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Propagation of Selected Annuals and Herbaceous Perennials Used as Ornamentals

INTRODUCTION

Herbaceous plants are classified as annuals, biennials, or perennials, although the differences among these types may not be obvious. They may also be classified as hardy, semi-hardy, or tender. In general, the propagation procedures for such plants depend on their categories and the locality where they are to be grown. In the following list of plants, seed germination data are given for some species, including suggested approximate temperatures that should give the most rapid and complete germination (223). Temperatures provided are for media temperature and it should be recognized that the medium can be several degrees cooler than the air temperature. In addition, media temperature can be severely lowered if irrigated with cold water, which will slow or retard germination. In addition, many seeds from herbaceous plants can show some dormancy (125). The propagation methods indicated serve as a guide, but some variation from these methods may be necessary with individual cultivars (24, 27).

Acanthus mollis. Bear's breeches. Hardy perennial used in containers or perennial bed for its bold foliage. Seed germination is at 18 to 21°C (65 to 70°F). Seeds may benefit from scarification. Plants are commonly multiplied by dormant divisions of the crown. It can also be propagated by root cuttings.

***Achillea* spp.** Yarrow. Hardy perennial used in garden beds or as cut flowers. Seed germination is at 18 to 21°C (65 to 70°F) with light. Fast propagation is common from summer softwood cuttings that respond to auxin (266). Propagation by division is easy and necessary for good garden performance (286). *A. filipendulina* can be micropropagated (109).

***Achimenes* spp. (92)**. Cupid's Bower. Tender perennial commonly used in hanging baskets. Seeds germinated in a warm greenhouse [24 to 27°C (75 to 81°F)] are used for propagating this species. Plants grow from small, scaly rhizomes, which can be divided for propagation. Commercial propagation is from softwood cuttings in early spring (322) under mist using bottom heat. Leaf cuttings have also been successful (213).

***Aconitum* spp. (286)**. Monkshood. Hardy perennial grown in garden beds or as a cut flower. Seeds often show dormancy and must be moist-chilled below 5°C (41°F) for 6 weeks before





planting. Considered difficult to propagate by seed, and fresh seed may be less dormant. Propagation is most often accomplished by division of the tuberous roots. Once established they should not be transplanted. All parts of the plants are poisonous. Can be micropropagated (318).

Adiantum. See Fern.

***Aegopodium* spp.** Goutweed. A hardy perennial used as a groundcover. Easily propagated by division.

African Violet. See *Saintpaulia ionantha*.

***Agapanthus* spp.** Lily-of-the-Nile. Tender perennial. Grown for blue lily-like flowers. Some selections come true from seeds. The thick rhizomes can also be divided to produce new plants. Plants have been micropropagated (156).

Agastache foeniculum. Anise hyssop. A long-blooming hardy perennial. Seeds germinate at 18 to 21°C (65 to 70°F). Propagated by dormant division of the crown or stem cuttings that root easily under mist.

***Agave* spp.** Many species of succulents, including the century plant. Plants are perennial. Seeds should be sown in sandy soil when mature at 15°C (59°F). Reproduces vegetatively by offsets from base of plant, or the production of plantlets on the flower stalk of some species; these are removed along with roots and repotted in spring. Some species produce bulbils that can be used for propagation. Agave are commercially mass-produced by tissue culture for the distillery market (244).

Ageratum houstonianum. Ageratum (223). Half-hardy annual. Blue and white flowering bedding plants. Taller forms are grown as cut flowers. Seed germination is at 24 to 29°C (75 to 85°F) and may benefit from light. Ageratum may also be propagated by mist propagated stem cuttings with bottom heat [21 to 24°C (70 to 75°F)] (99).

***Aglaonema* spp.** Chinese Evergreen. An important foliage plant that is easily propagated by canes (long stems), shoot cuttings, division, or seeds. Canes should be treated as delicate leaf cuttings. Rooting is enhanced with IBA and bottom heat [24 to 29°C (75 to 80°F)] (239). Can also be micropropagated (69).

Agrostemma githago. Corncockle. Hardy annual used in the garden bed or container. Seeds germinate within 1 week at 20°C (68°F).

***Ajuga* spp.** Bugle flower. Hardy perennial. Blue or pink flowers on a spreading groundcover. Naturally layers itself by stolons. Can be propagated by seeds,

cuttings, divisions, or tissue culture. Seeds germinate within 2 weeks at 20°C (68°F). Division is the most common form of multiplication. Variegated foliage types are from division or cuttings (286).

Alcea rosea. Hollyhock. Half-hardy biennial. Seed germination is at 20°C (68°F). Where winters are not too severe, sow seeds in summer, transplant in fall for bloom the following year. For annual production, sow seeds in a warm greenhouse in winter and transplant outdoors.

Alchemilla mollis. Lady's mantle. Short-lived hardy perennial grown for its interesting gray-green hairy foliage. Seed germination is at 18 to 21°C (65 to 70°F) with light. Plants can also be divided. Plants have been micropropagated (108).

***Allium* spp. (94)**. Ornamental onions; also onion, chives, and garlic. Often propagated by seed that is germinated at 18 to 21°C (65 to 70°F). Some ornamental species may benefit from chilling stratification for 2 weeks and germination at a cooler temperature 15°C (59°F). Plants grow from bulbs, which produce offsets. Clumps can also be divided. Many species produce aerial bulbils. Can be micropropagated (331).

***Aloe* spp.** Succulents of the lily family. Propagated by seed in well-drained sandy soil. Germination is at 20 to 24°C (68 to 75°F). Plants produce offshoots that can be detached and rooted. Plants with long stems can be made into cuttings, which should be exposed to air for a few hours to allow cut surfaces to suberize. Some species are commercially micropropagated. *Aloe barbadensis* can be micropropagated from shoot explants (206, 221).

***Alstroemeria* spp.** Parrot lily (92). Half-hardy perennial. Grown commercially as a cut flower and pot plant. Propagated by division of the fleshy rhizome. Rhizomes are also multiplied in tissue culture to produce disease-free plants (47, 216). *Alstroemeria* as pot plants are propagated from seed. Fresh seeds are dormant, but moistened 1-year-old seeds germinate after 4 weeks of 18 to 25°C (65 to 77°F) followed by 4 weeks of 7°C (45°F) conditions (173).

Alyssum. See *Aurinia* or *Lobularia*.

Alyxia olivaeformis. Maile. An important foliage plant, native to Hawaii. It is propagated almost exclusively by seeds which need to be depulped (295). Rooting of single-node maile stem cuttings is improved by removing one-half leaf surface area, placing greenhouse-grown cuttings in water prior to treatment, and propagating in a shady cloth-covered greenhouse.



A five-second quick-dip in 3,000 to 8,000 ppm IBA improves rooting (296).

Amaranthus caudatus. Love-lies-bleeding (223). Half-hardy annual. Seed germination is at 21 to 24°C (70 to 75°F). Light may increase germination (18). Sow in warm greenhouse for later transplanting or sow out-of-doors when frost danger is past.

A. tricolor. Joseph's coat. Same propagation methods as *A. caudatus*. Sensitive to excess water.

Amaryllis belladonna. Belladonna lily (92). Perennial. Grows from bulbs outdoors in mild areas or in pots in cold climates. Propagate by bulb cuttings, separation of bulbs, or tissue culture (73, 95).

Amsonia tabernaemontana. Willow amsonia. Hardy perennial. Pale blue flowers above willowlike foliage. Propagation is from seed or summer softwood cuttings. Seed should be stratified at 2 to 5°C (34 to 40°F) for 4 to 6 weeks.

Anaphalis margaritacea. Pearly everlasting. Hardy perennial used in garden beds or rock gardens. Propagation is by seed or division. Seeds germinate within 1 week at 18°C (65°F).

Anchusa capensis. Bugloss. Hardy annual or biennial. Seeds germinate within 1 week at 20 to 22°C (68 to 72°F) with light. Sow seeds in summer for bloom next year or plant in greenhouse in winter for later transplanting to garden.

A. azurea. Perennial. Selected clones best propagated by root cuttings or clump division (97).

***Anemone* spp.** Windflowers. Tender perennials.

A. coronaria. Poppy anemone (209). Seed germination is at 15°C (59°F) and may be sensitive to higher temperatures. Plants develop from tubers. There is an export market for *Anemone* tubers (128).

A. blanda. Greek windflower (92). Hardy perennial produced from a tuber. Propagated from seed or by division of the tuber into sections.

A. japonica. Japanese anemone and *A. xhybrida*. Hardy perennial. Since seeds do not come true, cultivars are propagated by division or by root cuttings (102). Roots are dug in fall and cut into 5-cm (2-in) pieces, which are laid in flats or in a cold frame, then covered with 2.5 cm (1 in) of soil. Plants can be potted after shoots appear.

***Anigozanthus* spp.** Kangaroo paw (189). This native perennial Australian genus is used for cut flower production and for containerized plants. Seed supplies are

often scarce, and germination rates of available seed are usually low and variable for many species. Hot-water and chemical pretreatment can be used to improve germination. Some hybrids are sterile and do not set seed at all. Clumps of rhizomes can be divided, but the rate of multiplication is low and unreliable. The most effective means of commercial propagation is through micropropagation (201).

Angelonia angustifolia. Summer snapdragon. A tender perennial commonly grown as an annual bedding plant. Can be propagated from seed or more commonly shoot tip cuttings. Seed is germinated at 22 to 24°C (72 to 76°F). Auxin-treated (2,500 ppm IBA) cuttings should be rooted under mist with bottom heat 24°C (75°F) (99).

***Anthemis* spp.** Golden Marguerite, camomile. Hardy perennial. Seed is germinated at 20°C (68°F). Plants can be divided or propagated by stem cuttings.

Anthurium andraeanum. Anthurium. Remove offshoots with attached roots from the parent plant or root two- or three-leaved terminal cuttings under mist. *Anthurium* can be micropropagated using a vegetative bud explant (185). Seed propagation is at 25°C (77°F) and is a lengthy process requiring 1.5 to 3 years for flowering, and cultivars do not come true from seed (143).

Antirrhinum majus. Snapdragon. Tender perennial, treated as an annual. Seed is germinated with 27°C (80°F) days and 24°C (75°F) nights (65). Chilling seeds at 5°C (40°F) can improve germination. Light seeds for the first 3 days, and then provide dark to allow radicle growth, and move back to light when seedlings emerge. Softwood cuttings root readily. *A. majus* is tissue cultured (224, 235).

***Aquilegia* spp.** Columbine. Hardy perennials. Seed is germinated at 21 to 24°C (70 to 75°F) in light. A short period of stratification for 3 to 4 weeks, moist-chilling at 5°C (41°F), can improve germination (116), but may not be necessary for all species. *A. chysantha* germinates better with alternating day/night temperature cycles of 25°C (76°F) day and 20°C (68°F) night (89).

***Arabis* spp.** Rockcress. Hardy perennials. Seed is germinated at 18 to 21°C (65 to 70°F) and may respond to light (18). Softwood cuttings taken from new growth immediately after bloom root readily. Plants can be divided in spring or fall.

Arctotis stoechadifolia. African daisy. Half-hardy annual. Seed is germinated at 20°C (68°F). Sow indoors for later transplanting.



***Arisaema* spp.** Jack-in-the-pulpit. Perennials developing from rhizomes or tubers that are used in woodland or rock gardens. Propagated by division of the tuber or rhizome. Seeds require 60 to 90 days of stratification prior to sowing.

***Armeria* spp.** Thrift. Hardy evergreen perennials. Seeds emerge within 2 weeks at 15 to 21°C (59 to 70°F). Can also be propagated by clump division in spring or fall.

***Artemisia* spp.** Hardy perennial. *A. ludoviciana* can be used as a foliage plant and is propagated by division or stem cuttings. *A. schmidtiana* (wormwood) is a hardy perennial used as a specimen plant and is propagated by stem cuttings, rather than by division.

Arum italicum 'Pictum.' Painted arum. Hardy perennial produced from a tuber. Evergreen foliage and naked red seed heads are attractive for the perennial garden. Propagated by division of the tuber. Seed requires stratification.

Aruncus dioicus (*A. sylvester*). Goat's beard. A hardy perennial used as a specimen or border plant. Seeds benefit from a cold stratification treatment of 5°C (40°F) for 4 weeks. Seeds germinate at 16°C (60°F). Usually propagated by dormant crown divisions.

***Asarum* spp.** Ginger. Perennial plants grown in the woodland or rock garden. Can be propagated by seed sown in the fall (125) or by division of the creeping rhizome.

***Asclepias tuberosa*.** Butterfly weed. Hardy perennial. Seed is germinated at 21 to 24°C (70 to 75°F). Fresh seed may need chilling. Vegetative propagation is from 3-cm-long root cuttings (105) or stem cuttings taken before the plants flower. Plants should not be disturbed once established.

***A. curassavica*.** Bloodflower. Tropical perennial. Propagated by seed or by rooting softwood cuttings. Long taproot makes division difficult.

***Asparagus asparagoides*.** *A. plumosus* (fern asparagus), *A. sprengeri* (Sprenger asparagus). Tender perennials. Propagated by seeds at 24 to 30°C (75 to 86°F). Sow seeds soon after they ripen, since seeds are short-lived (27). Cuttings can be made of young side shoots taken from old plants in spring; clumps can be divided.

***Asplenium nidus*.** Bird's nest fern. *See* Fern.

***Aster* spp.** Hardy perennials. Seed is germinated at 18 to 21°C (65 to 70°F). Cultivars are propagated by lifting clumps in fall and dividing into rooted sections, discarding the older parts. If stem cuttings are used, the

stems must be from juvenile material and rooted under long days or the resultant plant will be short and quickly flower (100). *A. frikartii* 'Monch' has been micropropagated commercially.

***Astilbe* spp.** Astilbe. Hardy perennials. Propagated by division in early spring when 2.5 cm (1 in) tall and then again following flowering (29). Seed germination is slow and produces a mixed progeny. Seed is germinated at 16 to 21°C (60 to 70°F) in the light (286).

***Astrantia* spp.** Masterwort. Perennial with unusual and attractive flowers. Generally propagated by division. Seeds require cold stratification.

***Athrium* spp.** Painted fern. *See* Fern.

***Aubrieta deltoidea*.** Aubrieta. Hardy perennials, sometimes treated as annuals. Seed is germinated at 18 to 21°C (65 to 70°F). Clumps are difficult to divide; cuttings may be taken immediately after blooming.

Aurinia saxatilis (formerly *Abyssum saxatile*). Goldentuft (223). Short-lived hardy perennial grown for its early yellow flower display. Seed is germinated at 15 to 21°C (60 to 70°F). Sow in summer for bloom the following year. Germination may be stimulated by light or exposure of moist seeds at 15°C (50°F) for 5 days (18). Propagate by division or by softwood cuttings in spring. Double forms must be propagated by cuttings or division.

***Baptisia* spp.** False Indigo. Hardy perennial. *Baptisia* is a hard-seeded legume and requires scarification. Seeds germinate in 3 weeks at 21°C (70°F). Stem cuttings can be rooted and they respond to auxin treatment (266). Plants can be divided, and micropropagation is also possible (21).

***Begonia* spp.** Begonia (262, 263). Tropical perennials. Seeds, which are very fine and need light, emerge in 2 to 4 weeks at 22°C (72°F). Best seed germination is at 28°C (82°F) for 5 to 7 days followed by 25°C (78°F) until seedlings emerge (223). Sow on moist, light medium with little or no covering. Begonia species, tuberous begonias, and wax begonias are propagated by seed, but other types are propagated vegetatively.

