *C. indica*, *C. iridiflora*, *C. langunose*, *C. liliflora*,

C. limbate, *C. lutea*, *C. nepalensis*, *C. pedunculata*, *C. speciose,* and *C. warscewiczii*. Some of the wild species of *Canna* are *C. glauca*, *C. indica*, *C. iridiflora*, *C. warscwiczii,* and *C. flaccid, etc.,* that involved in producing natural as well as manmade hybrids. The above five species are popularly known as elemental species of Canna. The entire cultivated garden Cannas are included under two artificial hybrid species *viz., Canna* x *orchiodes* L. H. Bailey and *Canna* x *generalis* L. H. Bailey (Hannay 1936; Khoshoo and Mukherjee 1970). All the hybrid cultivars share some common features and bind themselves under the same horticultural species. Some phenotypic transformations were also taken place when they were shifted from wild to cultivated condition. Breeding for ornamental use started in 1848 when M. Annee brought some *Canna* species he had collected in South America to France. He is probably the first man to grow cannas through seeds sown in 1848 of the real species *Canna nepalensis* which with all probability was pollinated with *C. glauca*. He named the resultant race of tall cannas as *C. annaei*. Further in 1863, a new race *C. ehemanni* (syn. *C. iridiflora hybrida*) was developed through *C. iridiflora* and *C. warscewiczii* which was intermediate in stature and had showy foliage and more pleasing drooping flowers. Though *C. ehemanni* race is still in the trade, the original one is almost extinct. This race was further crossed with other species and races and a selection of dwarf but large-flowered type race was developed in France from a large population, and therefore, this race is known as French cannas or Crozy (one of the renowned breeder there) cannas. In the middle of twentieth century, in Italy, another race Italian or orchid-flowered cannas was developed by using *C. flaccida* with garden forms and with *C. iridiflora* and the resultant hybrids had iris-like outlines but the flowers were short-lived. The varieties under this race are America, Austria, Bavaria, Burbank, Burgundia, Italia, Pandora, *etc.*

9.2.3 Collection and Conservation

In India, hybridization has played a dominant and decisive role in the origin of ornamental cannas. This has been made possible by the ecospecific differentiation of the parental species, which implies lack of barriers and a good deal of recombination associated with reasonably high fertility. National Botanical Research Institute, Lucknow, is having very rich germplasm of *Canna*. Some of the introduced or indigenously developed varieties in NBRI, Lucknow, are Aida, After Glow, Ailsen, Ali Petzi, Alison, Anarkali, Aristocrat, Ariel, Arjun, Atom Bomb, Bardara, Bharat, Black Knight, Bridal Veil, Brocade, Carmine King, Charmion, Cherub, Masterpiece, Matchless, Morning Glow, Nerissa, Percy Lancaster, Perfection, Pink Satin, Plume, President, Queen Elizabeth, Raj Mahal, Rosamund Coles, Rose Queen, Sangrila, Sirius, Sir John Anderson, Sans Souci, Soldier Boy, Star of India, Striped Queen, Stromboli, Sun Set, Sweet Heart, The Queen, Yellow Gal, *etc.* Mukherjee and Khoshoo have deeply studied pollination mechanism, breeding systems, and variation in phenotype in canna (Mukherjee and Khoshoo 1970). Percy Lancaster also worked on canna and bred some cultivars at Agri-Horticulture Society of India, Alipore, Kolkata. Agri-Horticultural Society, Calcutta, introduced 51 canna cultivars from Italy in between 1895 and 1904 and 10 from USA after 1904, *viz.*, Africa,

Alemannia, America, Aphrodite, Asia, Atlanta, Attika, Australia, Austria, Bavaria, Borussia, Britannia, Burbank, Burgundia, Campania, Charles Naudin, Crown Prince of Italy, Edouard Andre, Emelia, Hellas, Heinrich Siedel, H. Wendland, Iberia, Indiana, Ischia, Italia, King Herbert, Kronos, La France, Mrs. Kate Grey, Oceanus, Pandora, Partenope, Pennsylvania, Pereus, Philadelphia, Phoebe, Pluto, Prof. Traub, Queen of Italy, Rhea, Roma, Romagna, Rossi, Sicilia, Suevia, Trinacria, Umbria, Wintzer's Colossal, Wm Beck, and Wyoming. There are so many species and cultivars of canna and the genus seems to be in no danger of genetic deterioration. However, it is important to conserve the vast genetic diversity.

9.2.4 Characterization and Evaluation

Various studies were carried out by researchers to characterize different species and cultivars of genus *Canna*. *Canna* x *generalis* (*C. glauca* x *C. indica* x *C. iridiflora* x *C. warscewiczii*) and *C.* x *orchioides* (*C. glauca* x *C. indica* x *C. iridiflora* x *C. warscewiczii* x *C. flaccida*) are horticultural species with a range of plant height from 50 to 160 cm under which all the ornamental cultivars of hybrid origin are included, whereas the height of the elemental species (*C. flaccida, C. glauca, C. indica, C. iridiflora,* and *C. warscewiczii*) ranges from 89 cm to 500 cm. The characteristic features of *C.* x *generalis* hybrids are short to tall and slender, leaves from glaucous grey and leathery to dark chocolate-red and thin, flower shape and color from small narrow segments to large and ruffled, color being from pale-yellow to orange or scarlet, and of *C.* x *orchioides* hybrids, the flowers are very large, tubular at base, petals reflexed, usually splashed, or mottled and three broad wavy staminodes exceed by the lip, but now both are so much interbred that these are now referred to only as *C.* x *generalis.*

In a comparative trial of the new cultivars and the old ones, the standard old cultivars such as President, Gartenfeuer (Liebesglut), Felix Ragout, and Garteninspektor Nessler were found better than the new ones; however, the yellow-flowered new cultivar Schwabenland though less attractive but was found more vigorous and highly tolerant to weather conditions (Bosse 1968). Khoshoo and Guha (1975) studied the existing cultivars of *Canna* and classified them on the basis of their height, morphology, foliage, and floral characters. Canna are categorized into selfs (without spots or margin, one color only), spotted (usually a shade of red on cream or yellow ground or red spots on orange of red ground), striped red on a cream or a yellow ground, margin yellow, margined with a darker shade than the ground color, flaked red or orange on a paler ground, and splashed orange on a deeper ground. Khoshoo and Guha (1975) also studied the five elemental species and other cultivars of canna and concluded that morphological transformation from the wild to cultivated form caused reduction in plant height, change in form and color of foliage, increase in hardiness, increase in flower size, free flowering erect flowers, intensification of color, and durability of flowers. It was found that next to hybridization, triploidy has been an important mechanism in the origin of cultivars with thicker, more durable, and larger flower parts. The two types of triploids, autotriploids and segmental allotriploids, are

distinguishable by their morphological and cytogenetical properties (Khoshoo and Mukherjee 1970). The mutation breeding work on canna is limited to Chemarin et al. (1973) and a few breeders in India (Gupta 1966; Khoshoo 1968) and Thailand (Nakornthap 1965).

Sixty-six accessions of *Canna indica* from nine provinces in Indonesia are divided into two main clusters through molecular characterization: the green and red cultivar group. The green cultivar group is also divided into subcultivar green and green stripe purple based on color of sheaths, tip of bud, rachis inflorescence, petals, brachtea, and pattern of staminodea. The red cultivar is divided into subcultivar purple and subcultivar dark purple based on color of sheaths, rachis inflorescence, and petals (Sari et al. 2018). Edible Canna (*Canna edulis* Ker) was evaluated as an alternative starch source on the basis of genetic characteristics, agronomic traits, and starch properties (Piyachomkwan et al. 2002).

9.2.5 Future Perspective

Canna is an age-old plant with numerous economically important characters like presence of starch in rhizomes, antioxidant properties, medicinal properties, dye yielder, and ornamental value. So, selection among locally available material must be done for these characters, which can further be studied and improved by using breeding and molecular approaches. *C. indica* is also one of the several plant species that are used for waste water treatment as well as soil remediation. So, this aspect also needs further attention.

9.3 Crinum

9.3.1 Introduction

Crinum is an important and fascinating genus of the large and equally captivating family of Amaryllidaceae. Crinums are identified based on the lily-like flowers with underground bulbs. The name *Crinum* is derived from the Greek work "Krinos" meaning trailing hair or comet tail. There are about 130 species of *Crinum* widely distributed in and around the tropical and subtropical regions of the world. Larger in stature than most other Amaryllidaceae species, most *Crinums* are suitable as landscape plants. Furthermore, *Crinum* species have been used traditionally to cure ailments and diseases throughout the world and some of the most noted effects are analgesic, anticholinergic, antitumor, and antiviral.

9.3.2 Botany and Distribution

Crinums are bulbous, evergreen, perennial, herbaceous plants and assume a medium height. The plants have long, green, shiny, linear lanceolate, evergreen leaves around

1.0–1.5 meter long which emerges from large bulb. Flowers are white in color, which originates in clusters on thick and succulent stalk. Around 20–30 flowers are arranged in umbel. Corolla is around 8 cm long and white in color. Filament is about 5 cm long and anthers 2 cm in size. Ovary is three celled, with six stamens and one stigma. Roots are cylindrical which is around 25 cm long with a thickness of 1 cm. Fruit is globose nearly 5 cm across filled with large seed. Roots are adventitious which are below underground bulbs.

9.3.3 Origin, Domestication, and Spread

The representatives of the genus *Crinum* are found in the tropics of Africa, Asia, and America and in the temperate regions of the northern and southern hemispheres. In the south, crinums occur in South Africa, south-east Asia, and Australia, while in the north, it occurs mostly in Japan and the southern regions of the USA. The center of diversity is in Africa, south of the Sahara with a population of more than half the numbers of species found worldwide. In South Africa, 21 species are found, sparsely on mountain- or hill-slopes and more commonly in low lying areas, on river banks and at the coast.

Crinums were brought into general cultivation as early as the seventeenth century. The first species to be introduced to English gardeners was *C. asiaticum* from China in 1732. This was later followed by several species native to South Africa, including *C. bulbispermum* in 1752 and *C. macowanii* and *C. moorei* in 1874.

In India, *Crinum* is represented by 15 species, of which four are endemic to Western Ghats, viz. *C. brachynema* Herb., *C. malabaricum* Lekhak & S.R. Yadav, *C. wattii* Baker, *C. woodrowii* Baker ex W. Watson. *Crinum brachynema* and *C. woodrowii* are critically endangered species and are strictly confined to edges of lateritic plateaus and in semi-evergreen forests on hill slopes of Mahabaleshwar and adjoining areas of Satara district, Maharashtra (Yadav 1997; Gaikwad and Yadav 2004).

9.3.4 Plant Genetic Resources

Crinums are very desirable garden plants with their sturdy, decorative foliage, and large lily-like flowers. *Crinum asiaticum* L. and *C. latifolium* L. are commonly grown in gardens for their beautiful foliage and pure white to pink-tinged large elegant flowers. Some species, such as *C. moorei* and *C. neriodes*, are pleasantly scented. *C. bulbispermum* is a resilient variety as it can be grown in different types of soil, can survive long periods without water, and tolerant to cold.

Crinum brachynema is to endemic Mahabaleshwar (Kate's Point) in Satara district of Maharashtra and is listed as a critically threatened species. It is characterized by its fragrant night-blooming large, showy flowers and can be introduced into gardens as an ornamental plant. *Crinum malabaricum* is a recently described species which is so far known only from a fresh water stream bed at Periya region in Kasaragod district of Kerala. The species is represented by a population of about 1000 bulbs and restricted to about 0.5 sq. km area. The ribbon-shaped new leaves are

reported to have the longest leaves in the genus that attains a remarkable length of 3.65–4.57 m in one month. Another indigenous species is *Crinum woodrowii* that is sporadically distributed in the main ranges of northern Western Ghats and good populations are found on hill slopes around Mahabaleshwar and Khandala range. The plant has glaucous leaves and fragrant white flowers that bloom in night.

There are certain species of *Crinum* which are known to be fragrant *viz.*, *C. moorei* is highly fragrant; flowers of *C. acaule* are delicately perfumed like carnations and those of *C. minimum* resemble the sweetly scented frangipani flowers. Many of the smaller South African crinums can be readily crossed and produce semi-dwarf hybrids that do not multiply vegetatively.

9.3.5 Collections and Conservation

The natural populations of *Crinum* species are dwindling day by day due to habitat encroachment and various other anthropogenic activities. These species need necessary conservation efforts for their survival. *Crinum* species are particularly vulnerable and are much sought after as ornamental plants and have a long history of ethno-botanical usage worldwide. They are also highly valued as medicinal plants and have attracted interest from medical science whose chemical analyses have confirmed the rationale for the plant's usage with the isolation of active compounds. The genus possesses several biological features that further exacerbate conservation efforts. Application of tissue culture technique may prove to be a worthwhile alternative to conventional propagation techniques for their *ex situ* conservation.

9.3.6 Breeding Options and Constraints

With a lot of variation in the *Crinum* species, hybridization is adopted to yield more colorful species. Though hybrids are commonly obtained, most are usually sterile. The hybrid pollen may be viable, but unless it is parental, is unlikely to be accepted. Success, therefore, is limited due to genetic conflicts. Despite these difficulties, enthusiastic breeders have persisted in their efforts with the result that there are, today, a number of popular hybrids, both intergeneric and interspecific. One such example is "Crinodonna" which is the result of crossing *Amaryllis belladonna* with *Crinum moorei* and was first described in Florence in 1921. Chittenden (1956) also reports that hybrids between *Crinum* and *Hymenocallis* have been produced. *C.* x *powellii* is an interspecific hybrid between *C. bulbispermum* and *C. moorei* which is grown for its heavy umbels of sweetly fragrant flowers and is one of the best for garden use.

9.3.7 Looking Forward for Future Perspective

Ornamental crop production has become a highly specialized industry and has resulted in an increased demand for new species and cultivars. The *Crinum* species

as geophytes has been described as one with great potential to be developed as cut flowers and/or pot plants. This is because they are hardy and produce large numbers of attractive blooms for many months and good cut flowers with excellent vase life and some species are scented too. In addition, crinums have enormous phyto-constituents and pharmacological application showing its wide range of ethno-medicinal uses. Based on the potentiality of the crinums both for ornamental and medicinal values, efforts should be taken to conserve this plant species and should not be overexploited for maintaining their existence in the near future.

9.4 Dahlia

9.4.1 Botany and Distribution

Genus *Dahlia*, a member of family Asteraceae, is commonly grown as garden plants. Dahlia is a herbaceous perennial with hollow or solid, mostly erect, and branched stem growing up to 1.8–2.4 m and having fasciculated tuberous-roots. The tuber is having growing points in the crown where it is attached with the aerial stem. Leaves are opposite and simple or pinnatifide with serrations, and inflorescence is a solitary capitulum or head with long peduncle and consists of several hundred individual florets in a cyme. Heads are small to large, one per stem, having variable forms from open to ball and a diameter of 05 to 30 cm. Disc florets are yellow and fertile, actinomorphic, tubular, five lobed, and complete flowers, while ray florets are zygomorphic, pistillate, and spreading in outer whorls. They display bright colors. Fruit is an achene, oblong, or obovate with many flat seeds. Heads with varying ratios of disc and ray florets bloom in succession where ray florets (the only female flowers) open first from the outermost side towards the center. In single types, there are one to few whorls of ray florets while in double types, they for many whorls. Due to large, composite, and compact head, complete emasculation is a challenging task just like other members of Asteraceae.

The flower colors and their distribution in garden dahlia are a result of presence or absence of the two series of pigments viz., flavones and anthocynins as reported by W.J.C. Lawrence, 1929 with all types of color variations appearing only in ray florets with the disc florets remaining yellow. Lawrence (1942) also stated that the reasons for the profusion of different forms and colors are ~ (i) that dahlias being self-incompatible can never breed true, (ii) the factors producing flower color are in duplicate, two for flavone (ivory and yellow) and two for anthocyanin (pale and deep pigmentation), and (iii) each of these factors is represented four times. It was therefore evidently suggested that the plant arose as a hybrid between polyploid members of two color groups and that doubling of the chromosome number accompanied this hybridization.

Two basic different chromosome numbers are found in dahlia, *viz*. $x=8$ and $x=18$, the latter being derived from $x=9$ as reported by Gupta et al. (1972). Mehra and Ramanandan (1974) determined 2n=64 chromosomes (Octaploid) in *D. coccinea* and *D. rosea* with basic chromosome number of $x=8$. The great variety results from dahlias being octaploids (they have eight sets of homologous chromosomes, whereas

most plants have only two). They have haploid chromosome numbers of 16, 17, 18, and 32 with most of the garden cultivars including *Dahlia variabilis* being tetraploids having 2n=64 (Misra et al. 2017). Dahlia species with 2n=32 are allotetraploids, whereas the species, races, and varieties with 2n=64 are their autopolyploid (octaploid) derivatives. In situ hybridization using an rRNA gene probe indicated that the 2n=32 species have eight hybridization sites, while the 2n=64 species have 16 sites (Gatt et al. 1998).

9.4.2 Origin, Domestication, and Spread

The genus *Dahlia* is native to North America especially Mexico and is the national flower of Mexico. The distribution of Dahlia species is confined to the Central American region of Colombia, Mexico, and Guatemala, the majority of plants collected coming from Mexico which is a major center of diversification. Hence, the relative proximity of related species would increase the chances of interspecific hybridization, the probable result of which would be the evolution of forms showing considerable similarity (Lawrence 1929).

Antonio Jose Cavanilles, the staff of the Royal Botanic Garden in Madrid in the eighteenth century, gave the genus its Latin name "Dahlia" in the memory of a Swedish botanist and pupil of Linnaeus "Anders Dahl." Seeds of plants sent to Madrid from botanical garden of Mexico flowered for the first time in the botanical garden, Madrid, in October 1789, which was named *Dahlia pinnata* by Antonio Jose Cavanilles as per the records of his *Icones Plantarum* published in 1791 (Sørensen 1970). The dahlia was a cultivated plant much before its earliest scientific studies. In Mexico, it was named as Cocoxoehitl and was used as an ornamental, medicinal, and food plant. It was the part of the gardens of Aztecs, where it was domesticated and brought under cultivation even before the discovery of America. The records of Dahlia can be traced back in a book *Badianus Manuscript, An Aztec Herbal of 1552*, as the earliest illustration of a Dahlia written first in Nahuatl by Martinus de la Cruz and then translated into Latin by Juannes Badianus. After Spanish conquered the Mexico, King Phillip II of Spain commissioned his personal physician, Francisco Hernandez who was honored with the title "Protomedico of the Indies," to travel to Nueva Espana and prepare an account of the natural history of the land. Hernandez visited Mexico and Central America for the period of 1570 to 1577 where he noticed three spectacular dahlias, which he mentioned in his account of medicinal plants of New Spain published in 1651 entitled "Rerum Medicarum Novae Hispaniae Thesaurus seu Plantarum, Animalium, Mineralium Mexicanorum Historia." It had three sketches of dahlias along with their vernacular names in Nahuatl as cocotli, signifying word "syringa" meaning a hollow-stemmed plant; acocotli meaning "water-cane" or "water-pipe"; and cocoxochitl meaning "cane-flower" or "hollow-stem-flower." The French botanist Nicolas Joseph Thiery de Menonville who served King of France was sent on a secret mission "to secure (steal) living specimens of the jealously guarded cochineal insect (valued for its scarlet dye) and the Nopal cactus on which the insect lived." He narrated in his travel while collecting Nopal from the local merchants garden near Oaxaca city of Mexico he observed a double violet

dahlia which he mentioned as a "double violet aster" produced on shrubs which described roughly the *D. tenuicaulis* (Sørensen 1970).

Late in the eighteenth century, Vincente Cervantes from Mexican Botanic Garden consigned a shipment of seeds of various Mexican plants that also included Dahlias to Antonio Jose Cavanilles, Madrid. Dahlia seeds flowered for the first time in the botanical garden in October 1789, which was used to describe the first three species of Dahlia by Antonio Jose Cavanilles, the head of the Madrid Botanical Garden, in his book *Icones et Descriptiones Plantarum* published in 1791 with first species as a double type *Dahlia pinnata*. The next volume published in 1796 described two other species as *Dahlia coccinea* and *Dahlia rosea* with single flowers. From Madrid, the dahlias were sent by Cavanilles to M. Thibaud and Alphonse de Candolle from France in 1802 as well as other scientists in England and other parts of Europe (Sørensen 1970).

Introduction of dahlia to the Netherlands florists from Mexico occurred when a box of its root-tubers was sent from Mexico there, where only one plant survived the trip which produced spectacular red flowers with pointed petals and this was named as *Dahlia juarezii*. European nurserymen used this in crossing with certain other dahlias already present there, as parents and these became the earliest progenitors of all modern dahlia hybrids. The *Jardin des Plantes* in Paris received *Dahlia variabilis* in 1802 from Madrid which was grown in 1804 by the gardener at Holland House, Kensington. Later it spread in the rest part of the world.