Fibrous-Rooted Begonias. Wax begonias, Christmas begonias, and others are propagated by leaf cuttings or softwood cuttings taken from young shoots in spring or summer. The cytokinin PBA was more effective in bud and shoot development from leaf cuttings than BA or kinetin (88).

Rhizomatous Types. Various species and cultivars, including Rex begonia plants, are divided or their rhizomes are cut into sections. Propagation is usually

by leaf cuttings, but stem cuttings also will root. Treatment of leaf cuttings with a cytokinin increases the number of plantlets produced per leaf (320). *B. evansiana* produces small tubercles, which are detached and planted.

Tuberous Begonias (130). In addition to seed propagation, these can be grown from tuberous stems, which are divided into sections, each bearing at least one growing point. Leaf, leaf-bud, and short-stem cuttings (preferably with a piece of tuberous stem attached) will root readily. Can be micropropagated (220, 294).

Begonia can also be micropropagated using leaf petioles (212), petiole explants (243, 264, 265, 320), and somatic embryos (229).

Belamcanda chinensis. Blackberry lily. Summer-blooming hardy perennial with orange blossoms are held above iris-like foliage. Commercially propagated by seed that emerge in 3 to 4 weeks at 18°C (65°F). Division is also possible while plants are dormant.

Bellis perennis. English daisy. Hardy perennial often treated as an annual or biennial. Seed is germinated at 21 to 24°C (70 to 75°F) and may respond to light (18). Plants may also be multiplied by division.

Bergenia cordifolia. Hardy perennial with evergreen cabbage-like foliage and attractive spring flowers. Can be propagated by seed or division. Seeds require chilling stratification of 5°C (41°F) for 6 to 8 weeks. Germination is within 2 weeks at 21 to 24°C (70 to 75°F) in the light. *Bergenia* is commercially micropropagated (220, 294).

Bleeding heart. See *Dicentra*.

***Boltonia* spp.** Boltonia. Autumn-blooming, hardy perennial resembling asters. Seed is germinated at 20°C (68°F). Commercially propagated by division while plants are dormant.

Bouvardia ternifolia (153). Scarlet bouvardia. An outstanding perennial with scarlet tubular flowers that bloom from midsummer to frost in Texas and New Mexico. It is propagated by semi-hardwood cuttings throughout the growing season.

Brachycome iberidifolia. Swan River daisy. Annual plant grown in hanging baskets or as bedding plants. Seeds germinate in 1 week at 21°C (70°F) in light.

Brassica oleracea. Flowering cabbage or kale. Cool season plants grown for fall display of their colorful foliage. Seed is germinated at 21°C (70°F).

***Brodiaea* spp.** (syn. *Triteleia*) (134). Perennial plants grown as cut flowers and produced from a corm. *Brodiaea* is propagated from seed that requires

stratification for 8 weeks at 3°C (37°F) (133), or from cormels. Plants can also be propagated through liquid tissue cultures to develop corms (157).

Bromeliads. About 2,000 species of tropical herbs or subshrubs in 45 genera, of which the pineapple (*Ananas*) is the best known. Propagation is mainly by seeds or by asexual division of lateral shoots, but micropropagation has been used successfully with some species (148). Conditions vary for the successful micropropagation of *Cryptanthus* (178), *Guzmania*, *Puya* (308), *Tillandsia*, and *Vriesea* species (205).

***Browallia* spp.** Amethyst flower (223). Tender, blue-flowered perennial often treated as an annual. Can be used as flowering pot plant indoors in winter. Seed is germinated at 24°C (75°F). Softwood cuttings can be taken in fall or spring.

Brunnera macrophylla. Siberian bugloss. Hardy perennial with blue forget-me-not flowers that appear in the spring followed by large green leaves. Can be propagated by seed, division, or root cuttings. Commercially micropropagated (240).

Cactus (70, 234). Large group of many genera, species, and some cultivars. Tender to semi-hardy perennials. Seed propagation can be used for most species, but seeds often germinate slowly. Sow fungicide-treated seed in well-drained sterile mixture and water sparingly, but do not allow medium to dry out. Pieces of stem can be broken off and rooted as cuttings (306), or small offsets, which root readily, can be removed. Allow offsets to dry for a few days to heal (suberize) cut surfaces before rooting. High humidity during rooting is unnecessary, but bottom heat is beneficial. Grafting is used to provide a decay-resistant stock for certain kinds and to produce unusual growth forms. For example, the pendulous *Zygocactus truncatus* is sometimes grafted on tall erect stems of *Pereskia aculeata*. Intergeneric grafts are usually successful. A type of cleft graft or splice graft is used. The stem of the stock is cut off, and a wedge-shaped piece is removed. The scion is prepared by removing a thin slice from each side of the base, which is fitted into the opening in the stock. The scion is held in place with a pin or a thorn. A grafting adhesive can be used to adhere scions to stocks of transversally cut (tip-grafted) cactus (328). The completed graft is held in a warm greenhouse until healed (66, 106, 328). The development of cacti shoots by micropropagation can be extremely rapid in comparison with greenhouse-germinated seedlings (20), and where poor branching limits propagation by traditional vegetative propagation methods (76, 154, 190).



Caladium hybrids (323). This tropical perennial, grown for its strikingly colorful foliage, produces tubers. Propagation is by removing the tubers from the parent plant at the end of the 4- to 5-month dormancy period just before planting. Commercially, tubers are cut into 2-cm pieces (chips), each containing at least 2 buds (“eyes”). Caladiums do best out-of-doors when planted after the minimum night temperature is above 18°C (65°F) or as pot plants maintained with night temperatures of 18 to 21°C (65 to 70°F) and day temperatures of 24 to 29.5°C (75 to 85°F). Dried caladium seed has a short storage life. Seeds require light and temperatures between 25 to 30°C (68 to 86°F) (57). Can be micropropagated (132).

Calibrachoa spp. A tender perennial grown as an annual bedding plant. Flowers resemble small petunias. Commonly propagated from stem cuttings under mist and bottom heat 24°C (75°F) (99).

Calamagrostis acutiflora. Feather reed grass. Hardy perennial. Upright grass with attractive flowering plumes. Propagation is by division in late spring.

Calathea spp. Tropical perennials grown as indoor foliage plants. Propagation is from division or commercially by micropropagation (237).

Calceolaria spp. Pocketbook plant. Tender perennials often grown as annuals and seasonal pot plants. Seed is germinated at 21°C (70°F) with light. Germination percentages in some species can be low. In some cases, propagation is also possible by soft-wood cuttings.

Calendula officinalis. Pot marigold. Hardy annual grown as a bedding plant or cut flower. Plants can provide winter bloom in mild climates from seed sown in late summer. Seed is germinated at 21°C (70°F) in the dark.

Calla. See *Zantedeschia* spp.

Callistephus chinensis. China aster (297). Annual grown as a bedding plant or cut flower. Seeds germinate at 20°C (68°F).

Caltha palustris. Marsh marigold. A hardy perennial used around water gardens or ponds. Seeds require chilling stratification and may benefit from temperatures below freezing. Following stratification, sow seeds at 18°C (64°F). Propagation is by division.

Camassia spp. Quamash (92). Hardy perennials produced from bulbs. Blue or white spikes emerge in the spring above grass-like foliage. Propagation is by offsets of the bulb.

Campanula carpatica. Tussock, Bellflower. Hardy perennial. Seed is germinated at 18 to 21°C (65 to 70°F) and responds to light. Plants can also be divided and stem cuttings root easily.

C. isophylla. Falling stars. Perennial often grown as an annual pot plant for indoor use or hanging baskets. Seeds are used for hybrid cultivars and germinate in 3 weeks at 18 to 21°C (65 to 70°F) with light. Cuttings can also be rooted after treatment with 1,000 ppm IBA from vegetative stock plants kept under short days (100).

C. lactiflora. Bellflower. Hardy perennial. Seeds germinate best after 2 to 4 weeks of stratification at 4°C (40°F).

C. Medium. Canterbury bells. Hardy biennial. Seeds, which germinate in 2 to 3 weeks at 21°C (70°F), are sown in late spring or early summer for bloom the following year.

C. Persicifolia. Peach bells. Hardy perennial. Seeds germinate in 2 to 3 weeks at 18 to 21°C (65 to 70°F) in light. Small offsets can be detached and rooted.

Many of the named cultivars of *Campanula* species cannot be produced by seed, so division or cuttings are used. Cuttings are produced from the rhizomatous growth of stock plants, and rooting occurs from the etiolated base. Cuttings are placed in peat-perlite media and given basal heat under glass or in a tunnel (England) (269).

Canna spp. Canna (92). Tender perennial. Cultivars do not come true from seed. Seeds, which have hard coats, must be scarified before planting. Seeds germinate in 2 weeks at 21 to 24°C (70 to 75°F). Cultivars are propagated by dividing the rhizome, keeping as much stem tissue as possible for each growing point. In mild climates, rhizomes are divided after the shoots die down in the fall or before growth starts in the spring. In cold climates, the plants are dug in fall, stored over winter, and divided in spring for transplanting outdoors when frost danger is over. Plants can be micropropagated (182).

Capsicum annuum. Christmas or ornamental pepper. Tender annual used as a bedding plant or seasonal pot plant. Plants are most commonly propagated by seeds germinated at 21 to 24°C (70 to 75°F) that emerge within 2 weeks. Stem cuttings also root readily.

Carnation. See *Dianthus caryophyllus*.

Catananche caerulea. Cupid’s dart. Hardy perennial. Seed is germinated at 18 to 21°C (65 to 70°F). Plants may be divided in the fall.

Catharanthus roseus. Vinca (65). Tender annual. Vinca is a major bedding plant grown from seed. Optimum temperature for germination is 24 to 27°C (75 to 78°F) in the dark. Do not keep seeds too moist. Vinca is the commercial source of the cancer drugs vincristine and vinblastine.

Celosia argentea* and *C. spicata. Cockscomb. Tender annual. Both plumed and cockscomb (fasciated) cultivars are available as bedding plants and cut flowers. Seed is germinated at 24°C (75°F).

***Centaurea* spp.** Tender and hardy perennials. Seeds of *C. cyanus* (cornflower or bachelor button) and *C. moschata* (sweet sultan) emerge in 1 to 2 weeks at 18 to 21°C (65 to 70°F).

C. hypoleuca (knapweed), *C. macrocephala* (Globe centaurea), and *C. montana* are hardy perennials propagated by division or seed. Seeds of *C. montana* are germinated at 21 to 24°C (70 to 75°F). *C. macrocephala* has been micropropagated (149).

Centranthus ruber. Red valerian. Hardy perennial. Rose or white-colored flowers are produced throughout the summer. Seed is germinated at 15 to 18°C (60 to 65°F). Stem cuttings are also possible.

Cephalotus follicularis. Australian pitcher plant. Perennial carnivorous plant. Usually propagated from IBA-treated leaf or stem cuttings. Easily propagated by tissue culture (1).

Cerastium tomentosum. Snow-in-summer. Hardy perennial. Seed is germinated at 20°C (68°F). Easily propagated by division in the fall or by softwood cuttings in summer.

***Ceratostigma* spp.** Plumbago. Hardy perennials with bright blue flowers on trailing stems. Propagation is from softwood cuttings under mist, or division while dormant.

Cheiranthus cheiri (synonym is *Erysimum asperum*). Wallflower. Semi-hardy perennial often treated as a biennial. Seeds germinate in 1 week at 16°C (60°F) and may respond to light (18). Choice plants may be increased by cuttings taken in early summer.

***Chelone* spp.** (286). Turtlehead. A hardy perennial used in wet areas. Propagation is by division or by cuttings. Seeds may benefit from 2 to 4 weeks chilling stratification.

***Chionodoxa* spp.** Glory-of-the-snow. Hardy perennial bulb. Primarily grown from seed. Ripe seeds are stored through the summer at 17°C (63°F) and sown outdoors in September to stratify over winter (92). Bulb

cuttage (see *Hyacinthus*) and offsets are successful for vegetative propagation.

Chlorophytum comosum. Spider plant. Propagated mainly by planting miniature plants developing at ends of stolons. Stolon formation is under daylength control; short days (12 hours or less daily) promote stolon production (131). It can also be propagated by division.

Chrysanthemum. See *Dendranthema*.

Chrysogonum virginianum. Goldenstar. Trailing hardy perennial grown for its yellow flowers. Propagation is by division in spring or fall.

***Cimicifuga* spp.** Cohosh. Hardy perennials for the border or woodland garden. White flower spikes appear in late summer. Propagated by seed or division. Seed is germinated at 18°C (65°F) in light. Plants are divided in spring.

Clarkia amoena. (synonym *Godetia*). Hardy annuals grown as cut flowers or pot plants (8). Sow seeds in early spring; they germinate at 21°C (70°F).

Cleome spinosa. Spiderflower. Tender annual. Germinate seeds at 21 to 22°C (70 to 72°F) with light. Seeds may benefit from brief chilling stratification for 5 days. Can also be propagated by division.

***Clivia* spp.** (92). Tropical perennial grown indoors for its colorful floral display. Plants can be propagated by seeds sown as soon as they are ripe at 21°C (70°F). It is more common to divide plants after they finish blooming. Can be micropropagated (115).

Cobaea scandens. Cup and saucer vine. Tropical vine grown for its large purple flowers. Propagation is from seeds that germinate in 1 week at 21°C (70°F).

Codiaeum variegatum. Croton (247). Tropical perennial. Propagated by leafy terminal cuttings in spring or summer. Tall "leggy" plants can be propagated by air layering. Stem cutting root number (root initiation) was unaffected by bottom heat (28°C, 83°F) or increasing light intensity; however, root length was increased (314). During shipping of cuttings, exposure to light results in shorter roots. Unrooted cuttings can be shipped for 5 to 10 days at 15 to 30°C (59 to 86°F) (313).

Colchicum autumnale. Autumn crocus, saffron (92). Hardy perennial that grows from corms. Seeds are sown as soon as they are ripe in the fall but may require chilling over winter to germinate. Several years are required for plants to reach flowering size. Propagation is from offsets of the corm (see *Crocus*). Can be micropropagated (141).



Coleus. See *Solenostemon*.

Consilida ambigua. Larkspur. Upright annual plants similar to delphinium in bloom. Seeds germinate at 18°C (65°F) and can self-sow in the garden.

Convallaria majalis. Lily-of-the-valley. Hardy perennial that grows as a rhizome, whose end develops a large underground bud, commonly called a “pip.” In fall, the plants are dug, and the pip, with attached roots, is removed and used as the planting stock. Digging should take place in early autumn, with replanting completed by late autumn. Single pips may be stored in plastic bags in the refrigerator, then planted in late winter for spring bloom. Micropropagation has also been successful (309).

Convolvulus spp. Morning glory. Trailing annuals used in hanging baskets or as bedding plants. Seeds benefit from hot water scarification and germinate at 21°C (70°F).

Cordyline spp. Ti plant (*C. terminalis*) is easily propagated by cuttings and by micropropagation (90, 184). Other *Cordyline* species can be seed-propagated with seeds germinating in approximately 4 months with 30°C (86°F) days and 20°C (68°F) nights. A vegetative propagation technique for *C. australis*, *C. kaspar*, and *C. pumillo* by division of the underground stems of stock plants has been described (238).