9.4.3 Plant Genetic Resources

a. Geographic Distribution

The distribution of Dahlia species is confined to the Central American region of Colombia, Mexico, and Guatemala, the majority of plants collected coming from Mexico which is a major center of diversification. Hence, the relative proximity of related species would increase the chances of interspecific hybridization, the probable result of which would be the evolution of forms showing considerable similarity (Lawrence 1929). Mexico represents the main source of germplasm with 35 endemic species of Dahlia. The genre is present in 26 states with the largest number of species in Hidalgo and Oaxaca followed by Guerrero. The state of Jalisco represents the greatest collection and efforts made. Dahlia species inhabit nine types of habitats with 35 species in coniferous and oak forests, deciduous tropical forest 20 and the xerophilous thicket 17 as the major habitats. The range of distribution is from 24 to 3,810 m elevation with the maximum number of species growing at 2,000 to 2,500 m. *D. coccinea* found growing in all the nine habitats and an elevation of 24–3033 m showing greatest ecological range. The species diversity of Dahlia is found in the Mexican Transition Zone extends towards the Cuenca del Balsas, the Pacific Coast, the Chihuahuan Desert, Tamaulipas, and Veracruz with the highest in the provinces of Sierra Madre del Sur and Sierra Madre Oriental with the Sierra Gorda in the state of Querétaro concentrating the greatest number of species (Carrasco-Ortiz et al. 2019).

b. Primary Gene Pool

Dahlia is a monophyletic group. Dahlias are well known in ornamental horticulture. They have been the subject of intense modification genetics that has produced more than 50,000 cultivated varieties. These have changed their characteristics by increasing the inflorescence, forms of ray flowers, diversity of colors, size of individuals, and flowering time (Carrasco-Ortiz et al. 2019). The current day varieties resulted through a series of hybridization, selection, and mutation breeding (Misra et al. 2017).

c. Wild Genetic Resources and Others

There are 42 accepted species of Dahlia recognized at present and are continue to be described. *D. pinnata, D. coccinea, D. ro*sea are the major species involved in the development of new age dahlias. The sectional classification of *Dahlia* was given by Sørensen (1969) with 27 species and was further updated with identification of new species. The updated sectional classification of *Dahlia* species as per "The American Dahlia Society" into four sections is as follows:

(I) **Section** *Pseudodendron* Sherff: *D. campanulata* Saar, Sørensen, & Hjerting, *D. excelsa* Bentham (uncertain), *D. imperialis* Rözl ex Ortgies, *D. tenuicaulis* Sørensen,

(II) **Section** *Entemophyllon* Sørensen, *D. congestifolia* Sørensen, *D. dissecta* S. Watson, *D. foeniculifolia* Sherff, *D. linearis* Sherff, *D. rupicola* Sørensen, *D. scapigeroides* Sherff, *D.sublignosa* (Sørensen) Saar & Sørensen,

(III) **Section** *Dahlia* Sherff: *D. apiculata* (Sherff) Sørensen, *D. atropurpurea* Sørensen, *D. australis* (Sherff) Sørensen, *D. barkerae* Knowles and Westcott, *D. brevis* Sørensen, *D. coccinea* Cavanilles, *D. cordifolia* (Sessé & Mociño) McVaugh syn. *D. cardiophylla*, *D. cuspidata* Saar, Sørensen, & Hjerting, *D. hintonii* Sherff, *D. hjertingii* Hansen and Sørensen, *D. mollis* Sørensen, *D. moorei* Sherff, *D. neglecta* Saar, *D. pugana* Rodriguez & Castro, *D. parvibracteata* Saar & Sørensen, *D. pteropoda* Sherff, *D. purpusii* Brandegee, *D. rudis* Sørensen, *D. sherffii* Sørensen, *D. scapigera* (A. Dietrich) Knowles & Westcott, *D. sorensenii* Hansen & Hjerting, *D. spectabilis* Saar, Sørensen, & Hjerting, *D. tamaulipana* Reyes, Islas, and Art. Castro, *D. tenuis* Robinson & Greenman, *D. tubulata* Sørensen, *D. wixarika* Art. Castro, Carr.-Ortiz & Aarón Rodriguez

Subsection Merckii Sørensen: *D. merckii* Lehmann (sometimes spelled Dahlia merkii)

(IV) **Section** Epiphytum Sherff: *D. macdougallii* Sherff

9.4.4 Conservation

In Mexico, there are 176 Natural Protected Areas (ANP) comprising six categories as Biosphere Reserves, National Parks, Natural Monuments, Resource Protection

Areas, Natural Areas of Protection of Flora, and Fauna and Sanctuaries. As mentioned by Carrasco-Ortiz et al. (2019) with the studies on geographical distribution and area of occupation by the taxon in Mexico, all dahlia species are at risk. *D. congestifolia, D. hjertingii, D. purpusii, D. spectabilis*, and *D. Tamaulipana* are critically endangered (CR), 31 species are endangered (EN), *D. merckii* is vulnerable (VU), and *D. coccinea* is almost endangered (NT). In Mexico, Oaxaca and Guerrero, the Sierra Madre Oriental, plus the coniferous and oak forests have the highest number of species in CR and EN. Finally, none of the species in CR is within Protected Natural Areas (ANP), while 21 species in EN are in ANP.

Along with the natural reserves of these species, cultivars and hybrids are conserved by different societies, institutes, as well as the breeder firms in field, seeds, and tubers in gene banks and in vitro cultures. The National Dahlia Collection, UK, established in 1983 in Oxfordshire and then transferred to The Duchy College near Rosewarne with its home at Varfell Farm since 1998 under the current custodianship of Greenyard Flowers, UK LTD. is having a collection of more than 1600 varieties in the Dahlia Garden with some old favorites and many heritage varieties.

9.4.5 Characterization and Evaluation

The efforts of E. E. Sherff, Prof. Paul D. Sorensen, Prof. Dayle E. Saar have systematized the taxonomy of dahlia along strictly botanical principles along with the valuable contributions by Danish professors Hans V. Hansen and J. P. Hjerting. And more recently, teams of Mexican botanists are finding new species in remote areas of the country (The Americ. Dahlia Soc. 2020).

An early breeder of dahlia was Comte Leon Charles LeLieur de Ville-sur-Arce who had four varieties to work with and by 1806 he had produced three double-flowered dahlias. Since 1813, many amateur breeders produced thousands of cultivars, usually chosen for their stunning and brightly colored waxy flowers (Misra et al. 2017).

9.4.6 Breeding Options

Dahlia breeding programs focused to enhance ornamental values, including flower color, size and form, and production quality. The conventional breeding programs *viz.,* introduction, hybridization, composite crossing, multiline, and backcross breeding have introduced variety of desirable characteristics. But classical breeding methods of dahlias are expensive and time-consuming methods. Also, there are many limitations such as limitations in distant hybridization due to incompatibility reaction and differences in ploidy level that is very common in dahlias, polygenic nature of traits such as uniform growth and synchronous flowering, and several viruses infecting dahlias being major hurdles and breakdown of resistance due to fast evolving pathogens. There is a need to use alternative breeding methods to provide faster developments of improved and novel types of cultivars through the use of

recent developments in plant biotechnology such as directed mutation, genomics, and recombinant DNA technology (Dalda Şekerci and Gülşen 2016).

9.4.7 Looking Forward or Future Perspective

The future work on dahlia should include studies on fertility of different species and cultivars and generation of blue dahlias with the use of biotechnological tools with induction of delphinidins.

9.5 Eucharis

Eucharis is a genus of monocotyledonous geophytes, having horticultural importance due to their glossy broad leaves and striking white fragrant flowers. It is very good pot plant and adds elegant look to a shady corner in the garden. Its natural habitat is tropical rain forests thus adapted to low light conditions and plenty of moisture. It needs humidity and grows in pots and outside in shady places. Many species of this genus bloom throughout year and some bloom twice or thrice a year. *Eucharis* is popularly known as Amazon lily, but generally, the species *E. amazonica* and *E. grandiflora* are known by this name and these two species are grown for commercial purpose. There are some evidences which show that mucilage from *Eucharis* bulbs (*E. formosa*) used by the Jivaro Indians of Peru for treating facial blemishes and acne (Lewis 1986).

9.5.1 Botany and Distribution

Eucharis plant consists of large deep green glossy leaves which are 20–50 cm long and 10–20 cm broad and umbellate inflorescence which has 2–10 snow white flowers, generally on an erect 40–80 cm long scape. Flower of eucharis resembles little bit to narcissus flower in having a prominent central cup. The mature fruit is triloculicidal capsule. *Eucharis* is a perennial and propagated by removing the offsets or bulbs which are generally 2–6 cm (1–2 in) in diameter. The bulbs are globose or subglobose composed of concentric and modified leaf bases. The bulbs of Eucharis are sympodial in habit. The development of plant is directly related to size of bulb, nutrition, storage, and environmental factors. Bulb must go through juvenile stage and reach a size (>3.5 cm diameter) suitable for flowering (Schiappacasse 1996).

9.5.2 Origin, Domestication, and Spread

Most of the species of *Eucharis* genus are native to Central America and South America from Guetemala to Bolvia (Meerow 1989). Some species scattered to

Mexico, the West Indies, and tropical islands. The major center of distribution for *Eucharis* is in the western Amazon basins inclusive of major tributary system, that is, the Napo, Pastaza, and Huallaga and the adjoining lower slopes of the eastern Andean cordillera. The genus includes 17 species distributed throughout Central and South America, ten of which occur in Colombia *viz.E. candida* Planchon et Linden, *E. Formosa* Meerow, *E. bakeriana* N.E. Brown, *E. bonplandii* (Kunth) Traub, *E. caucana* Meerow, *E. ulei* Kranzlin, *E. lehmannii* Regel, *E. castelnaeana* (Baillon) Macbride, *E.* x *grandiflora* Planchon & Linden, and *E. sanderi* Baker (Yusti-Munoz and Velandia-Perilla 2013). *Eucharis x grandiflora* is natural hybrid between *E. moorie* and *E. sanderi* and widely commercialized. *E. sanderi* is endemic to western Columbia and is threatened extinction due to rapid loss of habitat. Some conservation measures are taken to protect the species at Isla Gorgona (Yusti-Munoz and Velandia-Perilla 2013).