Coreopsis spp. Hardy annuals and perennials. *C. grandiflorum* (tickseed) is a short-lived perennial usually grown from seed. Seedlings emerge within 2 weeks when sown at 18 to 24°C (65 to 75°F) in light. Growth regulator treatment or seed priming (61, 256) can improve seed germination.

C. verticillata can be propagated by cuttings and is hardy to zone 3 (81). Perennial clumps can be divided in spring or fall.

Cortaderia selloana. Pampass grass. A half-hardy, ornamental grass with large feathery plumes. Propagated by clump division. Micropropagation is possible from immature flower parts (250).

Corydalis spp. Garden perennials. Propagated by seeds that should be sown soon after they are ripe because they have a short storage life. Sow outdoors or provide 6 weeks warm [24°C (75°F)], moist conditions followed by 6 to 8 weeks' chilling [4°C (45°F)] and germination at 10°C (50°F). Commonly multiplied from dormant crown divisions.

Cosmos bipinnatus and C. sulphureus. Half-hardy annuals grown as cut flowers or garden plants. Seeds usually germinate within 1 week at 21°C (70°F).

Crassula argentea. Jade plant. Succulent perennial grown as an indoor pot plant. Can be propagated at any time by leaf or stem cuttings.

Crinum spp. Tender bulbs grown for seasonal flower display. Propagation is from offsets of the bulb or bulb cuttage techniques such as bulb chipping (see Chapter 15). Plants can be micropropagated (267, 301).

Crococsmia spp. Crocosmia (92). Hardy perennial used for cut flowers or border plants. Plants are propagated from offsets of the corm.

Crocus spp. (33). Hardy perennials that grow from corms. Seeds germinate as soon as ripe in summer; several years are required for plants to flower. When leaves die in fall, plants are dug and corms and cormels are separated and planted. Tissue culture propagation is from corm fragments, isolated buds, or flower parts (111, 145).

Crossandra infundibuliformis. Flame flower. Tender perennial grown as a specialty pot plant for indoor use. Can be propagated by seeds or cuttings. Seeds emerge sporadically over 2 to 3 weeks at 27 to 29°C (80 to 85°F), but show better germination at alternating 29 to 21°C (85 to 70°F) day/night regimes (100). Most commercial plants are grown from stem cuttings treated with 3,000 ppm IBA and rooted under mist or tents using bottom heat at 24°C (75°F). Micropropagation is possible from axillary shoot explants (129).

Cucurbita pepo var. ovifera. Ornamental gourds. Tender annuals. Seed is germinated at 20° to 30°C (68 to 86°F).

Cuphea spp. Mexican heather; bat-faced cuphea. Tender perennials grown as bedding plants or in baskets. Cuttings root readily without hormone under mist with bottom heat at 24°C (75°F).

Cyclamen spp. (92, 193, 199, 203). Tender and half-hardy perennials. Plants grow from a large tuberous stem. Cyclamen is propagated best by seeds that germinate in 3 to 4 weeks in the dark at temperatures about 20°C (68°F), no higher than 22°C. Seeds are planted from midsummer to midwinter. Germination is best in a medium of peat moss to which pulverized limestone and mineral nutrients have been added for a pH of 6 to 6.5 (321). Seedlings under commercial production conditions flower after 30 weeks (100). The tuberous stem can be divided for the production of a few plants identical to the parent. Short shoots of cyclamen with two to three leaves are easily rooted in 3 weeks when given a 10-second dip of 3,000 to 5,000 ppm K-IBA under intermittent mist, 21°C (70°F) basal heat, and 1 perlite:1

vermiculite rooting medium (193). Tissue culture is used to multiply F₁ hybrids (259).

Cymbalaria muralis. Kenilworth ivy. Semi-hardy perennial. Seed is germinated at 12°C (54°F). Self-seeds readily. Softwood cuttings or clump division may be used.

Cynara cardunculus. Cardoon. Large bold perennial grown for its thistle-like flowers that appear in late summer. Seeds germinate in 3 weeks at 24°C (75°F). Plants can also be multiplied by division while dormant and by root cuttings.

Cynoglossom amabile. Chinese forget-me-not. Hardy biennial grown as an annual. Seed is germinated at 20°C (68°F) and may respond to light (18).

Cypripedium. Lady slipper. See Orchids.

***Dahlia* (93)**. Tender perennials consisting of hundreds of cultivars. Commercially propagated by seed, division, or stem cuttings. Seed is germinated at 26°C (80°F) when planted indoors for later transplanting outdoors. Large plants can be dug in the fall before frost and stored over winter at 2 to 10°C (30 to 50°F) and covered with a material such as soil or vermiculite to prevent shriveling. In spring, when new sprouts begin to appear, divide the clumps so that each tuberous root section has at least one or two buds. Plant outdoors when danger of frost is over. Dahlias are often commercially propagated by softwood cuttings (93) from stems forced in the greenhouse in early spring. Tissue culture is used to recover virus-free plants (319).

Daylily. See *Hemerocallis* spp.

***Delphinium* spp.** Hardy perennials, usually propagated by seeds, which germinate at 18 to 24°C (65 to 75°F). ‘Giant Pacific’ germinates better with alternating 26°C (75°F) day and 21°C (70°F) night temperatures. There may be some benefit to chilling dry seed at 3°C (35°F) for 1 week prior to sowing seeds (59, 223). Seeds are short-lived and should be used fresh or stored in containers at low temperature and reduced moisture. Seeds can be sown outdoors in spring or summer to produce plants that flower the following year. Delphiniums can be propagated by softwood cuttings or root cuttings (97). Clumps can be divided in spring or fall, but such plants tend to be short-lived. Plants can be micropropagated (227).

Dendranthema xgrandiflorum (formerly *Chrysanthemum xmorifolium*). Garden and greenhouse chrysanthemum and *Argyranthemum frutescens* (formerly *C. frutescens*, Marguerite). Hardy and semi-hardy

perennials. Shoots 6 to 8 cm (2.5 to 3 in) long are rooted as softwood cuttings under mist and with 1,500 ppm IBA usually as a talc (99). The best source of new cuttings is a mother block (or increase block) grown in an isolated area away from the producing area kept under long days (43, 101). Such plants are grown in programs designed to keep them pathogen- and virus-free and true-to-type (27). Disease-indexed stock plants are regenerated through micropropagation (53). Unrooted cuttings can be held for as long as 30 days at 0.5°C (33°F). Chrysanthemum is readily micropropagated by shoot-tip and petal-segment explants (26, 171, 253).

***Dianthus caryophyllus* (36)**. Carnation. Tender to semi-hardy perennial grown as an annual that has many cultivars used in the florist’s trade. Seeds germinate easily but are used primarily for breeding. Carnations are readily propagated by softwood cuttings (144) with mist and auxin treatment. The best source of cuttings is a mother (or stock) block isolated from the producing area. This block originates from cuttings taken from stock plants maintained under a program designed to keep them pathogen- and virus-free and true-to-type. As with chrysanthemum, carnation stock blocks are periodically replenished with meristem-tip culture for disease-free plants. Conventional cutting propagation then proceeds with these clean stock blocks (see Chapter 16). Commercially, rooted cuttings are produced by propagation specialists for sale to growers. Lateral shoots (“breaks”) that arise after flowering are removed and used as cuttings. Cuttings root in 2 to 4 weeks. Carnations can also be micropropagated on a large scale using shoot-tip explants (104). Tissue culture is also possible from petal explants (166, 219) and somatic embryos have been recovered from leaf explants (327).

D. barbatus Sweet William. Short-lived perennial that is grown as a biennial. Seeds are germinated in the summer and seedlings emerge in 1 to 2 weeks at 21°C (70°F). Seedlings are overwintered in frames and flower the following spring. Plants can also be propagated by cuttings or division.

***D. chinensis*, *D. plumarius*, and Related Species**. Garden pinks. Hardy perennials, although some kinds are grown as annuals or biennials. Seeds germinate readily at 15 to 21°C (60 to 70°F). Softwood cuttings are taken in early summer and rooted to produce next year’s plants. Layering and division also can be used.

D. gratinanopolitanus. Cheddar pinks. A popular herbaceous perennial. Seeds germinate in 1 to 2 weeks at 21°C (70°F). The cultivars may be propagated by stem cuttings or division.



***Diascia* spp.** Twinspur. Annual plants grown as bedding or container plants. Seed germination is in 1 week at 21°C (70°F) in light. Shoot tip cuttings root easily without auxin or with 2,500 ppm IBA (99).

***Dicentra* spp.** Bleeding heart. Hardy perennials. Seeds are sown in late summer or fall for overwintering at low temperatures; alternatively, seeds should be stratified for 6 weeks below 5°C (41°F) before planting. Seeds will germinate in 3 to 4 weeks at 10 to 13°C (50 to 55°F). Divide clumps in spring or fall. Stem cuttings can be rooted if taken in spring after flowering. Root cuttings about 7.5 cm (3 in) long can be taken from large roots after flowering. *D. exima* is commercially propagated from seeds or division. *D. spectabilis* is usually propagated by division of the woody rhizome or from stem cuttings. It can also be micropropagated.

***Dictamnus albus*.** Gas plant. Hardy perennial. Seed germination is difficult and inconsistent. Stratify seeds at 1 to 5°C (34 to 41°F) for 3 to 4 months. Cultivars can be propagated from root cuttings. Gas plant is easily micropropagated from shoot explants (164). Plants should not be disturbed after establishment; thus, division is not done. Contact with the leaves of gas plant can produce severe dermatitis.

***Dieffenbachia* spp.** Dumbcane. Tropical perennial. Cut stem into 5-cm (2-in) segments, with one or two nodes per section, and place horizontally, half exposed in sand or other well-drained media. New shoots and roots will develop from nodes. If plant gets tall and “leggy,” the top may be cut off and rooted as a cutting, or the plant may be air layered. Leaves and stem are poisonous and may cause rashes on skin.

***Digitalis* spp.** Foxglove. Hardy biennial or perennial plants. Seed is germinated at 15 to 18°C (60 to 65°F) in light. Sow seeds outdoors in spring, transplant to a nursery row at 9-inch spacing, and then transplant to a permanent location in fall. Perennial species is increased by clump division.

***Dimorphotheca* spp.** Cape or African marigold. Half-hardy annual with daisy-like flowers. Seeds germinate within 1 week at 21°C (70°F).

***Dionaea muscipula*.** Venus flytrap. Carnivorous plants, which have unique appearance, unusual mode of life, and are in demand by plant collectors. Although plants can be grown from seed or division, they are usually propagated by tissue culture, from leaves, adventitious buds, and peduncle explants (32, 214).

***Dodecatheon maedia*.** Shooting star. Hardy perennial. Unique flowers in white or purple resemble tiny darts. Easily divided when plants are dormant (41).

Seed is sown in autumn to stratify over winter for spring emergence.

***Doronicum* spp.** Leopard’s bane. Hardy perennial grown for its early yellow, daisy-like flowers in spring. Seed is germinated at 20°C (68°F). Divide plants in spring or fall.

Dorotheatus bellidiformis (formerly *Mesembryanthemum criniflorum*). Livingstone daisy. Drought-tolerant annual grown as a bedding plant. Seedlings emerge within 2 weeks at 18°C (65°F) in light.

***Dracaena* spp.** Variable group of tropical perennial foliage plants which are available in bush, cane, tree, and stump forms. Seed is germinated at 30°C (86°F). Some species are propagated from leaf-bud cuttings that are treated with IBA and rooted under intermittent mist. *D. fragrans*, which is an important cane form used for interiorscapes, is propagated from cane stem cuttings which are cut into 30- to 183-cm (1- to 6-ft) sections waxed on the distal (top) end; basal ends are treated with IBA and placed in a porous medium without intermittent mist under shade (indoors or field-propagated). Branching of canes during field propagation is done by cutting one-third to one-half way through the cane, which results in the development of lateral buds anywhere from directly below to 15 cm (6 in) below the cut (75). Micropropagation is from stem explants (74, 90, 310).

***Drosera* spp.** Sundew. Easily grown carnivorous plants that produce leaves with conspicuous glandular hairs that trap insects. *Drosera* can be propagated by seed, root cuttings (68), or easily from tissue culture (9). Non-tuber-forming plants can also be propagated from IBA-treated leaf cuttings.

***Dryopteris* spp.** See Fern.

***Dusty miller*.** See *Senecio* spp. or *Tanacetum ptarmiciflorum*.

***Dyssodia tenuiloba*.** Dahlberg daisy. Tender annual. Yellow daisylike flowers on compact edging plants. Propagated from seed germinated at 18 to 21°C (65 to 70°F) in light. Germination can be erratic due to a percentage of dormant seeds.

***D. pentacheta*.** Perennial. A low-growing Texas wildflower suitable for xeriscapes. Propagated from softwood cuttings treated with IBA under mist or by tissue culture (330).

***Echeveria*.** See Succulents.

***Echinacea* spp.** Purple coneflower. Hardy perennial. Purple, orange, yellow, or white flowers typical of the sunflower family are attractive as garden plants or as cut



flowers. Seed is germinated at 21 to 25°C (70 to 78°F). Germination can be erratic and improved by seed priming or chilling stratification at 15°C (59°F) (256, 316, 317). Garden plants can be divided. *Echinacea* hybrids are commercially micropropagated (71, 139).

***Echinops* spp.** Globe thistle (223). Hardy perennials. Unique metallic blue flowers on thistlelike plants. Seed is germinated at 15 to 20°C (60 to 68°F). Plants may be divided in spring. Root cuttings, 5- to 7.5-cm (2- to 3-in) long, may be made in the fall and planted in sandy soil in a cold frame.

***Echium* spp.** Viper's bugloss. Annual and perennial plants grown as bedding or container plants. Plants produce large blue spikes of flowers. *E. candicans* (Pride of Madeira) is a drought tolerant plant often seen in seaside gardens. Propagation is from seed sown at 15 to 20°C (60 to 68°F). Larger plants can be propagated by stem cuttings.

***Epimedium* spp.** Barrenworts. Hardy perennials. Popular ground cover for shady areas. Propagated by division in the spring (174). Can be micropropagated (6).

***Epiphyllum* spp.** Leaf-flowering cactus. Tender perennial. Seeds do not germinate well when fresh but will after 6 to 12 months' storage if planted in a warm greenhouse. Propagated readily by leaf cuttings (botanically, modified stems called phyllocades) or by grafting to *Optunia*. Can be micropropagated (190). See Cactus.

***Epipremnum aureum*.** Golden pothos. Among the most important commercially produced foliage plants. Producers cut the long vines into single-node, leaf-bud cuttings for propagation. Leaf-bud cutting propagation is enhanced with light intensity of about 2,000 ft-c for stock plants and basal heat of 28°C (83°F) (312). Stock plants should be maintained at four to five nodes (14 to 15 leaves), with a 3-cm or longer internode section below the node, and a fraction of the old aerial root retained on the cuttings for most rapid axillary shoot development (315). Maintained in the juvenile phase by cutting propagation. Mature phase has a much larger leaf and flowers.

***Episcia* spp.** Flame violet. Tropical trailing plants grown indoors in hanging baskets. Seed propagation is at 24°C (75°F), but plants root easily from stem cuttings using mist and bottom heat or plantlets taken from ends of the runners.

***Eranthis hyemalis*.** Winter aconite (92). Hardy perennial produced from tubers. Early yellow flowering plants popular in the rock garden. Commercially propagated from seed (see *Chionodoxa*).

***Eremurus bungei*.** Foxtail lily (92). Tender perennial produced from a tuberous root. Tall flowering spikes are commercially grown as a cut flower. Propagated from seed or more commonly by division. Seeds apparently have an after-ripening requirement that is satisfied by dry storage at 30°C (86°F) for 2 months (329). Plants are commercially propagated by division of the tuberous roots.

***Erigeron* spp.** Fleabanes. Hardy perennial. Blue, pink, or white daisy-like flowers with yellow centers. Can be propagated by seed, division, and stem cuttings. Usually commercially propagated by seed that germinates at 21 to 24°C (70 to 75°F).

***Eryngium* spp.** Sea-holly. A diverse species of perennials, used as specimen and border plants or as cut flowers. Propagation by division is possible, but a long taproot makes transplanting difficult. Root cutting propagation is the commercial method for species not coming true from seed (286). Seeds have a warm-cold stratification requirement of 4 weeks at 21°C (70°F), followed by 6 weeks of 3°C (38°F) and then a warm temperature of 18 to 23°C (65 to 75°F).

***Erythronium* spp.** Dog's tooth violet or trout lily (92). Hardy woodland perennials with recurved lily-like flowers. Plants are used in rock or alpine gardens as well as being naturalized. Plants naturally multiply by seeds that are spread by ants and by producing new plants at the end of slender stolons. Propagation is by division.

***Eschscholzia californica*.** California poppy. Hardy annual grown en masse for its flower display. Seed is germinated at 21°C (70°F). Seeds can be sown outdoors in fall in mild climates or in early spring in colder areas. Tends to self-sow. Seedlings may be difficult to transplant because of a long taproot.

***Eucomis* spp.** Pineapple lily (92). Summer-blooming perennial bulb. Propagation is by offsets or from seeds. Micropropagation by twin scaling offers commercial potential (19).

***Euphorbia* spp.** Euphorbia, spurge. Perennials used as border and sometimes specimen plants. Plants are also grown for latex production. Propagation is easy by division. The thick seeds of *E. epithymoides* (*polychroma*) take 15 to 20 days to germinate at 18 to 21°C (65 to 70°F) (286). *In vitro* techniques have also been developed from stem explants (241).

***Eustoma grandiflorum*.** Lisianthus (223). Annual. Grown as a pot plant or cut flower. Seed is germinated at 22°C (72°F). Plants have been micropropagated (112).



Evolvulus glomeratus. Prostrate plant with blue flowers grown as a bedding plant or in hanging baskets. Propagation is by stem cuttings using mist.

Exacum affine. Exacum or Persian violet. A popular greenhouse-grown pot plant with fragrant flowers, multiple blooms, and good postharvest quality. Can be propagated from seed or cuttings. Seeds germinate within 2 weeks at 21 to 24°C (70 to 75°F). Herbaceous stem cuttings root easily with bottom heat [22°C (72°F)]. Exacum can also be micropropagated (299).

xFatsyhedera lizei. Tree ivy. An intergeneric cross between *Hedera helix* and *Fatsia japonica*. Propagated by auxin-treated stem cuttings using mist and bottom heat [24°C (75°F)] or by air layering.

***Felicia* spp.** Blue daisy. Tender, trailing plants most often grown for hanging baskets. Propagation is from stem cuttings using mist with bottom heat [21°C (70°F)].

***Festuca* spp.** Blue fescue. Hardy perennial grass. A clump-forming grass with blue foliage. A warm season grass, fescue should be divided in the spring or fall. *F. ovina glauca* comes relatively true from seeds that germinate within 1 week at 21°C (70°F).

***Fern* (233, 251, 291).** Many genera and species. Spores are collected from the spore cases on lower sides of fronds. Examine these sporangia with a magnifying glass to be sure they are ripe but not empty. Place fronds with the spores in a manila envelope and dry for a week at 21°C (70°F). Screen them to separate spores from the chaff. Transfer to a vacuum-tight bottle and store in a dry, cool place. Sow spores evenly on top of sterilized moist substrate (e.g., two-thirds peat moss, one-third perlite in flats), paying particular attention to sanitation. Leave 1 inch space on top and cover with a pane of glass. Use 18 to 24°C (65 to 75°F) air temperature; bottom heat may be helpful. Keep moist, preferably using distilled water to avoid salt injury.

Spores germinate and produce mosslike growth composed of many small gametophytic prothalli. Fertilization requires free water on the prothallus to allow motile male gametes to reach the female archegonium. After fertilization occurs, a small leafy sporophyte appears in 2 to 3 months on the surface of the prothallus. Transplant the developed sporophyte to a greenhouse substrate for further growth into the fern plant. Procedures have also been developed for *in vitro* fern propagation from spores (177, 188).

Several vegetative propagation methods are possible. Many ferns grow from rhizomes, which can be divided. In few species, like sword fern (*Nephrolepis tuberosa*), underground tubers are produced on thin

stolons and can be used for propagation. Certain other ferns (e.g., *Cystopteris bulbifera*, *Polystichum setiferum*) produce small plantlets (also called bulblets) along the leaf surface or leaf tip (*Camptosorus rhizophyllum*). These can be removed and used to produce a new plant (291).

Cultivars of the sterile (non-propagatable by spores) Boston fern group (*Nephrolepis*) are now largely micropropagated starting with rhizome tips (7, 51). This micropropagation technique is also applicable to other fern genera, such as *Adiantum* (maidenhair fern), *Alsophila* (Australian tree fern), *Pteris* (brake fern), *Microlepia*, *Playcerium* (staghorn fern), and *Woodwardia* (chain fern).

Ficus. See Chapter 20 (82, 91).

***Filipendula* spp.** Queen of the prairie. Hardy perennials used in garden beds or naturalized areas. Propagation is from dormant divisions or root cuttings.

Fragaria. Pink Panda. Perennial strawberry plant grown for its ornamental pink flowers rather than fruit, which it rarely produces. Propagation is from rooted plantlets produced on runners.

***Freesia* spp. (158).** Tender perennials produced from a corm. Commercially produced as a cut flower. Seeds planted in fall germinate in 4 to 6 weeks and will bloom the next spring. A germination temperature of about 18.5°C (65°F) is best (127). Plants are commercially propagated from cormels that are planted in spring and dug in fall. Micropropagation is also used to produce corms, as well as disease-free plants (22, 236).

***Fritillaria* spp.** Checker lily (92). Perennials produced from non-tunicate bulbs. Interesting group of spring-flowering bulbs of which *F. imperialis* (crown imperial) and *F. melaegris* are the best known. Propagated from offsets, bulb scaling, and bulb cuttage (chipping). Micropropagation is also successful (183).

Fuchsia xhybrida. *Fuchsia magellanica* hybrids. Fuchsias are tender perennials treated as annuals that are utilized as hanging baskets, containers, or trained to tree form on standards. The most effective way to propagate cultivars is by cuttings. Softwood cuttings root easily under mist or high humidity with bottom heat at 21°C (70°F). Auxin (1,000 ppm IBA) can improve rooting. For optimum cutting production it is best to maintain stock plants on short day, 10-hour photoperiods (311).

***Gaillardia* spp.** Blanketflower (223). Annuals and hardy perennials. Seed is germinated at 21 to 24°C (70 to 75°F) in light (18). Perennial kinds can be started from root cuttings or may be divided in spring or fall but are not long-lived.

***Galanthus* spp.** Snowdrop (92). Hardy perennial produced from an annual tunicate bulb. Bulbs are planted in the fall for bloom the following spring. Offsets are removed when bulbs are dug. *G. nivalis* and *G. elwesii* are mostly propagated by seed sown as soon as they are ripe in the spring. Bulb cuttage (chipping) and twin scale micropropagation can also be used (73, 156).

***Galtonia candicans*.** Summer hyacinth (92). Tender bulb with small pendant flowers that are fragrant. Propagated by offsets of the bulb. Plants can also be micropropagated (326).

***Gasteria*.** See Succulents.

***Gaura lindheimeri*.** Hardy perennial that produces wispy flowers on long stems. Seeds germinate within 2 weeks at 21°C (70°F). Can also be multiplied by dormant division of the crown.

***Gazania* spp. (223).** Tender perennial often grown as an annual. Seed is germinated at 21°C (70°F). Divide clumps after 3 or 4 years.

***Gentiana* spp.** Gentian. Many species, mostly hardy perennials, although some are annuals and biennials. Plant fresh seed in the fall to overwinter outdoors. Seeds germinate in 1 to 4 weeks at 20°C (68°F). However, seeds need to be stratified for 3 weeks at 2°C (36°F) or treated with 300 ppm GA₃ (39). Seedlings are very delicate and should not be transplanted until roots are established during the first month. Cutting propagation is used for some white cultivars, which have poor seed germination. Micropropagated liners are now becoming available (147).

***Geranium*.** See *Perargonium*.

***Geranium* spp.** Cranesbill. Hardy perennials. True geraniums are popular herbs and perennial garden plants. Geraniums can be propagated by seed, division, stem, or root cuttings. Seeds germinate in 2 to 4 weeks at 21°C (70°F), but fresh seeds may have a hard seed coat that requires scarification. Commercial propagation is most often by division when plants are dormant or from root cuttings taken in the winter. Root cuttings are sensitive to rot if overwatered. One approach is to allow buds to form on root pieces by holding them in “sweat” boxes (polyethylene tents) at near 100 percent humidity prior to planting in a potting medium.

***Gerbera jamesonii*.** Transvaal daisy. Tender perennial. Seed is germinated at 20°C (68°F); it is important to use fresh seed (64). Alternately, basal shoots from the rhizome can be used as cuttings. Commercially, micropropagation from shoot tips is used for rapid, large-scale multiplication (187, 218).

***Geum* spp.** Avens. Hardy perennials used in garden beds and cut flowers. Common perennial easily propagated by seeds. Seed is germinated at 18 to 21°C (65 to 70°F). Can also be propagated by crown division in spring or fall.

***Gladiolus* (78).** Tender perennial grown from a corm. Popular cut flower. Seed propagation is used for developing new cultivars. Seeds are planted in spring either indoors for later transplanting or outdoors when danger of frost is over (see Chapter 15). Commercial propagation is from cormels or division of the corm, leaving at least one bud (eye) per piece (202). *In vitro* techniques using buds or liquid-shake culture have improved multiplication rates (25, 196, 332).

***Gloriosa* spp.** Gloriosa lily (92). Tender perennial. Vines are produced from tuberous stems. Unique flowers with recurved petals are grown as cut flowers or container plants. Propagation is from daughter tubers that form at the shoot base of the original tuber. Micropropagation is possible from tuber explants (114).

***Gloxinia*.** See *Sinningia speciosa*.

***Godetia*.** See *Clarkia*.

***Gomphrena globosa*.** Globe amaranth (223). Button-like white or purple flowers make this a popular cut flower and bedding plant. Propagate from seeds that emerge in 1 to 2 weeks at 24 to 25°C (75 to 78°F).

***Gunnera* spp.** Tender perennials producing extremely large leaves on creeping rhizomes. Propagation is from seed or division. Seeds will germinate in 3 weeks at 18°C (65°F) with light. Division of the creeping rhizome is also possible while plants are dormant.

***Guzmania* spp.** See Bromeliads.

***Gypsophila* spp. (*G. elegans*).** Baby’s breath. Annual. Grown as a cut flower. Seed germinates in 2 to 3 weeks at 21 to 26°C (70 to 79°F).

***G. paniculata*.** Hardy perennial. Started by seed as above. Plants can be divided in spring and fall. Terminal stem cuttings treated with 3,000 ppm IBA can be rooted under mist (99). Double-flowered cultivars can be difficult to root and can be propagated by seeds that yield approximately 60 percent double plants. Double-flowering types have also been wedge-grafted on seedling *G. paniculata* (single-flowering) roots or crowns. Grafting can be done in summer and fall, using outdoor-grown plants for rootstocks and placing them in a cold frame for healing of the graft; grafting is also done in winter and early spring, using greenhouse-grown stock plants. *G. paniculata* can be micropropagated using shoot-tip explants (186).



Haworthia. See Succulents.

Hedychium spp. Ginger lily. Tropical plants producing attractive spikes of flowers from creeping rhizomes. Propagation is from division of the rhizome.

Helenium autumnale. Sneezeweed. Hardy perennial. Sunflower-like blooms in unique colors produced in late summer in the perennial garden. Seed is germinated at 22°C (72°F) with light. Cultivars are increased by division. Separate rooted shoots in spring, line-out in nursery, then transplant in fall and winter.

Helianthemum nummularium. Sunrose. Hardy perennial. Drought-tolerant spring blooming ground-cover. Seed is germinated at 21 to 24°C (70 to 75°F). Cultivars are propagated by softwood cuttings taken from young shoots in spring. Transplant to pots and place in permanent location the following winter or spring. Division of clumps is also possible, but plants tend to be short-lived.

Helianthus annuus. Sunflower. Hardy annual. Popular as a cut flower. Seeds germinate within a few days at 20 to 30°C (68 to 86°F). Some sunflower cultivars show dormancy and benefit from 6 weeks of chilling stratification (46). *H. decapetalus* and other hardy perennial species can be propagated by seeds or increased by division.

Helichrysum bracteatum (current name *Bracteantha bracteata*). Strawflower (223). Annual. Popular cut flower for drying. Propagated by seeds that emerge in 1 to 2 weeks at 21 to 24°C (70 to 75°F).

H. petiolare. (Licorice plant). A trailing plant with interesting foliage grown as a companion plant in hanging baskets. Propagated from stem cuttings treated with 3,000 ppm IBA under mist (99).

Heliconia spp. (85). These tropical ornamental herbaceous perennials are prized for their showy inflorescences. Commercially produced as a cut flower, they are easily propagated by division of the rhizomes. Micropropagated from rhizome buds (222).

Heliopsis spp. Heliopsis. Hardy perennial with sunflower-like flowers. Seed is germinated at 18 to 21°C (65 to 70°F). Divide clumps in fall.

Heliotropium spp. Heliotrope. Tender perennial usually grown as an annual. Seed germinates within 1 week at 21°C (70°F) and may respond to light (18). Plants will also root from softwood tip cuttings from stock plants grown under short days to remain vegetative (99).

Helleborus spp. Hellebore, Christmas and lenten rose. Perennials used as border and woodland gardens. One of the earliest plants to bloom in the perennial garden. Propagation by seed is very slow. *H. lividus* has a combinational dormancy requirement of warm stratification [21°C (70°F)] for 8 to 10 weeks followed by cold stratification of 3°C (37°F) for 8 to 10 weeks; seeds still may take up to 2 years to germinate. Division is the most common method, carried out by carefully separating the crown (286). Roots and leaves are poisonous. Hellebore can be micropropagated (52).

Hemerocallis spp. (87). Daylily. Hardy perennial. Seed propagation is used only to develop new cultivars and requires 6 weeks of stratification; germination takes 3 to 7 weeks at 16 to 21°C (60 to 70°F) (286). Divide clumps in fall or spring, separating into rooted sections, each with about three offshoots. Clones can also be micropropagated using flower petals and sepals as explants (10, 207).

Hepatica spp. Hardy perennial used in the rock garden or wildflower garden. Propagated by seed or division. Seeds have epicotyl dormancy (see Chapter 7) and may take 2 years to emerge. Division is in early spring before growth begins. Plants can be micropropagated (225).

Hesperis matronalis. Sweet rocket. A biennial or short-lived perennial grown in garden borders or in mass display. Seeds germinate in 1 week at 21 to 26°C (70 to 75°F).