9.5.3 Plant Genetic Resources and Conservation

A somatic chromosome number, that is, 2n=46 largely characterized in this genus. Two tetraplaoid species (2n=92) are *E. bonplandii* from Colombia and *E. bouchei* from Central America. *E. caucanafrom* Colombia is a hexaploid with the largest chromosome number in the genus (2n=138). *Eucharis amazonica*, 2n= 68, is the only known deviation from these 2x, 4x, or 6x karyotypes (Meerow 1987). On the basis of greenhouse pollination attempts, it was concluded that all species of *Eucharis* demonstrated some degree of self-incompatibility and only *E. castelnaeana* sets capsule with self-pollen. The phenomenon of protandry was also recorded and this further suggests that most species are predominantly outcrossing (Meerow 1989). A hybrid has been raised between *Eucharis* and the allied genus *Urceolina* and given the hybrid name *Urceocharis.* This genus have a great potential as a pot plant so further work for conservation of species, standardization of various multiplication methods and in the direction of hybridization and crop improvement is required.

9.6 *Hymenocallis*

The plants under the genus "*Hymenocallis*" are commonly called as Spider lilies. It was recognized as a distinct genus under family Amaryllidaceae since 1812. The generic name *Hymenocallis* is derived from the *Greek* words "*hymen*" (meaning a membrane) and "*callos*" (meaning "beauty") which literally means a beautiful membrane and refers to the membrane that unites the filaments and forms the staminal cup. Different species find their economic importance owing to their chemical constituents for medicinal components and their ornamental values. As stated by Singh and Saxena (2017), *Hymenocallis littoralis* an ornamental and medical plant which has been traditionally used for wound healing is found rich in many phyto-constituents that are useful in drug designing with antitumor, anticancer, antiviral, antimicrobial, antibacterial, antifungal cytotoxicity activity. It is also

having allelochemical importance such as defensive compounds, insect repellents, attractants and also maintains the ecological balance.

9.6.1 Botany and Distribution

The 40 different species in the genus *Hymenocallis* are glabrous and perennial herbs having large, onion-like round to oblong tunicated bulbs and often underground stems (rhizomes) with thick white roots. The strap or sword shaped, narrow to broad, erect or arching, bright green to bluish green, deciduous or evergreen, often coriaceous, distichous, hairless, and somewhat fleshy leaves arise directly from the bulb in two ranks. Flowers are hermphrodite, sessile, bracteate, fragrant, and 1 to 16 in number borne terminally on leafless stalk called scape which may be two-edged or roundish. The flowers form an umbel. The ovary is three locular, with one or more ovules per locule. A flower bears a slender greenish white *floral tube which* divides at its tip into six long, reflexed and narrow, white or pale green membranous *tepals* that gives flower a spidery look. Above the tepals, a delicate white, saucer or funnel like membranous *staminal cup* joins the bases of the six long and thin stamens (Smith and Garland 2003; Tapia-Campos et al. 2012; Garland et al. 2013). The fruit is a fleshy capsule bearing 1–6 seeds (Smith and Garland 2003). Seeds are fleshy, heavy, exhibit no dormancy, and germinate in 3–4 weeks after dispersal (Meerow et al. 2002).

Jee and Vijayavalli (1999) studied and reported the karyotypes of eight taxa of *Hymenocallis* Salisb. viz., *H. harrisiana* Herb (2n=74), *H. speciosa* Salisb. (2n=54), *H. littoralis* Salisb., *H. rotata* Salisb., and *H. occidentalis* Kunth. (2n=46) with three different chromosome numbers (2n=42, 44, and 46) in three accessions of *H. daphe* Herb. They further suggested that polyploidy and aneuploidy have contributed significantly in the evolution of chromosomes in the genus with n=23 as the secondarily derived basic number for the genus. Haron (2003) has reported that the *H. littoralis* has 2n=44, 46, 48, and 68. Later 2n=68 in *H. littorallis* was also reported by Nwankiti (1985) and was recently recorded with 2n=52 from Thailand using the FISH technique (Tanee et al. 2018). Smith et al. (2001) identified a new species *H. frankliensis* from Florida with 2n=43, 44. The lowest chromosome number (2n=38) is reported in *H. henry* Traub (Smith and Flory 1990).

9.6.2 Origin, Domestication, and Spread

Hymenocallis Salisb. is an entirely American genus of the family Amaryllidaceae with species distributed along the warmer parts of North, South and Latin America, West Indies (Flory 1976; Jee and Vijayavalli 1999; Meerow et al. 2002; Grossi 2007), SE United states, Mexico, Central America. Mexico is home to the greatest number of species with a secondary area of diversity in the USA (Grossi 2007). Only three species are endemic to South America (*H. littoralis*, *H. pedalis,* and *H. tubiflora*) (Meerow et al. 2002; Grossi 2007). *Hymenocallis* sp. grow in diverse

habitats. The North American species inhabit in and around the wetland habitats and less often in dry, flat woods or in disturbed sites while the Mexican species grow all around Mexico from xeric to aquatic conditions from tropical coastal areas to higher elevations and arid climates (Preuss 2002; Tapia-Campos et al. 2012). The genus ranges through the tropics, subtropics, and warm temperate regions of the New World and includes about 40 species (Garland et al. 2013). As indicated by Smith and his co-workers, 13 species are found in Florida (Garland et al. 2013).

9.6.3 Plant Genetic Resources

9.6.3.1 Geographic Distribution

H. littoralis originates from South and Central America, but it is cultivated and naturalized in tropical Africa, Asia, and the Pacific islands in the Malesian region, and it is recorded as naturalized in Java, the Philippines, and the Bismarck Archipelago (Haron 2003) Argentina, Brazil, China, Colombia, French, Guinea, Liberia, Mexico, Peru, South India, United States (Sarma and Debnath 2016) and in many other tropical regions as medicinal and an ornamental plant (Tanee et al. 2018). Jee and Vijayavalli (1999) collected eight taxa from South Indian states of Kerala and Tamil Nadu while *H. lottorolis* in Tripura by Sarma and Debnath (2016). Several species other than *H. littoralis* are cultivated as an ornamental in the Malesian region, for example, *H. caribea* (L.) Herbert, *H. Narcissiflora* (Jacq.) MacBr., and *H. speciosa* (Salisb.) Salisb., but only *H. littoralis* has become naturalized (Haron 2003).

9.6.4 Gene Pool

The different wild and cultivated species of *Hymenocallis* and closely related genera *Ismene, Elisena,* and *Leptochiton* previously classified as *Hymenocallis* and their complex hybrids and cultivars form the important gene pool for *Hymenocallis*.

9.6.5 Collections

The genetic diversity of cultivated and naturalized plants of *Hymenocallis* in South-East Asia may be very low. In Central America, several *Hymenocallis* species are classified as endangered. In Puebla (Mexico), a germplasm collection of ornamental geophytes is maintained including *Hymenocallis* (Haron 2003). The Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco (CIATEJ), Mexico, are also conducting collection, domestication, and breeding programs with different promising ornamental species native to Mexico along with *Hymenocallis* (Cruz-Duque et al. 2019). The institutes like USDA are emphasizing on conservation of natural habitats of *Hymenocallis* and the natural flora of America.

9.6.6 Characterization and Evaluation

Sealy (1954) narrated a history of the genus, taxonomic criteria, and brief review of 27 perfectly known and three other imperfectly known species of Hymenocallis while Traub (1962) has classified the species into six alliances based on the morphological characteristics as (I) Speciosa with species is having evergreen, petiolate, and broad leaves with tropical origin and distribution in Brazil, Mexico, and Carribean. (II) Caribaea is having tropical and subtropical species with evergreen, sessile, broad, oblong leaves and distribution in Central America, Florida, and Caribbean. (III) Littoralis is having species with slightly lanceolate and evergreen leaves and shortly joined perigonium segments with staminal corona and distributed in Colombia, Ecuador, and Mexico. (IV) Caroliniana with deciduous, South American species is having caduceus leaves, introrse anthers, and globular ovary with less than four ovules per locule. (V) Henryae distributed in Florida and Cuba is having cadudeus leaves, pale green tepals, introrse anthers, oblong ovaries with more than four ovules per locule and (VI) Mexicana with deciduous Mexican native species with sessile or subpetiolate, ensiform or caduceus elliptical leaves (Grossi 2007; Tapia-Campos et al. 2012).

Gerald L. Smith and co-workers *viz*., Anderson, Garland, Flory, *etc.,* had a great work on identification and characterization of flora of *Hymenocallis* after the initial works by Tarub and others.

The scientific and common names of important species of spiderlilies as per the website of USDA are: *Hymenocallis caribaea* (L.) Herb. (Caribbean spiderlily), *Hymenocallis choctawensis* Traub (Choctaw spiderlily), *Hymenocallis coronaria* (Leconte) Kunth (Shoals spiderlily), *Hymenocallis crassifolia* Herb. (Coastal Carolina spiderlily), *Hymenocallis duvalensis* Traub (Dixie spiderlily), *Hymenocallis expansa* (Herb.) (West Indian spiderlily), *Hymenocallis franklinensis* G. Lom. Sm., L.C. Anderson & Flory (Franklin spiderlily), *Hymenocallis gholsonii* G. Lom. Sm. & Garland – (Gholson's spiderlily), *Hymenocallis godfreyi* G. Lom. Sm. & Darst (Godfrey's spiderlily), *Hymenocallis henryae* Traub (Henry's spiderlily), *Hymenocallis latifolia* (Mill.) M. Roem. (Perfumed spiderlily), *Hymenocallis liriosme* (Raf.) Shinners (spring spiderlily), *Hymenocallis littoralis* (Jacq.) Salisb. (Beach spiderlily), *Hymenocallis occidentalis* (Leconte) Kunth (Northern spiderlily), *Hymenocallis palmeri* S. Watson (Alligatorlily), *Hymenocallis puntagordensis* Traub (Punta Gorda spiderlily), *Hymenocallis pygmaea* Traub (Dwarf spiderlily), *Hymenocallis rotata* (Ker Gawl.) Herb. (Streambank spiderlily), *Hymenocallis speciosa* (L. f.) Salisb. (Greentinge spiderlily), *Hymenocallis tridentata* Small (Florida spiderlily).

9.6.7 Use of Plant Genetic Resources

These bulbous plants are suitable for tropical plains and also for hilly altitudes up to 3000 m. These plants are suitable for growing along swamps, water channels and pools, on the borders, along the paths, in the beds, in pots, and for mass effects.

Tropical Giant, Bellum, Sulphur Queen, Pax (yellow hybrid), Sofforthiae (most popular fragrant hybrid with bright golden yellow blooms most suitable as cut flowers), Zwanenburg (suitable for cut flowers or as pot plants), Zeylanicum, Carribea (a cut flower hybrid), *etc*., are important genotypes developed in *Hymenocallis*.

9.6.8 Looking Forward or Future Perspective

The spider lilies are lacking in color variations which should be introduced through the genetic engineering tools, mutation breeding, and wide hybridization tools to create novelty in the genus. The types with more postharvest life should also be bred to enhance the status of the crop and growers around the world.

H. littoralis, an interesting medicinal plant, deserves more attention as a source of alkaloids and compounds with anticancer and antiviral (including anti-HIV) activities, but the reputed beneficial effects of bulb extracts internally on asthma and cough as well as externally on wounds, swellings, bruises, and boils also merit more attention and research (Haron 2003).

9.7 Iris

9.7.1 Introduction

The genus *Iris* is a large group of flowering plants comprising of 260–300 species with colorful showy flowers. It takes its name from the Greek goddess "Iris" word for a rainbow, referring to the wide variety of flower colors found among the many species. The genus *Iris* is separated into two major groups *viz.* the bulbous and the nonbulbous (rhizomatous) (De Munk and Schipper 1993). For flower production, the bulbous Irises are the most important and comprise of three major groups: Reticulata, Juno, and Xiphium. The nonbulbous (rhizomatous) group is important for flower bulb industry. Most of the commercial cultivars belong to the Dutch Iris (*Iris hollandica*) group, which was derived from crosses between two *Xiphium* species *viz., X. vulgare* and *X. tingitanum*.

9.7.2 Botany and Distribution

Species of the genus *Iris* are recognized by their basal fan of unifacial leaves; colorful perianth of three horizontal sepals and three upright petals that are basally fused into a tube; style branches that are fused at the base, petaloid distally and extend beyond the small flap-like, transverse stigma as a bifid crest; and three stamens that are opposite to the sepals and petaloid style. They have distichous

leaves and the large spathe valves are either membranous or herbaceous. It is a terrestrial or lithophytic herb or undershrub to 1.5–2.0 m tall. Iris flowers round the year with its peak bloom during the months of March–May.

Various species of *Iris* grow abundantly in diverse habitats such as alpine and subalpine meadows, roadsides, stream banks, public gardens, orchards, saffron fields, graveyards, and cemeteries (Zeerak and Wani 2007). Plants of genus *Iris* comprises of over 3000 species in the world of which 12 species are reported in India (Bhattacharjee 1998) but most commonly grown *Iris* species found in India are *I. croceae, I. ensata, I. germanica, I. hookerian, I. kumaonensis,* and *I. kashmiriana* which are confined to Himalayan regions.

9.7.3 Origin, Domestication, and Spread

Irises are widespread and found growing wild in all parts of the northern temperate zone from California in the west right round the globe to China and Japan. To the north, they extend as far as Alaska, Kamchatka, and Siberia and to the south to Hong-Kong, Southern Arabia and Florida. They have a wide range of growth habit from a few yards of the sea as, for instance, in Portugal where *Iris subbiflora* grows on the coast near Coimbra, or in Maine where a form of *Iris setosa* flourishes within reach of the salt spray, while in China and Tibet they are found at elevations of more than 12,000 feet.

The **Xiphiums**, which comprises the so-called English and Spanish Irises, are confined to Spain and Portugal with the neighboring countries of Southern France and North Africa and are characterized by the shape of their flowers and by the bulbs.

The **Juno** species are found near the shores of the Mediterranean, in Asia Minor, Northern Mesopotamia, Turkestan, and in the Salt Gange on the Northwest frontier of India.

The third section **Reticulata** is confined to the region between the Caucasus and the south of Palestine, from a valley in Turkestan.

The nonbulbous Irises have a rhizome, which is a creeping stem. Based on the presence of rhizome, irises are classified as bearded and beardless species, which are known as Pogoniris and Apogons. Species of the Pogoniris section are found growing wild from the Atlantic coast of Portugal and the Atlas mountains of Morocco through Central and Southern Europe, and Asia Minor to Turkestan and the mountains of Manchuria, Tibet, and Western China. Further, the bearded irises are classified into three minor sections *viz.,* Oncocyclus, Regelias, and Pseudo-regelias. The Oncocyclus species ranges through Asia Minor, Syria, the Caucasus, and Western Persia. Another species Regelias are confined to the northern side of the great mountainous backbone of Central Asia, while Pseudoregelia are found on the southern side in northern India.

The Apogons or Beardless species are by far the most widely distributed of all the divisions of the genus and are found all over the temperate regions of Europe, Asia, and North America.

9.7.4 Collections and Conservation

The genus *Iris* comprises of 53 threatened taxa and out of which 29 belong to the section Oncocyclus (Walter and Gillet 1998). Oncocyclus have been of interest to the horticulturists due to its large showy flowers (Foster 1899). They are xerophytic plants growing naturally in the Caucasus, eastern Turkey, Syria, Lebanon, Jordan, and Israel, and further to the east in Iraq, Iran, and Afghanistan. Results of the field surveys by various workers have indicated that there has been a decrease in *Iris* populations worldwide and more specifically the Oncocyclus irises. Today the main factors affecting the potential extinction are the human activities which have shaped the number of populations to a critical stage during the past few years. In an effort to conserve the *Iris* populations in Lebanon, microreserves are being established. Rescue from possible extinction could be performed through the reinforcement of populations by introducing individuals from adjacent populations. In this regard, defining species and differentiating taxa is a crucial and a prerequisite in order to define conservation units.

Another species under threat is the Western blue flag (*Iris missourensis*) which is a native of Canada and is mostly confined to areas with high soil moisture in spring and dry conditions later in summer. The most significant threats to Western Blue Flag are the continuous habitat loss, fragmentation and degradation from trampling or overgrazing by livestock, and invasive alien plant species. Threats of a lower significance include fire suppression, excavation of soil, alteration of hydrology (sewer outlet), and encroachment of problematic native species (woody vegetation encroachment). In an effort to conserve the Western Blue Flag, a conservation program was established in 2002 to deliver and monitor the plant population. Management and conservation plan for *Iris missourensis* consists of inventory and monitoring; research as part of an adaptive management framework, communication, collaboration, and engagement; and habitat assessment, management, and conservation (Environment and Climate Change for Canada 2017).

Method of conservation	Place	Species conserved
Ex situ conservation	Millennium Seed Bank (Wakehurst Place, Botanic Gardens Kew, UK)	*I .cedretii* and *I. sofarana subsp. Kasruwana* seeds (Saad et al. 2009)
	Seed Bank at Herbarium of Hebrew University and University Botanical Garden of Jerusalem	Highly endangered *I. atropurpurea* and *I. hieruchamensis* (Cohen and Avishai 2000)
In situ conservation	Creation of two living collections outside the natural populations, but within the same ecological conditions; and relocation experiments from the Northern Negev, Israel	Critically endangered plant species, *I. atrofusca* (Volis et al. 2010)
	Creation of Nature Reserve in Israel	Highly endangered *I. atropurpurea* and *I. hieruchamensis* (Cohen and Avishai 2000)
	Wikemong Reserve in Canada	special concerned Dwarf Lake Iris (*I. lacustris*) (Cosewic 2010)

9.7.5 Characterization and Evaluation

It is very important to understand the genetic diversity and relationships among plant species and varieties from the breeding point of view and intellectual property rights (IPR) (Tay 2006; Wanjala et al. 2013). The genus *Iris* has a rich genetic diversity due to which there is relatively large genetic differentiation at the species level. Wild relative of *Iris* can be used for crossbreeding, as well as for ornamental and medicinal purposes. Morphological characteristics of 53 accessions were collected from Liaoning Province, which is a primary distribution area of *Iris* in China. *Iris tigridia* Bunge and *Iris ensata* Thunb. had shown to have better ornamental value than the other species under evaluation (Zheng et al. 2016).

Having a larger reservoir of variation leads to higher chances of finding particular characters, such as resistance genes for diseases and pests or for adaptation to wider ecological amplitudes and stress conditions. In recent years, more than 60 new genotypes of *Iris germanica* and *I. spuria* have been bred in Iran, which are used for hybridization and can provide new perspectives on the composition of wild types and other species. Important species of Iranian irises include *Iris acutiloba*, *Iris persica*, *Iris iberica*, and *Iris spuria*. From the medicinal point of view, *I. acutiloba* had the highest concentration of anthocyanins, flavonoids, and carotenoids (Azimi et al. 2019).

Iris species have beautiful linear foliage that makes them one of the most favored ornamental plants. Additionally, because of their high resistance to cold, drought, disease, and salinity, some species, such as *Iris lactea, Iris sanguinea, and Iris halophila*, can be successfully grown in coastal and saline-alkaline areas (Bai et al. 2008). In addition, *Iris tectorum, Belamcanda sinensis, Iris germanica,* and a few other species have medicinal value, containing flavonoids with good detoxification effects (Agarwal et al. 1984; Burcu et al. 2014). On the basis of soil and water requirements, *Iris* can be divided into three categories: the first group includes species that prefer weakly alkaline, calcareous, damp, fertile, and well-drained soil, such as *Iris tectorum* Maxim. and *I. germanica*; the second group includes the species that thrive in acidic and wet soil, such as *I. japonica* and *I. pseudacorus;* the third group includes species that can adapt to any type of soil-poor, dry or wet such as *I. lactea var. chinensis.* Among the different species, *Iris germanica* is also known to show the highest drought tolerance (Liu et al. 2005; Xu et al. 2019).

Many new cultivars with desirable traits have been bred through crossbreeding, by using the extensive collections of wild species and varieties. Embryo culture, somatic hybridization, and transgenic breeding are a few other successful methods used for *Iris* breeding (Shimizu et al. 1999). Till 2009, reports have shown that there were more than 30, 000 *Iris* cultivars in the world, as catalogued by the American Iris Association (Lin et al. 2010; Zhang 2010). In China, wild *Iris* resources with many good genes are abundant, and these may be used to improve, innovate, and preserve the *Iris* germplasm. However, *Iris* breeding started late and developed relatively slowly in China. Only a small part of the *Iris* resource was utilized directly without any modification, probably due to the lack of systematic research. In breeding

programs, breeders typically select parents with good performance and a wide hereditary basis, according to their genetic diversity and relatedness to parental germplasm, which are very important criteria for crossbreeding (Hesham and Yan 2010; Matus and Hayes 2002).