Heuchera spp. American alumroot, coralbells. Perennials used as border plants for their foliage and flowers. Propagated by dormant crown division. Seed is germinated at 18°C (65°F) in light. Commercially micropropagated from stem explants (279).

Hibiscus spp. Mallow. Hardy perennials. Large saucer-shaped flowers in vibrant colors. Cultivars are propagated by division while dormant. Seed is germinated at 21 to 26°C (70 to 75°F).

Hippeastrum spp. Amaryllis (228). Tender bulbous perennial. Garden plant and popular indoor flowering bulb. Propagated by offsets or micropropagation. Bulb offsets will flower the second year. Bulb cuttings (chipping) can be made in late summer. Dry membranous seeds are borne in dehiscent capsules. Seeds germinate under warm conditions at 20 to 30°C (68 to 86°F). Seedlings take 2 to 4 years to produce flowers. Micropropagated by the twin scaling method (73, 151).

Hosta spp. Plantain-lily. Herbaceous perennials which are used for massed plantings or as specimen plants for their foliage and flowers. Propagated by clump division

in spring. One producer removes the apical dominance of the crown (terminal) bud, slices (divides) the remaining clumps into quarters, places the quarters outdoors in trays (England) which are winter-protected, and then plants when they begin to shoot. Offset formation has also been increased by spraying crowns with cytokinin (123). It takes 3 years to produce a flowering plant from seed. Micropropagation is being used with new cultivars to speed up propagation (208).

Houttuynia cordata. An aggressive hardy perennial plant growing by rhizomes. Tolerates wet conditions and is often confined to a shallow pond. Propagation is from division or softwood cuttings.

Hoya spp. Wax flower. Tropical vines grown in indoor hanging baskets for its attractive foliage and flowers. Propagation is from single node stem cuttings that benefit from bottom heat.

Humulus lupulus. Hops. Tender perennial vine grown as an annual for quick coverage of a support. The yellow foliage 'Aureus' is most common in gardens. Propagated from stem cuttings.

Hunnemannia fumariifolia. Goldencup. Tender perennial often grown as an annual. Seeds germinate in 2 to 3 weeks at 20°C (68°F). For bloom first year, sow seeds early indoors then transplant outdoors when danger of freezing is over.

Hyacinthus spp. Hyacinth (226). Hardy, spring-flowering perennial; bulbs are planted in the fall. Removal of offset bulbs gives small increase. For commercial propagation, new bulbs are obtained by scoring or scooping mature bulbs (see Chapter 15). Micropropagation, using segments of the bulb, leaf, inflorescence, or stem as an explant, is successful (23, 155). Seeds may be planted outdoors in fall, but up to 6 years are required to produce blooms.

Hymenocallis spp. Spider lily (92). Tender bulb producing large white flowers with extended tepals, suggesting the common name. Propagated by offsets from the bulb. Plants can also be micropropagated (325).

Hypericum spp. St. John's wort. Hardy herbaceous and woody perennials grown for their saucer-shaped yellow flowers. Also grown as a cut flower. Seed is germinated at 21°C (70°F). Plants are also propagated by division of the crown or creeping rhizome. Stem cuttings will also root easily.

Hypoestes phyllostachya. Polka dot plant (223). Tender annual. Grown as a bedding plant or indoor plant because of unique spotted foliage. Propagated

from seeds that emerge in 1 to 2 weeks at 21 to 24°C (70 to 75°F). Stem cuttings root easily without auxin.

Iberis spp. Candytuft. Hardy annual and perennial species. Seed is germinated at 15 to 18°C (60 to 65°F) in light. Cultivars are propagated by softwood cuttings in summer or plants are divided in fall.

Impatiens spp. Touch-me-not, balsam. Impatiens are important bedding plants and include impatiens (*I. walleriana*), New Guinea impatiens (*I. hawkeri*), balsam (*I. balsamina*), and several new hybrids. They can be propagated by seeds or cuttings. Seed germination is at 24 to 25°C (75 to 78°F) and benefits from light (63). Light seeds for the first 3 days and then move to darkness until seedling emergence. Plants can be started by terminal cuttings treated with 2,500 ppm IBA under mist with bottom heat [22°C (72°F)]. Impatiens have also been micropropagated (283, 284).

Incarvillea spp. Incarvillea. Hardy perennial producing large gloxinia-like flowers in the spring. Seed is germinated at 20°C (68°F). Divide in fall or, preferably, in spring. Basal cuttings taken in the spring can also be rooted.

Ipomoea spp. Morning glory, ornamental sweet potato. Tender perennials grown as an annual. Seeds germinate within 1 week at 18 to 21°C (65 to 70°F). Notch seed coats or soak seeds overnight in warm water before planting.

I. batatas. Sweet potato vine. Popular annual vine with bright yellow or dark purple foliage used in containers or for bedding. Cuttings are easily rooted without auxin under mist.

Iresine spp. Bloodleaf. Tender perennial used as an indoor plant or outdoors as a container or bedding plant. Seeds germinate at 24°C (75°F) with light. Softwood cuttings root easily without auxin.

***Iris spp.* (96)**. Perennials. There are several different groups of hardy or semi-hardy iris, which grow either from rhizomes or from bulbs. Rhizomes are divided after bloom. Discard the older portion and use only the vigorous side shoots. Leaves are trimmed to about 15 cm (6 in).

Bulbous species follow a typical spring-flowering, fall-planting sequence. The old bulb completely disintegrates, leaving a cluster of various-sized new bulbs. These are separated and graded, the largest size being used to produce flowers, the smaller for further growth.

Seeds, which are used to propagate species and to develop new cultivars, should be planted as soon as ripe after being given a moist-chilling period; germination is often irregular and slow. Removal of embryo from



the seed and growing it in artificial culture has yielded prompt germination in some cases. Iris can be micropropagated, which greatly hastens production of new cultivars over the customary division of rhizomes (155, 161, 305).

***Ixia* spp.** Corn lily (92). Tender, summer- or fall-flowering perennials grown from corms. In cold climates, these are dug in fall and stored over winter. Small cormels are removed and planted in the ground or in flats to reach flowering size, as is done with gladiolus. Can be micropropagated (293).

***Ixora* spp.** (245). *Ixora*. Tender perennial used for indoor gardens. Several species are used in Hawaii as landscape and flowering pot plants. Many species are easy to propagate by cuttings. Difficult-to-root *I. acuminata* three-node cuttings had optimal rooting when given a 5-second dip of IBA-NAA, both at 2,500 ppm.

***Justicia* spp.** Shrimp plant (*J. brandegeana*) and Brazilian plume (*J. carnea*) are tropical plants grown as landscape plants where hardy and indoor flowering pot plants. Propagation is from softwood cuttings with bottom heat [24°C (75°F)].

***Kalanchoe blossfeldiana*.** A tropical succulent perennial grown as an indoor flowering pot plant. Plants can be propagated by cuttings or tissue culture, but they are more commonly propagated from terminal cuttings. Cuttings are rooted easily under mist or poly tent with bottom heat [22°C (72°F)]. Disease-free cuttings are available from commercial specialists that have been cleaned in tissue culture (31). Plants can also be micropropagated (270).

***K. diagreontiana*.** (formerly *Bryophyllum*). A succulent plant grown for its interesting habit of forming plantlets (often called foliar embryos) along the margin of the leaf. These plantlets can be removed for propagation.

Kangaroo Paw. See *Anigozanthus* spp.

***Kirengeshoma palmata*.** Yellow wax bells. Herbaceous perennial producing pendulous yellow blossoms for shady garden beds. Propagated by crown division when plants are dormant.

***Knautia* spp.** Herbaceous perennial plants, many of which were formerly in *Scabiosa*. Used in perennial beds. Propagation is from dormant crown division or stem cuttings from new growth in spring.

***Kniphofia hybrids* (*K. tritoma*) (286).** Torch lily or poker plant. Perennials used as specimen plants, borders, and cut flowers. Seeds germinate at 18 to 24°C

(65 to 75°F) in light. Many of the cultivars are propagated by crown division.

***Lachnelia* spp.** Cape cowslip (92). Tender bulbous perennials most often seen as container plants in display areas. Propagated by bulb offsets or micropropagation (176).

***Lamium galeobdolan*.** Yellow archangel. Hardy perennial used as a ground cover for shade gardens. Grown for the attractive variegated foliage. Only cultivars are grown and these are usually propagated by softwood cuttings. Division is also possible.

***Lamium maculatum*.** Spotted deadnettle. Hardy perennial with trailing stems that are used as a ground cover for shade. Propagation is by stem cuttings treated with 2,500 ppm IBA under mist. Plants can also be divided.

***Lantana sellowiana*, *L. camara*.** Lantana. Tender perennials treated as landscape plants where hardy and as annuals where tender. Lantana has become invasive in some tropical countries. Seeds germinate at 20°C (68°F). Softwood cuttings root easily under mist.

***Lathyrus latifolius*.** Perennial pea vine. Hardy perennial. Seeds germinate at 13 to 18°C (55 to 65°F). Clumps may be divided.

***L. odoratus*.** Sweet pea. Hardy annual grown for garden display or cut flowers. Seed germinates in 2 weeks at 20°C (68°F). Notching seed or soaking in warm water may hasten germination. Plant outdoors in fall where winters are mild, in spring where winters are severe.

***Lavandula* spp.** Lavender. Half-hardy perennial native to Mediterranean. Essential oils from these plants are important for the perfume industry. Seeds germinate at 18 to 24°C (65 to 75°F) in light. Stem cuttings are treated with 2,500 ppm IBA and rooted under mist with bottom heat. Divide clumps in the fall. Micropropagation is from hypocotyl explants (55) or leaf-derived callus (300).

***Lavatera trimestris*.** Tender herbaceous perennials used as annuals. Plants produce showy hibiscus-like flowers. Seeds germination is at 21°C (70°F).

***Leonotis leonurus*.** Lion's ear. Tender perennial usually grown as a container plant, greenhouse displays, or in garden beds. Propagation is from stem cuttings taken prior to flowering.

***Leontopodium alpinum*.** Edelweiss (223). Hardy perennial. Mounded plants with silvery leaves and unique flowers. Seeds germinate at 20 to 22°C (68 to

72°F). Division is also possible. Plants can also be multiplied in tissue culture (146).

***Lespedeza* spp.** Bushclover. Considered an herbaceous perennial in more northern latitudes or a semi-woody shrub in the southern United States. Excellent landscape shrub for massing and screening with its bluegrass foliage and purple flowers. Seeds can be direct-sown after harvest or scarified with a 15-minute acid treatment if stored. Roots easily from softwood cuttings with 1,000 ppm IBA.

Leucanthemum xsuperbum (formerly *Chrysanthemum superbum*). Shasta daisy. Hardy perennial but often treated as a biennial, since it is short-lived. Propagated by seeds at 18 to 21°C (65 to 70°F) that emerge in about 1 week. Division is from side shoots that have roots. Can be commercially micropropagated.

Leucocorne ixioiodes. Glory of the sun. Tender bulb grown as a pot plant or for cut flowers. Propagation is from bulb offsets.

***Leucojum* spp. (92)**. Spring snowflake. Hardy perennial bulb. Bulbs have been collected for sale from native populations to the point of endangerment. Plants produced from seed take 4 to 5 years to flower. Propagation is normally done by separating bulbs, which is done by digging bulbs after foliage has turned brown. Can be micropropagated (73, 277).

Lewisia cotyledon. Semi-hardy perennial commonly seen in rock, alpine, or dish gardens. Seeds germinate at 21°C (70°F) (2). Cuttings from the basal rosette are possible. Leaf cuttings can also be used to produce new plants.

***Liatris* spp.** Gayfeather (203). Hardy perennials used in garden beds, naturalized prairies, as well as cutflowers (16). Seeds may benefit from stratification at 4°C (34°F) for 6 weeks and will germinate at 21°C (70°F), but flower development can take 2 years. Asexual propagation is by woody corms or rhizomes, which are divided in the spring (286). *L. spicata* has been micropropagated (289).

***Ligularia* spp.** Large herbaceous perennials producing yellow composite flowers and ornamental foliage. Seeds germinate at 18°C (65°F) in dark. Plants can also be divided.

***Lilium* spp. (30, 204)**. Lily. Hardy perennials. These are spring- and summer-flowering plants grown from scaly bulbs; most have a vertical axis, but in some species growth is horizontal with a rhizomatous structure. Lilies include many species, hybrids, and named cultivars. Seed propagation is used for species and for

new cultivars. Seeds of different lily species have different germination requirements (252).

Immediate seed germinators include most commercially important species and hybrids (*L. amabile*, *L. concolor*, *L. longiflorum*, *L. regale*, *L. tigrinum*, Aurelian hybrids, Mid-Century hybrids, and others). Germination is epigeous; shoots generally emerge 3 to 6 weeks after planting at moderately high temperatures. Treat seeds with a fungicide to control *Botrytis*. Sow 3/4 inches deep in flats during winter or outdoors in a seed bed in early spring. Dig the small bulblets in fall, sort for size, and replant with similar sizes together. Plants normally grow 2 years in a seed bed and 2 years in a nursery row before producing good-sized flowering bulbs.

Another group consists of the slow seed germinators of the epigeal type (*L. candidum*, *L. henri*, Aurelian hybrids, and others), in which seed germination is slow and erratic; the procedures used are essentially the same as described above. The most difficult group to propagate are the slow seed germinators of the hypogeous type (*L. auratum*, *L. bolanderi*, *L. canadense*, *L. martagon*, *L. parvum*, *L. speciosum*, and others). Seeds of this group require 3 months under warm conditions for the root to grow and produce a small bulblet, then a cold period of about 6 weeks, followed by another warm period in which the leaves and stem begin to grow. This sequence can be provided by planting the seeds outdoors in summer as soon as they are ripe, or by planting seeds in flats and then storing under appropriate conditions to provide the required temperature sequence. These procedures are described in Chapter 15. *L. longiflorum* can also be propagated by leaf cuttings.

Vegetative methods of propagation include natural increase of the bulbs, such as bulblet production on underground stems (either naturally or artificially), aerial stem bulblets (bulbils), or scaling. Outer and middle scales are used for scale propagation to increase the number of forcible commercial bulbs (200).

Lilies can be micropropagated from bulb scales (288) and pedicels (198). *L. longiflorum* can also be propagated by leaf cuttings.

***Limonium* spp.** Statice. *L. sinuatum* is a perennial herb, native to the eastern Mediterranean, which is grown commercially around the world as a cut flower for both fresh- and dry-flower arrangements. *L. latifolia* is a hardy perennial. Plants are propagated by seeds that germinate at 21°C (70°F). Statice has been micropropagated (54, 138).

***Linaria* spp.** Toadflax, butter and eggs. Hardy annual and perennials. Seeds germinate in 1 to 2 weeks at 18°C (65°F) in light. Perennial species may take 2 years



to produce bloom from seed. Perennial types can be divided in spring or fall.

***Linum* spp.** Flax. Hardy annual and perennial species with blue or yellow flowers. Used in perennial beds and rock gardens. Seeds germinate in 2 to 3 weeks at 18 to 24°C (65 to 75°F). Divide clumps of perennial species in fall or spring.

***Liriope* spp.** Lily turf. Hardy perennial. Vigorous ground cover. Can be propagated by seed or division. Seeds have morphological dormancy and require warm stratification [21 to 30°C (70 to 85°F)] for germination (110). However, commercial propagation is by division in spring or autumn. Plants can be micropropagated (119).