There is little information available on the genetic diversity and relationships among the different species of iris considering its vast genetic diversity. Understanding the genetic variations within and between populations is essential for the establishment of effective and efficient methods of conservation of plants. In *Iris* particularly, where there is a great genetic diversity in species, the use of molecular markers is a powerful tool in the genetic study of such populations. The use of DNA markers, AFLP, SSR, RAPD, and ISSR represents an alternative method in detection of polymorphism. Genetic variations in some wild iris genotypes in Iran *viz. Iris kopetdaghensis, I. songarica, I. fosteriana* were evaluated using ISSR markers. These markers have proved to be an efficient tool in determining the high genetic diversity among these wild genotypes and have been successfully used in *Iris* breeding programs (Atari et al. 2017).

Amplified fragment length polymorphism (AFLP) markers in conjunction with a combination of EcoRI/MseI restriction enzymes have also been used to study the genetic diversity and relationships among 15 species of *Iris* collected in China. An assessment of genetic diversity parameters using AFLP markers showed that *Iris* has high genetic diversity at the species level. Clustering analysis and principal coordinate analysis showed that the 15 species of *Iris* were genetically similar and thus related. When the genetic similarity coefficient was 0.55, the 15 species could be divided into five distinct groups. These findings verify, replenish, and consummate the classical taxonomy and systematology of *Iris* and also provide references for the conservation, management, classification, identification, and breeding of *Iris* resources.

9.7.6 Breeding and Use of Plant Genetic Resources

Breeding and crop improvement of Iris had been started at the beginning of the twentieth century in the Netherlands (Dix 1974), and initially the "Spanish" irises (*X. vulgare* group) and many other varieties were released. The "German irises" were diploid bearded types that had 12 pairs of chromosomes and were descended from complex crosses involving two wild species-the lavender *Iris pallida* and the yellow and red *I. variegata*, both from southern Europe. During the initial phase of the year 1910, these garden diploids were crossed with a series of wild tetraploids (*I. ciipriana, I. ernesopotamica*, etc.) that had 24 pairs of chromosomes. These forms, all from the eastern Mediterranean region, were all purplish blue in color, taller, larger, as well as susceptible to cold and other unfavorable conditions than the older diploids. The modern tall bearded irises have been developed from these crosses.

Two very important breakthroughs took place in Iris breeding *viz.* the successful inter-specific crosses between small bulbing cultivars of the *X. vulgare* group and the crosses between the two different types of the *X. tingitanum* species. Subsequently, these crosses produced cultivars with large bulbs like Wedgwood, Prof. Blaauw, and Blue Magic which are adapted to year-round flower production (Dix 1974). "Blue Magic" is still the most widely grown cultivar in the Netherlands. Initially, breeding with these inter-specific hybrids was limited since they were sterile. However, a fertile spontaneous tetraploid of "Wedgwood" was observed during 1952 which made it possible to make crosses with cultivars of the *X. vulgare* types and several triploid cultivars, among which "Telstar" was one.

A few fertile plants were also found in "Prof. Blaauw" in different ecological conditions in western France (Brittany) (Le Nard, unpublished data). The seeds of these plants were collected and sown which also produced fertile plants having tetraploid chromosome. Inter-crossing and crossing of these plants with diploid cultivars were carried out and the resulting selections were released for cultivation in the year 1990. Systematic and scientific research devoted to *Iris* breeding is limited and is being carried out mostly by *Iris* growers and bulb-producing companies. In Netherlands, a breeding program using inter-specific hybridization was initiated to get different colored cultivars with the ability to flower year round (Eikelboom and Van Eijk 1990). The findings of the research showed some successful data on the transmission of flower colors; however, the use of colchicine for the production of fertile tetraploid plants was not successful. It has been suggested by Kim and De Hertogh (1997) to use a combination of mitotic substances and in vitro culture for successful breeding of the bulbous Iris.

9.7.7 Major Constraints in the Crop Production

Irises are very slow growing geophytes which take nearly two years or more for the plants to come into the flowering stage. This causes a major hindrance in the breeding program of Irises. For successful crosses, hybridization success rates vary from 25 to 65% and germination percentage of around 30 to 33%. The flowers of *Iris* are rarely pollinated naturally; however, it will set seed freely when hand-pollinated. Therefore, it is not necessary to remove the anthers and enclose the flowers in bags when making crosses. Irises are usually propagated through underground stems or rhizomes which perpetuate the genetic composition of the original plant. This makes it easy to keep parents indefinitely for comparison with or crossing with their descendants. Reticulata *Iris* breeding can be enhanced by developing polyploids either by tetraploids (4n) or possibly octaploids (8n). These polyploids have larger flowers, tolerate poor weather, and have a longer flowering period (Mc. Murtrie 2016).

Common sources used to overcome production constraints are listing of genetic resources, genetic stocks (including aneuploids series, substitution and translocation

lines, recombinant inbred lines, *etc*.), inbred lines, released cultivars associated with desired traits, genes with gene symbols, mapping populations, *etc*.

9.8 Ixia

Ixia, a winter annual, is commonly known as "wand flower" that refers to the thin, wiry but strong stems that wave in the wind or "African cornflowers" or "corn lily" referring to the stem with its buds that resembles the stalk of corn. The derivation of the genus name "*Ixia*" has two different opinions. The one says that it came from the *Greek* word "*ixos*" meaning mistletoe (viscum), birdlime, referring to the viscous juicy sap, while the other says that Linnaeus derived the name from an old *Greek* name for a plant noted for the variability of its flower color (Lewis 1962). Since *Ixia* is a variable genus of many flower colors, the later explanation is more appropriate.

9.8.1 Origin, Domestication, and Spread

Ixia is native to the western and southern parts of South Africa, that is, Cape Province of South Africa. It is restricted to the winter-rainfall zone of South Africa. This African flower has been widely naturalized in Europe, south-western USA (*i.e.,* California), and parts of southern Australia (*i.e.,* in the coastal districts of central and southern New South Wales, Victoria, Tasmania, south-eastern South Australia and on Kangaroo Island, and in south-western Western Australia. However, in many parts, it has escaped the cultivation and became weed in woodlands, shaded moist sites, urban bushland, roadsides, disturbed sites, and waste areas.

9.8.2 Botany and Distribution

Ixias are tufted deciduous geophytic herbs characterized by sword like long and narrow leaves arising annually from perennial corm. Stems are 40 to 100 cm tall, slender, wiry, erect usually with 1 or more almost erect branches. Stems require support to be held upright. Leaves are flat or curved with narrowly elliptical blades 25 to 40 cm long and 3–10 mm broader and prominent veins. Roots are small, corms globular with fine roots and smaller cormels. Flower stems of almost equal length of 30–100 cm length borne during spring to summer. Flower heads are 4–20 flowered spikes having membranous floral bracts that are attached at the base of the ovary. Flowers are sessile, perianth 50–70 mm long of varying colors with a long narrow funnel shaped tube with six radiating tepals giving it a star shape outline. Outer three tepals are narrowly egg shaped, 20–25 mm long, and about 3–6 mm wide, while the inner three are slightly narrower. Ovary is inferior. Style is thread like, branching 2 mm long, spoon shaped, curved. Stamens are attached to the perianth tube, filaments are free, anthers 5–6 mm long and erect. Pollination is by insects *viz*., bees, beetles, flies, and butterflies that visit the flowers for mating, to eat away the

nectar and pollens. Fruits are botanically capsules with many brown seeds. The capsule dries and splits open and seeds are scattered about the parent as the stem weaves and bobs in the breeze. It is commonly reproduced vegetatively by corms. Spread of the species is by movement of corms in water flows and soil.

9.8.3 Plant Genetic Resources

The genus was established in late seventeenth century and currently genus Ixia consists of 99 species, each being a little different from others, especially in terms of its flower color and structure and are taxonomically classified into four sections *viz*., *Ixia* (29 species), *Dichone* (17 species), *Hyalis* (19 species), *Morphixia* (34 species) with few circumscriptions between Lewis and Goldblatt & Manning. It belongs to the Iridaceae family and is placed in the largest subfamily Crocoidae (Goldblatt et al. 2015; Goldblatt and Manning 2012, 2016) in a tribe Ixieae with 14 genera.

Ixia* sect. *Dichone (Salisb. ex Baker) Goldblatt and J. C. Manning (Goldblatt and Manning 2011, 2016)

Dichone is one of four sections in the genus currently includes 17 species and three varieties. The meaning of a *Greek* word "*Dichone*" is two tubes that might refer to the incompletely dehiscent anther thecae. The section is vegetatively identical to section Ixia but is distinguished by the following floral characters: filiform lower part and short to vestigial upper part of the relatively short perianth tube; filaments not decurrent; stamens unilateral and reclinate in some species with horizontal to pendent anthers and incompletely dehiscent anthers in few species, opening from the base; style tightly clasping and branches involute-tubular and stigmatic only at the tips; anthers short, oblong to suborbicular, usually so-called subdidymous. Flowers are usually with shades of pink (rarely white), but blue-mauve in *I. brevituba*.

Ixia* sect. *Ixia (Goldblatt and Manning 2011, 2016)

Flowers with a filiform perianth tube, usually well developed and sometimes elongate; anthers linear, dehiscent along their entire length; style branches narrowly channeled (Lewis 1962, described the style branches as conduplicate, but they are not folded together, but rather form a narrow channel) and stigmatic along the margins, sometimes only toward the tips. The stamens are always symmetrically arranged with the filaments inserted at the base of the tepals and not decurrent. Leaf number is indeterminate, but usually at least four and up to 10. The upper leaves decrease in size progressively above, becoming partly to largely sheathing, but lack a sharp distinction between basal foliage and upper sheathing leaves. Flowers are usually unscented and often brightly colored and frequently have a dark central mark, either restricted to the tepal bases or including the filaments and sometimes the anthers and style branches. Nineteen species are currently recognized.

Ixia* sect. *Morphixia (Ker Gawl.) (Pax 1888; Goldblatt and Manning 2011, 2016)

Perianth tube is hollow; filaments inserted within the tube and decurrent, not connivent at the base. The style branches are usually fairly short and recurved, but of the same type as in sect. Ixia. Although usually central, the stamens are occasionally

unilateral (a feature not known to Lewis): horizontal in *Ixia pauciflora*, declinate in *I. reclinata*, and ± arcuate in *I. stenophylla*. The tepals are seldom brightly colored, more often being muted shades of blue-grey, mauve pink, or white and only rarely with weakly developed markings. Floral scent is common and usually reminiscent of rose to violet but *I. rivulicola* has a rich floral scent with notes of passion fruit and sweet pea. Nectar is always present in the base of the perianth tube, sometimes in substantial quantities. An important feature of the section is that leaf number is determinate, usually three, occasionally more, and the basal leaves with expanded blades are sharply distinct from the uppermost one or two, which are entirely sheathing. There are 31 species recognized in the section.