Lisianthus. See *Eustoma*.

Lithodora diffusa. Semi-hardy prostrate perennial grown for intense blue flowers. Propagated by stem cuttings in summer or from division.

***Lithops* spp.** Living stones. Interesting succulents with plants adapted to mimic stones. Propagation is from seeds sown at 18 to 24°C (65 to 75°F). Some species produce offsets that can be divided.

Lobelia erinus. Lobelia. Tender perennial grown as an annual. Seeds germinate at 24 to 26°C (75 to 80°F), but seedling growth is slow. May respond to light (18). Mature plants, if potted in the fall and kept in greenhouse over winter, can be used to provide new growth for cuttings to be taken in late winter. Commercial cuttings are treated with 2,500 ppm IBA under mist.

***Lobelia cardinalis* (cardinal flower), *L. siphilitica* (blue cardinal flower) and hybrids.** Hardy and half-hardy perennials. Seeds germinate at 20 to 24°C (68 to 75°F). Species self-seeds. Divide clumps in fall or spring.

Lobularia maritima. Sweet alyssum (223). Perennial grown as a hardy annual. Seed germinates in 1 to 2 weeks at 26 to 28°C (75 to 82°F) in light and blooms appear in 6 weeks. Often seeded with more than one seed per plug for better pack development.

Lunaria annua. Honesty or money plant. Biennial, sometimes grown as an annual. Seeds germinate at 20°C (68°F).

L. rediviva. Hardy perennial. Propagated at 20°C (68°F). Also increased by dormant division.

***Lupinus* spp. and hybrids.** Hardy annuals and perennials. All lupines have physical seed dormancy and require scarification. Seeds germinate at 20°C (68°F).

L. texensis. (Texas bluebonnet) *L. texensis* has been micropropagated from cotyledonary node explants (302). Sow seeds in spring or summer, or propagate by cuttings taken in early spring with a small piece of root or crown left attached.

***Lychnis* spp.** Campion. Mostly hardy perennials, but some are grown as annuals or biennials. Seeds germinate at 20°C (68°F) or propagated from dormant crown divisions.

***Lycoris* spp.** Spider lily, surprise lily (92). Tender and semi-hardy perennials from a tunicate bulb. Propagation is by bulb offsets, which are removed when the dormant bulbs are dug. These are replanted to grow larger. Bulb cuttings can also be used for increase. Micropropagation by twin scaling has also been developed (152).

***Lysimachia* spp.** Loosestrife. Hardy perennial. Vigorous plants with striking white or yellow flowers. Trailing plants are grown for their colorful foliage. Can be propagated from seed, division, or softwood cuttings. Seeds germinate at 18 to 21°C (65 to 70°F). Terminal stem cuttings root easily under mist without auxin.

Lythrum salicaria. Purple loosestrife. Hardy perennial. Long-blooming plants produce purple flowering spikes. *Lythrum* can be an invasive weed in wet habitats and some states prohibit its use. Propagation is easy from softwood cuttings. Division is possible but difficult, because the roots are woody.

Macleaya cordata. Plume poppy. Aggressive, hardy perennial from a creeping rhizome. Produces bold foliage and large plumes of small white flowers. Propagation is from division of the rhizome.

Malva alcea. Hollyhock mallow; and *M. moschata.* Musk mallow. Drought-tolerant perennials utilized in border plantings. Seeds germinate within 2 weeks at 21°C (70°F). Plants can also be propagated by division.

Mammillaria. See Cactus.

Maranta leuconeura. Prayer plant. Tender perennials grown as indoor potted plants. They are normally propagated asexually by stem cuttings because seeds are difficult to germinate. Cuttings are rooted in humidity tents for 4 to 6 weeks. *M. leuconeura* 'Kerchoviana' can be micropropagated (103).

Marigold. See *Tagetes* spp.

Matteuccia. Ostrich fern. See Fern.

Matthiola incana. Common stock (223); *M. longipetala bicornis.* Evening scented stock. Perennials grown as biennial or annual plants most often used as

cut flowers or for bedding. Seed germinates at 18 to 21°C (65 to 70°F) and may respond to light (18). Seeds are sown in summer or fall for winter bloom, in late winter indoors for spring bloom, or outdoors in spring for summer bloom.

Mazus reptans. Hardy perennial that forms a creeping mat of foliage and purple-blue flowers. Propagated from division or cuttings of the creeping stem.

***Meconopsis* spp.** A group of alpine annual and short-lived perennials. Poppy-like flowers can be white, red, yellow, or blue depending on the species. Must have cool summers to survive. Seeds germinate at 13°C (55°F). Most often the seeds are sown in a cold frame in fall for spring emergence. Perennial plants can also be divided before growth begins in spring.

Melampodium paludosum. Annual. Rounded plants produce yellow daisy-like flowers throughout the growing season. Seeds germinate at 18°C (65°F). Self-sowing can be a problem in the garden. Plants also root from softwood cuttings.

***Mertensia* spp.** Hardy perennial plants usually grown in woodland gardens but also at home in the perennial bed. *M. virginiana* (currently *M. pulmonarioides*) Virginia blue bells produces nodding blue flowers early in the spring. Propagation is most often from division in dormant plants.

***Mesembryanthemum* spp.** See Succulents.

***Mimulus* spp.** Monkey flower. Includes many species of tender to hardy plants. Mostly perennials but sometimes grown as annuals. Seeds germinate at 15 to 21°C (60 to 70°F). Softwood cuttings taken from young shoots can be rooted under mist.

Miscanthus sinensis. Maiden grass. There are many cultivars of this popular perennial grass. They make excellent specimens in the landscape with their showy feathery inflorescences. Cultivars are propagated by division. *Miscanthus* is a warm-season grass and should be divided in late spring. *Miscanthus* can be micropropagated (124).

Molluccella laevis. Bells of Ireland. Half-hardy annual grown as a garden plant or cut flower. Seed germinates at 10°C (50°F) but may do better with 30°C (86°F) days alternating with 10°C (50°F) nights (223). Plants can be difficult to transplant.

Monarda didyma. Bee balm (286). A perennial garden plant native to eastern North America. Can be propagated by seed, which germinates at 16 to 21°C (60 to 70°F). May benefit from a brief (1 week) chilling

stratification. Can also be propagated by softwood cuttings or by crown division.

Monstera deliciosa. Swiss cheese plant. Cut-leaf philodendron. Easily propagated by rooting sections of the main stem, by stem cuttings, or by air layering. Seeds germinate at 21 to 29°C (70 to 85°F).

***Muscari* spp.** Grape hyacinth (255). Hardy perennials from tunicate bulbs. Plants bloom in spring; bulbs become dormant in fall when they are lifted and divided by removing bulb offsets. Seed propagation can also be used. Bulb scooping and scoring produce bulb offsets. Micropropagation is easy from leaves, scales, or flower parts (231).

Mussaenda erythrophylla. Red Flag Bush. Tropical evergreen perennials used as a landscape plant where hardy and as a container plant in other regions. Flowers are subtended by colorful bracts. Propagation is from stem cuttings with bottom heat (275). Plants can be micropropagated (84).

Myosotis sylvatica. Forget-me-not. Hardy biennial or short-lived perennial. Grown for its blue or pink flowers in the spring. Plants may naturalize from seeds. Seeds germinate at 20°C (68°F). Sow in summer and transplant to permanent location the following spring. *M. scorpioides* is a perennial started from seed; division in spring is also used.

Narcissus. Daffodil (135). Hardy perennials; spring-flowering tunicate bulbs. Vegetative propagation procedures are described in Chapter 15. Commercial propagation is mainly from natural bulb offset production. Vegetative techniques include twin scaling, chipping (almost the same method as twin scaling, except that the bulb is cut across the root plate into 8 to 16 pieces with up to 2 bulbils developing per section), and micropropagation (73, 136, 150).

Nasturtium. See *Tropaeolum majus*.

Nelumbo lutea. American lotus; *N. nucifera*. Sacred Lotus. Aquatic plants for water gardens. Lotus produces one of the longest-lived seeds, which have physical dormancy and must be scarified. Seeds germinate readily at 24°C (75°F). Lotus is usually propagated vegetatively through rhizome division. Rhizome cultures have been established *in vitro* from excised embryos (167).

Nemesia strumosa. Capejewels. Half-hardy annual used as bedding plants. Seeds germinate at 13 to 18°C (55 to 65°F) in darkness. Temperatures above 18°C (65°F) can inhibit germination. Terminal stem cuttings root easily under mist without auxin.



***Nemophila* spp.** Baby blue eyes. Low-growing native North American annuals used as bedding plants. Seeds germinate at 18°C (65°F) and require darkness to germinate.

Neoregelia. See Bromeliads.

***Nepenthes* spp.** A large group of carnivorous plants producing pitchers to trap insects. Traps are formed at the tips of tendrils that extend from the midrib of the leaves. Propagation is from seeds at 27°C (81°F), leaf or stem cuttings (68), and tissue culture (248).

***Nepeta* spp.** Catmint. Hardy perennial. Seeds germinate at 20°C (68°F). Softwood cuttings of non-flowering side shoots taken in early summer root readily. Plants may be divided in spring, using newest parts and discarding older portion of clumps.

***Nerine* spp. (303).** A tender, perennial tunicate bulb. Landscape bulb also used as a cut flower crop. Propagation is from offsets or bulb cuttage, but mostly by twin scaling. Tissue culture is possible from scales, lateral buds, and the young flower stalk (86).

***Nicotiana* spp.** Flowering tobacco. Half-hardy annuals with bright fragrant flowers. Seeds germinate at 24°C (75°F) and may respond to light (18). Stem cuttings root readily and plants are easily micropropagated.

***Nierembergia* spp.** Cupflower (223). Tender perennial, sometimes grown as an annual. Seeds germinate at 21°C (70°F). Softwood cuttings removed from new growth in spring root readily. Clumps can be divided.

Nigella damascena. Love-in-a-mist. Herbaceous annuals grown as bedding plants or as cut flowers for the interesting seed pods. Seeds germinate at 18 to 24°C (65 to 75°F).

Nolana paradoxa. Prostrate, annual plant with flowers that resemble small petunia blossoms. Seeds germinate at 20 to 22°C (68 to 72°F). Can also be propagated from stem cuttings.

***Nymphaea* spp.** Water lily. Consists of numerous species and many named cultivars. Plants grow as rhizomes. Clumps are divided in spring. Seeds are used to grow species and to develop new cultivars. Tropical water lily hybrids and species grow from tubers. Seeds do not reproduce hybrids. Both kinds of seeds are planted 2.5 cm (1 in) deep in sandy soil, then immersed in water 3- to 4-inch deep. Hardy species should be started at 16°C (60°F), tropical species at 21 to 27°C (70 to 80°F). Vegetative propagation is either from small tubers that can be removed from old tubers in fall or from small epiphyllous plantlets growing from

the leaf (268). Micropropagation is also possible by using epiphyllous plantlets as explants (162). *N.* 'Gladstone' production can be extended by photoperiod control (169).

Ocimum basilicum. Basil. Annual plants usually reserved for the herb garden, but numerous colored leaf forms are available for the flower garden. Seeds germinate in 1 week at 21°C (70°F). Stem cuttings also root easily.

***Oenothera* spp.** Evening-primrose. Hardy perennials, but some kinds are biennial. Seeds germinate at 21 to 26°C (70 to 80°F). Plants can also be increased by dormant crown divisions.

Ophiopogon japonicus. Mondo grass. Hardy perennial. Evergreen ground cover. Propagation is by division in the spring or fall. Plants can be micropropagated (119).

***Opuntia* spp.** Prickly pear cactus. Hardy perennial. The only cactus hardy to the northern United States. Propagation is from seed, division, or cuttings (191). See Cactus.

***Orchids* (217, 261, 285).** Many genera, hybrids, and cultivars are cultivated, and many more are found in nature. Some, such as *Aerides*, *Arachnis*, *Phalaenopsis*, *Renanthera*, and *Vanda*, exhibit a monopodial habit of growth. This means they are erect and grow continuously from the shoot apex and can be propagated by tip cuttings. Adventitious roots are produced along the stem and inflorescences are produced laterally from leaf axils. Most others including *Brassovola*, *Calanthe*, *Cattleya*, *Cymbidium*, *Laelia*, *Miltonia*, *Odontoglossom*, *Oncidium*, and *Phalus* have a sympodial habit of growth, are procumbent, and do not grow continuously from the apex. Their main axis is a rhizome in which new growth arises from offshoots or "breaks." Pseudobulbs are usually present on plants of this type. Many orchids are epiphytes (i.e., air plants), typically growing on branches of trees. Others (*Cypripedium* and *Paphiopedilum*) are terrestrial and grow in the soil (12).

Epiphytic Orchids. Seed propagation is mainly used for hybridization. Many important cultivars are seedling hybrids, either from species or between genera, resulting from controlled crosses of carefully selected parents. Many such important crosses are between tetraploid and diploid parents to produce triploids. These offspring are sterile and are not usable as parents. Seedling variation occurs, since orchids are heterozygous. Five to seven years are required for a seedling plant to bloom. Orchid flowers are hand-pollinated. A seed capsule requires 6 to 12 months to mature.

A single capsule will contain many thousands of tiny seeds with relatively underdeveloped embryos. *In vitro* culture is universally used for seed propagation. (The procedure is described in Chapter 18.) Knudson's C medium is usually used. Arditti (12, 13) has summarized the many experiences of testing various nutritional and other factors for orchid seed germination. Orchid seed can be stored for many years if held in sealed containers over calcium chloride at about 2°C (36°F). Vegetative methods for orchids are generally slow, difficult for many genera, and usually too low-yielding for extensive commercial use. Sympodial species are increased by division of the rhizome while it is dormant or just as new growth begins. Four or five pseudobulbs are included in each section. "Back-bulbs" and "greenbulbs" can be used for some genera.

Orchids with long canelike stems, such as *Dendrobium* and *Epidendrum*, sometimes produce offshoots ("keiki") that produce roots. Offshoots can also be produced if the stem is cut off and laid horizontally in moist sphagnum or some other medium. Flower stems of *Phaius* and *Phalaenopsis* can be cut off after blooming and handled in the same way. A drastic method of inducing offshoots is to cut out or mutilate the growing point of *Phalaenopsis*, remove the small leaves, and treat the injured portion with a fungicide. Offshoots may then be produced. Monopodial species can be propagated by long (30 to 37 cm) tip cuttings with a few roots already present. Air layering is also possible. Vegetative propagation by proliferation of shoot-tip (meristem) cultures *in vitro* has revolutionized orchid propagation, particularly for *Cymbidium*, *Cattleya*, and some other genera (14, 217). The shoot growing point is dissected from the plant and grown on a special, sterile medium; a proliferated mass of tissue and small protocorms develops, which can be divided periodically. Many thousands of separate protocorms can be developed in this way within a matter of months, each of which will eventually differentiate shoots and roots to produce an orchid plant (14). The procedure is described in Chapter 18. *Vanilla planifolia*, which is an orchid, essential for its oil, that grows as a vine, is normally propagated commercially by cuttings; nodal stem explants of this species were successfully micropropagated with BA and microshoots rooted *ex vitro* (179).

Terrestrial Orchids. These orchids can be difficult to propagate because they require a symbiotic relationship with an appropriate mycorrhizal fungus. *In vitro* seed germination using techniques similar to those used with epiphytic orchids has been successful both

with and without fungal assistance (11). However, these procedures have not been extensively used commercially. Sowing seeds in pasteurized potting mixes containing mycorrhizal fungi has been successful and offers commercial potential (242).