Ixia sect. Hyalis (Baker) (Diels 1930; Goldblatt and Manning 2011, 2016)

A residual group includes species with style and anthers of the sect. Ixia type; an indeterminate leaf number, the upper leaves weakly differentiated from the lower, and usually with free blades; and tubular or funnel-shaped perianth tube ranging from hollow throughout to filiform in the lower two thirds and expanded above (thus, with decurrent filaments). Nectar is normally produced and the flowers are often scented (depending on the pollination system – those pollinated by long-proboscid flies are unscented). The outer bracts with usually only one prominent central vein are a feature of most species. The circumscription of sect. *Hyalis* adopted here thus differs from Lewis's; in that it is not restricted to species with an elongate perianth tube although the type species, *Ixia paniculata*, has the longest tube in the genus. There are 18 recognized species under this section.

Within sections Hyalis and Morphixia, there are recognized eight informal clusters of species sharing one or more derived features, for convenience called series, and most of these are monophyletic but some may be paraphyletic. The species of sect. Hyalis are distributed among three separate series and those of sect. Morphixia among five.

9.8.4 Cultivation

The Ixias are ideal ornamentals for the hot, dry climatic conditions and can be grown in warmer climates under protection from rains and water under partial or full sun. In landscaping, they are used for group planting in borders, containers, and bedding plants for their attractive and brilliantly blossoms with six petalled flowers colored from deep crimson to orange with contrasting spots and dots on them. The sites sheltered from high winds receiving full sun with well-drained sandy to loamy soils rich in organic matter and slightly acidic to slightly alkaline with lime are best. They are grown with the corms as are the members of Iridaceae family. Corms are planted in mid- to late autumn on beds at a depth of 3–4" and spacing of 3–4" apart. Apply irrigations @ 1 inch per week by moderate quality of water to just moisten and not to saturate the media with due care during active growth stages. Fertilizers are applied when sprouts come out within 1–3 weeks from planting that will bloom through spring and summer. After the harvest of cut flowers, keep the leaves intact for their corm development and multiplication. Later, when leaves turn yellow denoting the

maturity of corms, the leaves are cut back and dig out corms and store in a cool location in a dry medium until the following spring or kept as it is for next season.

For pots, tubs, and urns, fill the containers with good quality, well-drained soil or any commercially available potting media mix with adequate drainage holes in container. Keep the containers where they will receive full sun. Plant the bulbs 2–3" apart for a good display at a depth of 4" inches into the media. After planting, water well to gently soak and settle the soil around the corms. The corms will give out roots earlier but shooting and flowering can be seen in spring and summer. After blooming has finished for the season, keep the leaves intact on plant for nourishing the developing corms. When leaves turn and dry out, remove them and let the corms remain in the container till next autumn in dormant stage. In dormant stage, protect them from mealybugs. In autumn, fertigate the corms for the nourishment and to encourage better flowering in the next spring.

A growth retardant, Paclobutrazol can be applied as a preplant corm soak, a postemergent drench, or a postemergent spray in combination with a 2- to 4-week preplant storage of corms at 7 °C and an 18 °C day/10 °C night forcing temperature to produce dwarfer, attractive, and marketable pot plants (Wulster and Ombrello 2000).

9.9 Nerine

The genus *Nerine* comprises of perennial bulbous ornamentals bearing colorful long lasting flowers of white pink to crimson shade in a spherical umbel of lily type flowers. Though they are known as Japanese spider lily and cape flower lily, these are not true lily, that is, liliaceae family, but more closely related to its relative *Amaryllis*. There are 20–30 species in the genus, but only *N. bowdenii*, *N. sarniensis*, and *N. undulate* (Syn.*N. flexuosa*) are commercialized. Nerine is gaining more and more horticultural interest for fresh cut flowers and garden plants but some species and cultivarshave gained popularity as potted plant too. The colorful, elegant flowers of Nerines can survive up to 14 days in a vase with water without showing any signs of wilting, senescence, or fading. It is an important cut flower but low flowering percentage limits its share in Dutch cut flower market.

9.9.1 Botany and Distribution

The genus *Nerine* is a member of class monocotyledonae, order Asparagales, family Amaryllidaceae, and tribe Amaryllidae. The geophytic organ is a true perennial bulb, comprised of fleshy leaf bases and covered with papery tunics. The bulbs of *Nerine* species need a minimum of two years growth and development in order to produce their first flowers. The largest bulbs can give rise to two stems or more if they have been grown under suitable conditions. Depending on the species, the leaves are long and slender and they can be evergreen or deciduous and sometime hysteranthous. In the case of deciduous species, the inflorescence may appear on naked stems before

the leaves develop (hysteranthy), otherwise they appear together with the flowers (synanthy) or afterwards. Generally, flowers (8–20) are borne in umbels on leafless scapes and they can be red, rose, pink, purple, or white.

9.9.2 Origin, Domestication, and Spread

All species of the genus *Nerine* are native to South Africa and these species occupy wide spread range of habitat. This group is endemic to five southern African countries: Botswana, Lesotho, Namibia, South Africa, and Swaziland (Duncan 2005). Concentrated in the summer rain fall zone in the eastern part of South Africa and comprises some 23 species (Zonneveld and Duncan 2006). The habitat diverse range starts from cool mountains, swamps, and desert plain ascending to mountain. They prefer rocky, arid habitats, and most species are found in the summer rainfall region (Snijman and Linder 1996).

9.9.3 Plant Genetic Resources

The basic chromosome number is 11 (2n=22) but plants with 2n=24 and triploids are also recorded (Traub 1967). During the early history of the crop improvement and hybridization of *Nerine*, the plant breeders contributed to great achievement using only a few species (Du Plessis and Duncan 1989). In nineteenth century, many hybrids appeared in England were developed using *N. sarnensis*, *N. undulate,* and *N. humilis*, but *N. bowdenii* was only introduced in the early 1900s providing breeders with the most valuable *Nerine* species of all (Duncan 2002). *N. bowdenii* is one of the hardiest species and thus used for breeding hardy varieties with wider color range. Some of the cultivars are *N. Bowdenii* "Alba," "Pallida," "Marnie Rogerson," "White Magic," "Stefanie," and "Blush White." Along with *N. bowdenii,* other species like *N. sarnensis* and different cultivars have been extensively used in plant breeding programs that have produced the majority of the commercially available hybrids. Consequently, commercial cultivation of *Nerine* now occurs throughout the world, particularly The Netherlands, Israel, South Africa, New Zealand, and Southern Australia. Its cultivation is also started in India. *N. sarniensis* is the main parent of 300 years of *Nerine* breeding. The world's largest collection of *N. sarniensis* hybrids is kept at Exbury Gardens in the United Kingdom.

9.9.4 Important Species of *Nerine*

Nerine bowdenii: *N. bowdenii* is named after Cornish Bowden who brought this variety from South Africa to England in 1903. This species is also known as Cornish lily. It is hardiest species and more robust than the other species of the genus *Nerine*. This may be the reason that it has been used as a parent in crosses to obtain hardy plants along with a wider color range and flower morphology.

***Nerine sarniensis*:** *N. sarnensis*is also known as Guernsey lily as it is associated with the island of Guernsey. It has long lasting cut flowers. A wide range of color from white through pink, red orange, and mauve with well-formed inflorescence is present but multiplication rate is slow.

***Nerine pancratiodes*:** It is a distinct species of the genus and cannot be easily confused with other members of the genus. It has pure white, funnel shaped, suberect flowers borne on densely pubescent suberect pedicels. The inflorescence is borne on a very long, erect, glabrous scape and the ovary is distinctive deep pinkish maroon.

9.9.5 Molecular Characterization and Evaluation

With the developing field of genome size measurement, it has been shown that when species in a genus have the same chromosome number, as in *Nerine* (2n=2x=22), differences in nuclear DNA content can be used as an additional character to delimit species and intrageneric divisions. Studies were carried out on genome size of Nerine and correlation was demonstrated with their nuclear DNA content, growth cycle, leaf width, and other morphological characters (Zonneveld and Duncan 2006).

9.9.6 Conservation

Some *Nerine* species in different parts of South Africa are rare or in danger of extinction due to degradation of their habitat due to summer rains, overgrazing, and erosion due to construction of roads. Some of these species are *N. pudica, N. marincowitzi, N. masoniorum, N. filamentosa, N. masoniorum, N. gibsonii, etc.* Graham Duncan has done great work on collection and hybridization and is well known for his expertise on Nerine. Different measures have been taken to conserve the species and to relieve the threat of extinction and one of them is *ex situ* conservation. Graham Duncan contributed a lot in collection and conservation of Nerine species at the Kirstenbosch National Botanical Garden. Some of these species are *N. filamentosa, N. gibsonni*, *N. huttoniae,* and *N. masonioruminthe*. In Guernsey, the national flower is *Nerine sarniensis*, and the island collection of nerines is seeking recognition by National Council for the Conservation of Plants and Gardens as a national collection.

9.9.7 Future Perspective

This plant has great horticultural economic value. But the major problems in different species like low multiplication rate, short scape, long period to first flowering and comparatively less flowering limit its popularity in world flower trade. So, there is further need to work on its micripropagation and to bred early and profuse flowering cultivars with wide range of color.

9.10 Zephyranthes

9.10.1 Introduction

Zephyr lily is a bulbous perennial. Native to south-eastern North America, it has pale pink-tinged, white flowers. The name *Zephyranthes* is derived from word "Zephyrus" means the Greek God of west wind that reawakened nature each spring and "anthos" meaning flower. Common names for the species in this genus are fairy lily, rain flower, zephyr lily, magic lily and rain lily. *Zephyranthes* species grows from truncated bulbs and their active period of growth and flowering takes place in summer and a rest period during winter (John Peter Arulanandam et al. 2015). Many *Zephyranthes* species are appreciated as ornamentals and are traditionally known as "rain lilies" due to their tendency to flower shortly after rainy periods.

9.10.2 Botany and Distribution

The genus *Zephyranthes* vary in bulb, flower, and leaf characteristics in respect of size, color, *etc.* The species belonging to this genus are perennial bulbs which tolerate many natural habitats from wet soil to dry conditions. It is a glabrous perennial herb with bulbs, often clumped. Leaf blades are elongate and linear, grass like with overlapping sheath bases. Flowers are radially symmetrical, single, and terminal on scape, with a spathecous bract below, tubular in bud but splits at anthesis about half its length. The ovary is inferior and perianth is tubular with six segments. Flowers are yellow, pink, or white. Stamens are six in number, inserted on the throat of the perianth, anthers medially attached on the back, and stigmas three in number. Capsules are three lobed, locular with numerous, black and lustrous flat seeds.

9.10.3 Origin, Domestication, and Spread

The genus *Zephyranthes* is native to western hemisphere and to the higher altitudes like Mexico, Argentina, where the species possesses greatest cold hardiness potential. Several species have become naturalized and are cultivated as ornamental plants in other places like Hawaii, Indonesia, Thailand, *etc*. The species that is native to the higher altitudes in Mexico (*Z. lindleyana*) Central America, Costa Rica (*Z. carinata*), and parts of North America (*Z. longifolia*) or Argentina (*Z. candida*) represent the species having the greatest potential for cold hardiness. Broadly these plants are distributed in temperate to tropical areas of the world.

9.10.4 Plant Genetic Resources

Zephyranthes atamasca is native to Central Florida, North Florida, and the rest of the southeastern United States. This lily is commonly known as atamasco lily, rain lily, and blooms in March and April. Flowers are large – 3 inches wide or larger – white, and funnel shaped. The flowers are perched on 10-inch stems and will fade to pink. This rain lily is often found in rich, moist soils in swampy forests and coastal prairies and seen in roadside ditches. Clumps of broad, grassy leaves emerge in early winter and die down in late spring or early summer.

Zephyranthes candida, commonly known as fairy lily or white zephyr lily, is native to Argentina and Uruguay, where it is found along rivers and in marshes. This rain lily rapidly forms thick clumps of dark-green, upright, rush-like leaves. The clumps are up to 10 inches tall. In the late summer and fall, fairy lily produces 1–2 inch, white, crocus-like flowers.

Zephyranthes citrina, commonly known as yellow rain lily or citron zephyr lily, is native to the Yucatan peninsula of Mexico. During late summer and fall, these lilies produce small, deep-yellow flowers on stem which is 8–10 inches long. Leaves of this rain lily are up to 12 inches long.

Zephyranthes grandiflora, also known as pink rain lily or rose pink zephyr lily, is native to Central America and the West Indies islands. This rain lily produces bright-pink, funnel-shaped flowers all summer long. Individual flowers are up to 4 inches across and 3 inches long and perched on 10–12 inches tall stems. Each bulb produces clusters of dark-green, strap-like leaves up to 12 inches long. Bulbs rapidly form large clumps and can display up to 20 flowers at once. This lily is also known to be salt tolerant.

Zephyranthes treatiae is also known as Treat's zephyr lily and it flowers during the spring. It is found naturalized in wet pinelands and roadsides. It is native from Southern Georgia and Central peninsular Florida.

Zephyranthes simpsonii is known as red margin zephyr lily and is endemic to Central and Southern Peninsular Florida. It is found growing in wet pinelands and roadsides and flowers during spring and summer.

Zephyranthes rosea is native to Cuba and flowers during summer. Flowers are white to pink in color.

Zephyranthes tubispatha is native of Peru, tropical America, and the West Indies and has been naturalized all throughout the gardens. It is found in well-drained soils and grassy ground of hilly areas which flowers during September.

Zephyranthes susatana is found in semi-arid enclave of high plains of Bogota in Columbia. It is locally abundant in open dry grasslands, which are severely disturbed by man and cattle. It flowers twice in a year *viz.* February to March and November to December. Flowers are vinaceous yellow in the exterior and interior is dark yellow.

Zephyranthes albiella: This species is native to Central Columbia (Cundinamarca). The plants generally presenting leaves simultaneously with flowers. Flowers are white in color with greenish base.

Zephyranthes puertoricensis: It is a native of Puerto Rico and has flowers which are white, greenish in the throat and of intermediate size.

Zephyranthes robusta: This species is considered a native of Argentina, Uruguay, Rio de Grande, and Brazil.

9.10.5 Collections and Conservation

Zephyr lily is found in low woods and wet meadows. It readily colonizes road shoulders in areas of appropriate habitat, apparently benefiting from the extra light and decreased competition in this nonnatural setting. The main threat to this relatively common species is habitat destruction, fire suppression, conversion of habitat to pine plantations and agricultural fields, ditching, draining, and filling wetlands.

9.10.6 Characterization and Evaluation

Zephyranthes species can tolerate many ecological niches (periodically wet soil to desert conditions) and have many ornamental characteristics. The genus has been evaluated for possible medicinal properties and the biochemically toxic compounds are classed as alkaloids. Along with floral morphology, characteristics such as bulb size, bulb tunic, and leaf morphology have also been studied that help to identify individual species. Foliage in the wild is often ephemeral, but under cultivation it becomes more persistent. Leaf color ranges from the bright grassy green of *Z. candida* to rather broad glaucous colored foliage such as found in *Z. drummondii.* A few of the species have distinct bronze tints in the foliage when grown in bright light. Size of leaves in these species ranges from dark green and tiny grassy leaves in species like *Z. jonesi* or *Z. longifolia* to broader, glaucous leaves in species like *Z. drummondii*. Perhaps largest leaves of all are found on *Z. lindleyana* from Mexico, usually distributed as a cultivar called "Horsetail Falls"; this species has handsome broad leaves almost like a Hippeastrum. Flower color in the species ranges from white to yellow (various tints of this color from lemon to sulfur) and pink. *Zephyranthes* have erect flower stalks which support a flower that may be upward facing or slightly nodding. The funnel-shaped flowers with six petals can be crocus shaped, but may also open flat such as in *Z. jonesii* or even reflex slightly. The flowers of some species have a sweet, pleasant fragrance. Fragrance appears to be recessive in crosses, but there are a few species or hybrids, *Z. drummondii* (white), *Z. morrisclintae* (pink), and *Z. jonesii* (light yellow) that all carry the trait. Two of these open their flowers at night and are attractive to nocturnal insects. The flowers typically last only for a day or two; but new flowers may appear in a succession of blooms, especially during humid or rainy weather. Various members of the genus may bloom spring only or repeat and continue into autumn, often a few days after rainstorms thus one of the common names, rain lilies. Periods of synchronous bloom, which breeders have dubbed "blitzes," are part of their ornamental value and the breeders exploit for the purpose of producing new hybrids. Most species under cultivation will bloom without the naturally imposed

drought and wet that occurs in nature. Greenhouse grown plants bloom very freely but cycle through periods of bloom. One of the longest blooming of all the species is *Z. primulina* which blooms from April until October. Some other species such as *Z. morrisclintae* appear to bloom only in the spring season. Most of these species are easily propagated vegetatively through offsets or twin scaling. A few of the species such as *Z. clintae* are slow to produce offsets. Sexual reproduction is via seed. Seed usually is best sown quickly after harvest, although short term storage can be successful. Maiden seedling can be brought into bloom for some of the hybrid in 8–12 months after sowing in ideal conditions. This makes it easy to carry out checks for apomixis. The apomictic species freely set seed and faithfully reproduce the maternal phenotype (Gangopadhyay et al. 2009).

9.10.7 Use of Plant Genetic Resources

In *Zephyranthes,* inter-specific and inter-generic hybridizations are complicated by the fact that some of the species are apomictic or pseudogamous, cross incompatible, or have widely variable 2n chromosome numbers. Chromosome number within *Zephyranthes* ranges from 2n=18-96, posing a barrier for crosses among the species (Raina and Khoshoo 1971). Among the different species of Zephyr lily*, Z. primulina*, although it is apomictic, it is a choice parent for crosses because of its rapid repeat flowering trait and long blooming season. In zephyr lilies, the stamens are often spatially separated with either exserted pistils or hidden pistils. This arrangement significantly influences pollination in the wild. Flowers with hidden stigmas are self-pollinated unless insect visited. Several species of *Zephyranthes*, such as *Z. jonesii* which have hidden pistils and are mildly fragrant, bloom at night and release pollen at dawn. This arrangement of stamens insures self-pollination unless the corolla with attached stamens is excised before pollen release when hand pollinating.

Although the presence of alkaloids has been documented in several species (Kojima et al. 1997), and other species have been evaluated for medicinal value (Katoch and Singh 2015), the primary interest in breeding programs is for the ornamental value of the flowers. Collections of wild naturally occurring hybrids such as *Zephyranthes tenexico* have apricot-colored flowers which can be used in breeding programs for extending the color availability (Fellers 1996). Although many of the species have small ephemeral flowers, some hybrids produce larger flowers that will remain open for up to 3 days. However, the potential for new cultivars via cross pollination is limited because of some reproductive barriers in these plants.

Pollination investigation reveals that all studied species of *Zephyranthes* are self-pollinated (Afroz et al. 2018). A summary of the barriers to cross pollination in *Zephyranthes* species and hybrids as well as other genera is as follows (Chowdhury and Hubstenberger 2006):

1. Plant structural morphologies: These include length of the floral tube, spatial arrangement of the stamens, and length of the pistils.

2. Chromosome number or ploidy level: A wide variety of 2n chromosome numbers is a deterrent to crosses.
3. Pollen production: Certain species and hybrids produce limited amounts of pollen.
4. Self or Cross incompatibility: Apparent sterility might actually be incompatibility.
5. Apomixis and/or Pseudogamy: These species often produce prolific seed which reproduces the maternal phenotype.
6. Flowering season: Some species are once-flowering; others repeat flowering throughout the growing season.
7. Receptivity of the stigma: Some species remain open for more than one day and may actually be receptive on day 2 of anthesis.

Identification of breeding lines is important for a successful breeding program. Some of the lines identified are hybrid F_1, *Z grandiflora* which are fertile and have the largest flowers which make it easier for pollination, tri-hybrid female parents [(*Z. candida* x *Z.citrina*) x *Z.macrosiphon*] which represents the cold tolerance of *Z. candida*, deep yellow color of *Z. citrina,* and large pink flowers of *Z. macrosiphon; Z. traubii* and *Z. labuffarosea* are nocturnal hybrids which are presumed to be insect pollinated and are fragrant.

9.10.8 Looking Forward or Future Perspective

The delimiting factors in *Zephyranthes* crop improvement lie in its reproductive biology. Taxonomic studies and classifications of either known or newly introduced species are important. Currently, studies using classical or molecular approaches are also limited and scanty. Clarifying the geographic distribution of wild geophyte species and their genetic diversity is important not only for breeding studies but also for the conservation of rare and endangered species. Re-evaluation of known geophytes is also necessary in their natural habitats both for conservation purposes and for obtaining information. Effective propagation systems, including *in vitro* propagation, need to be developed for many bulb crops.

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