***Origanum* spp.** Oregano, Dittany of Crete. Tender perennials usually produced as annuals. This genus contains the culinary herbs oregano and marjoram, but also contains showy ornamentals grown as bedding or container plants. Seeds germinate at 21°C (70°F).

***Ornithogalum* spp.** Star of Bethlehem (92). Herbaceous perennials that grow from tunicate bulbs. They are grown as garden plants, but are most important as cut flowers and seasonal pot plants. Plants have been propagated by seeds, leaf cuttings, bulb divisions, and tissue culture. Emerging leaves can be taken as leaf cuttings with plant regeneration taking place under mist (see Chapter 15). Micropropagation is also practiced (307, 325).

***Osmunda* spp.** See Fern.

***Osteospermum* spp.** Tender annual and perennial plants grown as bedding or container plants. Flowers are daisy-like with some interesting cultivars that have spoon-type ray florets. Seeds germinate at 21 to 24°C (70 to 75°F). Tip cuttings (99) are treated with 3,000 ppm IBA under mist with bottom heat 22°C (72°F).

***Oxalis* spp.** Shamrock or wood sorrel (92). Herbaceous perennials used in the garden or grown as a seasonal pot plant. *Oxalis* is an interesting and diverse group of plants. Some members of this genus are perhaps the only dicot species that produces a bulb. Others produce tubers or rhizomes. Propagation is usually from offsets of the bulbs or division of the tubers or rhizomes. Can be micropropagated (170).

***Pachysandra* spp.** See Chapter 20.

***Paeonia* spp.** *Paeonia* hybrids (*P. hybrida*), fernleaf peony (*P. tenuifolia*), tree peony [*P. suffruticosa* (*P. arborea*)]. Hardy perennials native to China used for specimen plants in borders and as cut flowers. Seed propagation is difficult, taking 5 to 7 years to produce a flowering plant from seed (286). Germination may take 1 to 2 years to meet epicotyl dormancy requirement. Seeds are sown in fall for cold stratification requirement during the winter. Roots develop during the first summer, and shoots develop the second spring. Plants developed from seed are generally not true-to-type. Another method is to collect seeds before they become black and completely ripe. Do not allow them to dry out; sow in pots, which should be buried in the



ground for 6 to 7 weeks. Roots will develop; dig up and plant in a protected location or under mulch over winter. Best propagation method for herbaceous peonies is to divide clumps in fall; each tuberous root should have at least one bud or "eye," preferably three to five.

P. suffruticosa is wedge grafted in late summer onto a herbaceous (*P. lactiflora*) understock (254). Peonies can be micropropagated (3, 45, 50).

Pansy. See *Viola*.

***Papaver nudicaule*.** Iceland poppy. Hardy perennial often grown as a biennial. Seeds germinate in 1 to 2 weeks at 18 to 24°C (65 to 75°F). Sow in permanent location in summer for bloom next year.

***P. orientale*.** Oriental poppy. Hardy perennial. Very fine seeds, which may respond to light, should be covered very lightly (18). Seeds germinate in same time as *P. nudicaule*. Cultivars are propagated by root cuttings. Dig when leaves die down in fall, cut into 7.5- to 10-cm (3- to 4-in) sections, and lay horizontally in a flat covered by 2.5 cm (1 in) of a sandy greenhouse substrate. Root cuttings are transplanted in spring. Or dig plants in spring, prepare root cuttings, and plant directly in a permanent location.

***P. rhoeas*.** Corn poppy, Shirley poppy. Hardy annual. Seed germinates at 13°C (55°F). Sow in late summer for early spring bloom or in early spring for summer bloom.

***Pelargonium* spp.** Geranium. A group of tender perennials grown as bedding plants, hanging baskets, and seasonal pot plants. Plants are propagated by seeds or cuttings.

***Pelargonium xdomesticum*.** Regal Geranium. Grown primarily as a cool-season conservatory plant or as a seasonal pot plant. If used in the garden, summer temperatures must be cool to keep plants in bloom. Propagation is from stem cuttings under mist with bottom heat [21 to 24°C (70 to 75°F)] from disease-free stock plants.

***P. xhortorum*.** Geranium. Started by cuttings and by seed. Traditionally propagated by cuttings, which root easily with bottom heat, but *Pythium* and *Botrytis* infection can be serious problems. Pathogen-free stock, identified by culture indexing, should be used and can be supplied by specialists (298). There may be practical value in applying ABA in the shipment and storage of geranium cuttings (17).

In the mid-1970s, large-scale seed propagation of geraniums began with the introduction of certain

cultivars that would grow from seed to flower in 14 to 16 weeks. Seeds germinate best at about 21 to 24°C (70 to 75°F) in medium greenhouse substrate (15). Plant growth regulators (like cycocel) are utilized in greenhouse to produce compact, early-flowering, well-branched plants (258). *In vitro* propagation has been developed and can be used for virus elimination in stock plants (67, 98).

***P. peltatum*.** Ivy geranium. Popular as a window box or hanging basket plant. Propagation is from terminal stem or leaf-bud cuttings handled as described for other geraniums.

***Pennisetum* spp.** Fountain grass. Perennial grasses with feathery inflorescences. They are propagated by division in late spring to early summer (81). Seeds germinate easily, and volunteers in the garden can be a nuisance.

***Penstemon* spp.** Beardtongue. Semi-hardy to hardy perennials, sometimes handled as annuals. Seeds germinate at 18 to 21°C (65 to 70°F), but growth can be slow and uneven; seeds may respond to light (18). Some species benefit from 8 weeks of stratification at 15°C (59°F) (5). Plants started indoors in early spring and transplanted outdoors later may bloom the first year. Plants are usually short-lived.

Softwood cuttings taken from non-flowering side shoots of old plants root readily. Make cuttings in fall to obtain plants for next season. Clumps may be divided. *Penstemon* can also be micropropagated from lateral buds used as explants (197).

***Pentas lanceolata*.** Star-cluster pentas. Tender perennial with clusters of white, pink, lavender or red star-shaped flowers grown as a pot or bedding plant. Can be propagated from seeds or cuttings. Seeds germinate at 21 to 22°C (70 to 72°F). Tip cuttings from non-flowering plants are treated with 1,000 ppm IBA + 500 ppm NAA and rooted under mist with bottom heat at [20 to 22°C (68 to 72°F)] (99).

***Peperomia* spp.** Tender perennials grown as indoor house plants and occasionally as bedding plants. Softwood stem, leaf-bud, or leaf cuttings root readily. Plants can also be divided. *Peperomia* can also be micropropagated from excised leaf explants (142) and petioles (243).

***Pericallis xhybrida*.** Florist's cineraria (formerly *Senecio cruentus*) is a cool-season crop with true blue or lavender flowers grown as a seasonal pot plant. Seeds germinated at 20 to 22°C (68 to 72°F) will emerge in 2 weeks in light (168). Plants are most often produced from seeds because vegetatively propagated plants can

show reduced vigor and flower size. Plants have been micropropagated (77, 126).

Periwinkle. See *Vinca minor*.

Persicaria spp. Fleecflower or knot weeds. This genus now contains plants that were formerly *Polygonum* and *Tovara*. Versatile perennials and annuals used as ground covers, in rock gardens, planters, and hanging baskets. Generally propagated by division or seed. *P. capitatum* 'Magic Carpet,' which is an excellent annual ground cover, is propagated by seed at 21 to 27°C (70 to 80°F). Other species (*P. affine*, *P. amplexicaulis*, and *P. virginiana*) are more commonly propagated by division.

Pervoskia atriplicifolia. Russian sage. Hardy perennial. Large shrub-like perennial with silvery foliage and blue flowering spikes. Propagated from softwood cuttings.

Petunia xhybrida. Petunia (65). Tender perennial often grown as an annual. Seeds germinate at 24 to 25°C (75 to 78°F). Give light for the first 3 days then move to darkness until seedlings emerge. Several cultivars are propagated from stem cuttings that root easily under mist. Petunia is easily micropropagated from leaf segments (287).

Philodendron spp. Tropical vines. Seeds germinate readily at about 25°C (77°F) if sown as soon as they are ripe and before they become dry. Vining types are propagated by single node leaf-bud or stem cuttings. Larger plants may be multiplied by air layering. Non-vining types are propagated from seeds or, more commonly, tissue culture (274).

Phlomis russeliana. Jerusalem sage. Hardy perennial grown for pale yellow flowers on stiff, upright stems. Most commonly propagated by crown division or stem cuttings.

Phlox spp. Phlox. Colorful herbaceous annual or perennial garden plants. Propagated by seeds or cuttings.

Phlox divaricata. Sweet William. Hardy perennial. Expose seeds to cold during winter or chilling stratification before planting. Softwood cuttings taken in spring root easily. Divide clumps in spring or fall.

Phlox drummondii. Annual phlox (65). Hardy annual. Seed germinate at 15 to 18°C (60 to 65°F). Initial seed germination occurs in either light or darkness, but light inhibits radicle growth, so it is common to germinate phlox in the dark (62). Start indoors for later outdoor planting, or outdoors after frost.

Phlox paniculata. Garden phlox. Hardy perennial. Plants do not come true from seed. Sow seeds as soon as ripe in fall to germinate the next spring. Seed

will germinate at 20°C (68°F). Grow plants one season and transplant in fall. Softwood cuttings taken from young shoots in spring or summer root easily, but are subject to damping-off if kept too wet. Garden phlox are often commercially propagated from root cuttings (195). Dig clumps in fall; remove all large roots to within 5 cm (2 in) of crown (which is replanted). Cut roots into 2-inch lengths and place in flats of sand; cover 13 mm (0.5 in) deep. Transplant next spring. Divide clumps in fall or spring. Phlox can be micropropagated using shoot explants (257, 292).

Phlox subulata. Moss pink. Hardy perennial. Evergreen ground cover with profusion of blooms in early spring. Propagation is by division of dormant plants or softwood stem cuttings taken after plants finish blooming in the spring. Cuttings are treated with 1,000 ppm IBA under mist. Plants can be micropropagated (257).

Physalis alkekengi. Chinese lantern. Hardy perennial grown for showy fruits shaped like orange paper lanterns. Seeds emerge in 2 weeks at 16 to 21°C (60 to 70°F). Can be divided in the autumn.

Physostegia virginiana. False dragonhead or lions-heart. A herbaceous perennial that is used as a field-grown cut flower crop (16). Seeds will germinate at 18 to 21°C (65 to 70°F). This species can also be propagated by division.

Pinguicula spp. Butterwort. Perennial carnivorous plants. Glandular hairs are produced on the leaves of these rosette plants to trap insects. An attractive flowering carnivorous plant. Propagation is from seed or tissue culture (1).

Platycodon grandiflorus. Balloon flower. Hardy perennial. Long-lasting blue flowers that resemble balloons when in bud. Most commonly propagated by seeds that emerge in 1 to 2 weeks at 20 to 21°C (68 to 70°F) with light. Plants can also be divided in spring.

Plectranthus spp. Spurflowers. Tender herbaceous perennials related to coleus. Plants are primarily grown for their interesting foliage, but some have showy flowers. Propagation is primarily from stem cuttings with bottom heat (21 to 24°C; 70 to 75°F) that root easily without auxin.

Poinsettia (Euphorbia pulcherrima). See Chapter 20.

Polemonium spp. Jacob's ladder. Hardy perennial. In spring, blue or white flowers appear on plants with a leaflet pattern that resembles a ladder. Seeds germinate at 21°C (70°F). Plants can also be multiplied by crown division and stem cuttings.



Polianthes tuberosa. Tuberose (34). Tender bulbous perennial. Propagated by removing offsets at planting time. The small bulbs take more than 1 year to flower. Divide clumps every 4 years. Plants can be micropropagated (44).

***Poliomintha longiflora* (153)**. Mexican oregano. Has small evergreen leaves that smell like the spice oregano and is a striking landscape plant that produces light lavender flowers throughout the summer. It is easily rooted from stem cuttings.

***Polygonatum* spp.** Solomon's seal. Hardy perennials. Used in wildflower and perennial gardens. Propagation is by seed or division. Cultivars are propagated by dividing rhizomes in the spring.

***Portulaca* spp.** Moss rose, flowering purslane. Half-hardy annual used as a bedding or container plant. Seeds germinate at 24 to 27°C (75 to 80°F) and may respond to light (18). Can also be propagated by tip cuttings.

***Potentilla* spp.** Cinquefoil. Hardy perennial. Creeping perennials with attractive blooms. Can be propagated by seed, division, or stem cuttings. *P. nepalensis* is a common garden perennial and is grown from seed germinated at 21°C (70°F).

Pothos. See *Epipremnum*.

***Primula* spp.** Primrose. A group of cool-season perennials used in the rock or perennial garden. Some species and hybrids used as seasonal pot plants. Most primroses are propagated by seed. Seed germination can be erratic. Seeds generally require light, and germination temperature should be below 21°C (70°F). Erratic germination may be related to seed dormancy, and germination has been enhanced by a pregermination treatment with gibberellic acid (100). Micropropagation is possible (35).

***P. xpolyantha* and *P. vulgaris* (syn *P. acaule*)**. Hardy perennials grown outdoors or used as seasonal pot plants. Seeds are slow to germinate and can take up to 30 days. Germination is at 16 to 18°C (60 to 65°F), but some species may require lower temperatures (80, 107). It is best to collect and sow seeds as soon as they are ripe in the fall. Clumps can be divided just after flowering.

Primula malacoides. Fairy primrose. Seeds will germinate in 2 to 3 weeks at 15 to 18°C (59 to 65°F).

Primula obconica. Primrose. Tender perennial grown as an annual. Seeds germinate well in a cool greenhouse or after 3 to 4 weeks at 18 to 20°C (65 to 68°F). The very tiny seeds respond to light and should not be covered.

Primula sinensis. Chinese primrose. Seeds will germinate within 3 weeks at 20°C (68°F). In these species, double-flowering cultivars do not produce seeds but are propagated by cuttings taken in spring, or by division.

***Pulmonaria* spp.** Lungwort. Hardy perennial grown for their attractive spotted or silvery foliage on plants adapted to the shade garden. Common companion plant to hostas. Can be propagated by division, root cuttings (48), or tissue culture. Tissue culture propagation and the introduction of new cultivars has increased the availability of lungworts (290).

***Pulsatilla* spp.** Pasque flower (formerly *Anemone pulsatilla*). Hardy perennial with showy anemone-like flowers and feathery seed heads. Seed germination is at 20°C (68°F) but may be sensitive to high temperature. Plants can be divided or propagated from root.

Puschkinia scilloides. Striped squil (92). Hardy perennial bulb. Propagation is the same as *Scilla*.

***Ranunculus* spp.** Buttercup (210). A group of herbaceous perennials produced on tuberous roots or rhizomes. Plants are used as annual or perennial garden plants, seasonal pot plants, and cut flowers. Commonly propagated by seeds germinated at 20°C (68°F). Divide perennial types while dormant in spring or fall.

Ranunculus asiaticus. Turban or Persian ranunculus. Tender perennial. Plants are most commonly propagated from seeds that germinate at 15 to 17°C (58 to 62°F). Plants can also be multiplied by division of the tuberous root, or micropropagated (172, 211).

***Ratibida* spp.** Prairie coneflower. Hardy perennial producing yellow coneflowers. Most often used in native prairie plantings and wildflower mixes. Seed germination is at 21 to 24°C (70 to 75°F) and may benefit from several weeks of chilling stratification. Plants can be divided.

Reseda odorata. Mignonette. Hardy annual. Seeds should not be covered; Seed germination is at 12°C (54°F), and seeds may respond to light (18).

***Rhipsalidopsis* spp.** Easter cactus. Propagation same as *Epiphyllum*.

Ricinus communis. Castor bean. Soak seeds in water for 24 hours or nick with file before planting. Seed germination is at 21°C (70°F). Seeds are poisonous.

***Rodgersia* spp.** Featherleaf, Rodgersflower. Perennial for moist border with attractive foliage and ornamental flowers. Propagation is by seeds or division.

***Rudbeckia* spp.** Black-eyed Susan, coneflower. Hardy annual, biennial, and perennial species. Seeds germinate in 2 to 3 weeks at 21 to 24°C (70 to 75°F). Perennial kinds are propagated by crown division. Plants often re-seed naturally. Seed priming can improve germination (113).

Rumex sanguineus. Red-veined dock. Semi-hardy perennial grown for the interesting red-veined pattern on leaves. Propagation is from seed germinated at 20°C (68°F).

Saintpaulia ionantha. African violet (159, 181, 324). Tropical perennial. Propagation is by seed, division, or cuttings. The very fine seeds, which germinate at 30°C (86°F), should not be covered. Seedlings are subject to damping-off. Vegetative methods are necessary to maintain cultivars. Leaf cuttings (blade and petiole) are easily propagated using a rooting medium at 25°C (75°F) and air temperature at 18°C (64°F) (260). Variegated leaf cultivars that do not come true from leaf cuttings should be propagated by crown divisions or tissue culture (271). Rapid, large-scale propagation can be accomplished by *in vitro* culture techniques using leaf petiole sections (40, 83, 165, 281).

Salpiglossis sinuata. Painted tongue. Semi-hardy annual. Seed germination is at 21 to 22°C (70 to 72°F) but can be slow and uneven. Can be micropropagated (194).

***Salvia* spp.** Sage (65). Annual, biennial, and perennial species. *Salvia* are used in borders, containers, or as cut flowers (16). Seed germination is at 24 to 25°C (75 to 78°F) and may respond to light (18). Softwood cuttings from non-flowering plants root readily under mist and may benefit from 1,000 ppm IBA.

S. greggii. Easily propagated by semi-hardwood cuttings (153). Plants can be divided, but such divisions are slow to recover.

S. officinalis. Basal cuttings root better than apical cuttings. Flowering reduces rooting and removal of flowers enhances propagation. Rooting is enhanced with basal dips of 1,000 ppm K-IBA salt (246). Rooting ability was highest in spring (Israel).

S. splendens. Scarlet sage. Tender perennial grown as an annual. Germinate seeds at 24 to 25°C (75 to 78°F), then grow at 13°C (55°F) night temperature. Seeds soaked for 6 days at 6°C (43°F) can promote germination (56). Softwood cuttings taken in fall root readily.

Sandersonia aurantiaca. Climbing, tender, tuberous plant with orange flowers like inverted lanterns. Grown as a container plant or cut flower. Propagation

is by division of the tuberous root or by micropropagation (114).

Sanguinaria canadensis. Bloodroot. Ephemeral, North American native producing white flowers in early spring. Seeds have morphophysiological dormancy and require cycles of warm followed by chilling stratification. It can take several years to produce a seedling.

***Sansevieria trifasciata* and *S. 'habnii'* (Dwarf Form).** Bowstrip hemp. Snakeplant. Tropical perennial. Plants grow from a rhizome, which can be readily divided. Leaves may be cut into sections, several inches long, and inserted into a rooting medium; a new shoot and roots will develop from the base of leaf cutting. The variegated form, *S. trifasciata* 'Laurentii,' is a chimera, which can be maintained only by division. *S. trifasciata* has been micropropagated (42).

Santolina chamaecyparissus (incana). Lavender cotton. A perennial native to the Mediterranean that is used as carpet bedding or a low hedge. Must be trimmed to maintain compact growth. Seeds germinate at 18 to 21°C (65 to 70°F). It is easily propagated by stem cuttings.

Sanvitalia procumbens. Creeping zinnia. Hardy annual. Seed germination is at 20°C (68°F). Plants are easily propagated using stem cuttings treated with up to 2,500 ppm IBA under mist (99).

Saponaria ocymoides. Rock soapwort. Hardy short-lived perennial used in rock gardens or as a bedding plant. Seed germination is at 21°C (70°F) in the dark.

S. pfficinalis. Bouncing Bet. Hardy perennial. Seeds germinate at 20°C (68°F). The plant spreads rapidly by an underground creeping stem, which can be divided.

***Sarracenia* spp.** Pitcher plant. Perennial carnivorous plants native to bog ecosystems. Leaves are modified to form spectacular pitchers that entrap insects. Also grown for cut foliage for the florist industry. Propagation is by division of the rhizome (68).

***Saxifraga* spp.** Many interesting unusual species and hybrids. Tender or hardy perennials. Seeds germinate easily at 21°C; they are preferably sown when ripe. Seed germination is at 21 to 24°C (70 to 75°F). Some hybrids and cultivars are maintained only by vegetative methods and are propagated once flowering is finished in June or July (England) (269). Cuttings are small and slow growing—it takes one year to grow a liner.



Cuttings are rooted in a cold frame or seed tray. Most plants grow as small rosettes and are easily propagated by making small cuttings involving single rosettes. Small plants from stolons root readily. Plants can be divided in spring or fall.

S. stolonifera. Strawberry geranium. A tender perennial grown indoors or as a bedding plant. It can be reproduced by removing plantlets from the runners.

***Scabiosa* spp.** Pincushion flower. Annual and hardy perennial garden plants. Seed germination is at 18 to 21°C (65 to 70°F). Perennial kinds can be divided.

Scaevola aemula. Fan flower. Tender perennial grown for its trailing habit and blue flowers. Most commonly used as a hanging basket. Propagation is from stem cuttings that are rooted under moderate mist with bottom heat at 20 to 22°C (68 to 72°F). Auxin is not required but up to 2,500 ppm IBA can be used to improve uniformity (99). Micropropagation is possible (38).

Scarlet Sage. See *Salvia splendens*.

***Schefflera* (synonym *Brassaia*) *arboricola* and *S. actinophylla* (137)**. Umbrella tree. Tropical perennial plants used in warm climate landscapes and as an important indoor foliage plant. Schefflera is an important foliage plant that can be propagated easily by seeds, cuttings, or air layering. Basal cuttings develop more roots and longer shoots and require less time to break lateral buds than do apical cuttings (137). As single-node cutting length increased to 20 cm (8 in) so did rooting, bud-break, and shoot growth. Seeds germinate at 22 to 24°C (72 to 75°F).

***Schizanthus* spp.** Butterfly flower. Tender annual grown as a seasonal pot plant. Seed germination is at 18 to 22°C (64 to 72°F) in the dark. Seeds are sensitive to high temperatures (18). Sow seeds in fall for early spring blooms indoors, or sow in early spring to be transplanted outdoors for summer blooms.

Schlumbergera truncata. Christmas cactus. Propagation same as *Epiphyllum*.

***Scilla* spp.** Squill (92). Includes several kinds of bulbous hardy and half-hardy spring-flowering perennials. Dig plants when leaves die down in summer and remove the bulbets. *S. autumnalis* is planted in spring and blooms in fall. Can be micropropagated (155).

***Scutellaria* spp.** Skullcap. Annual or herbaceous perennials used as bedding plants, in containers or in the perennial bed. Seed germination is at 21 to 24°C (70 to 75°F) in light. Perennial types can also be divided or multiplied by stem cuttings.

***Sedum* spp. (269)**. Sedum is composed of a wide range of species including herbaceous perennials, evergreens, and monocarps. Many of the *Sedum* species can be raised by seed, but generally this method is limited to herbaceous perennials only; seeds germinate at 15 to 18°C (65°F) in light. *S. acre* should have alternating day [29°C (86°F)] and night [21°C (70°F)]. The mat-forming species are propagated by division, since the creeping shoots root into the ground as they travel and mats are easily pulled apart. Direct sticking cuttings into containers is done, since many species root so readily.

Sempervivum. See Succulents.

Senecio cineraria. Dusty miller (223). Semi-hardy perennials usually grown as annuals for their silvery foliage. Seeds germinate at 24 to 26°C (75 to 80°F). Stem-tip cuttings root rapidly if treated with IBA and placed under mist with bottom heat.

Sidalcea malviflora. Sidalcea (286). A native western U.S. perennial used as a border plant. Seeds germinate at 18 to 21°C (65 to 70°F). Cultivars are commonly propagated by division.

***Silene* spp.** Catchfly, campion. Annual and short-lived perennials grown for bright pink, red, or white flowers. Seeds germinate at 18 to 21°C (65 to 70°F). Perennial types are divided, or basal stem cuttings can be rooted.

Sinningia speciosa. Gloxinia. Tropical perennial. Commonly grown from seeds, which are very fine and require light. Sow uncovered, in well-drained peat moss medium; they emerge in two weeks at 20°C (68°F). Vegetative methods are required to reproduce cultivars. Plant grows from a tuber on which a rosette of leaves is produced. The root can be divided as described for tuberous begonia. Softwood cuttings or leaf cuttings taken in spring from young shoots starting from the tubers root easily. Gloxinia can also be micropropagated using leaf explants (163).

Snapdragon. See *Antirrhinum majus*.

***Solanum* spp.** A diverse group of tender, annual, herbaceous, and woody perennials related to potato. *S. pseudocapsicum* (Christmas cherry) is grown as a seasonal container plant. It is propagated by seeds, which germinate at 18 to 21°C (65 to 70°F) in light.

S. crispum and *S. kasminoides* are vines and *S. rantonnettii* is a woody shrub usually grown as a container standard. All are commonly propagated by softwood stem cuttings rooted under mist.

Solenostemon scutellarioides. (formerly *Coleus blumei*) (27). Tender perennials. Used for containers and as bedding plants. Plants are grown for their wide selection colorful foliage. Seeds germinate at 21 to 24°C (70 to 75°F) in light. Coleus is commonly propagated from cuttings that root easily under mist without auxin.

***Solidago* spp.** Goldenrod. Hardy perennial. Grown as a cut flower and for the perennial garden. Plants can be grown from seeds or division, but are usually propagated from stem cuttings. Seeds germinate at 20 to 22°C (68 to 72°F) and some species benefit from 10 weeks of chilling stratification (46). Stem cuttings are taken from basal vegetative growth in the spring and rooted under mist without auxin. Division is from dormant plants.

xSolidaster. An intergeneric hybrid between *Solidago* and *Aster* that is also grown as a cut flower from stem cuttings. Plants can also be divided.

***Spathophyllum* spp.** Spatheflower. Tropical evergreen plants grown in indoor containers or as bedding plants in tropical regions. Plants can be propagated by crown division or commercially by micropropagation (117).

Spider plant. See *Chlorophytum comosum*.

Spigelia marilandica. Pinkroot. Herbaceous perennial with tubular red flowers. Underused perennial due to difficulty in propagation. Plants can be multiplied by division or stem cuttings. Stem cuttings root under mist when taken from greenhouse-grown stock plants (118). Plants can also be micropropagated.

***Stachys* spp.** Lamb's ear (*S. byzantina*), big betony (*S. grandiflora*). Hardy perennials used as border plants or ground covers. Propagated by clump division or by seed. Seed germinates at 21°C (70°F).

***Stapelia* spp.** Carrion flower. Tender perennial succulent that produces large star-shaped flowers that have an unpleasant odor, which attracts flies as pollinators. Propagated by seeds sown at 21°C (70°F), by division or stem cuttings. See Succulents for detailed information.

Sternbergia lutea. Autumn daffodil. Small fall flowering bulb with bright yellow flowers. Propagated by offsets of the bulb.

Stock. See *Matthiola*.

Stokesia laevis. Stokes aster. Hardy perennial. Seeds germinate at 21 to 24°C (70 to 75°F) and the plants bloom the first year. Commonly propagated from root cuttings or division.

Strelitzia reginae. Bird-of-paradise. Tropical perennial producing the recognizable bird of paradise flower. Grown as a greenhouse ornamental and a cut flower. Seed propagation of this tropical perennial is undesirable due to juvenility and genetic variation. Seeds germinate in 6 to 8 weeks using bottom heat at 37°C (98°F) (72). This species grows from a rhizome, which can be divided in the spring; however, division is limited by a low rate of multiplication with 0.5 to 1.5 divisions per branch per year. A technique has been developed to overcome the strong apical dominance, which inhibits branching of axillary buds into propagules. A triangular incision with a knife is made at the base of a separated branch 8 to 12 mm above the basal plate to reach and remove the apex from adult plants (304). After 2 to 6 months, 2 to 30 lateral shoots develop from each fan (separated branch). During the next 6 months, newly formed laterals root and can be divided into individual plants (see Chapter 15).

Streptocarpus xhybridus. Cape primrose is a herbaceous perennial in the Gesneriaceae. It is generally propagated by seed or leaf cuttings. Seeds germinate at 21°C (70°F). Seeds are tiny and should not be allowed to dry out. Leaf cuttings are made by splitting the leaf down the midrib to form two leaf segments. The base of the leaf segment is removed and the remaining leaf cutting is placed into a peat-lite medium held at 21°C (70°F). New plants appear in several months. Cape primrose has been successfully micropropagated using explants of leaf discs, shoot apices, stem, petiole, pedicel segments, and corolla flower parts (230).

***Succulents* (28, 106, 234, 282)**. This loosely defined horticultural group includes many genera, such as *Agave*, *Aloe*, *Crassula*, *Echevaria*, *Euphorbia*, *Gasteria*, *Haworthia*, *Hoya*, *Kalanchoe*, *Mesembryanthemum*, *Portulaca*, *Sedum*, *Sempervirens*, and *Yucca*. These are plants with fleshy stems and leaves that store water, or plants that are highly drought-resistant. Most are half-hardy or tender perennials. Seed propagation is possible, although young plants are often slow to develop and to produce flowers. It is best to germinate seeds indoors at high day temperatures (29 to 35°C, 85 to 95°F). Seedlings are susceptible to damping-off.

Cuttings of most species root readily—either stem, leaf-bud, or leaf—in a 1:1 peat-perlite medium. They should be exposed to the open air or inserted into dry sand for a few days to allow callus to develop over the cut end. Some protection from drying is needed during rooting. Some species can be reproduced by removing offsets. Grafting is possible as described for cacti. Many of the succulents can be micropropagated (249, 270, 276, 287).



***Sutera* spp.** Bacopa. Trailing annual mainly grown in hanging baskets or mixed containers. Plants are propagated from cuttings treated with 2,500 ppm IBA under mist with bottom heat at 18 to 20°C (65 to 68°F). Overuse of mist can be a problem if rooting substrate becomes saturated (99).

Sweet Alyssum. See *Lobularia maritima*.

Sweet Pea. See *Lathyrus*.

***Symphytum* spp.** Comfrey. Hardy perennial. Grown as an herb or ornamental garden plant. Cultivars are propagated mainly from root cuttings or division. Micropropagation is from stem explants (140).

***Syngonium podophyllum*.** Arrowhead vine. Tropical perennial vine grown as an indoor foliage plant. Seeds germinate at 24 to 27°C (75 to 80°F). Plants also root easily from single eye leaf-bud or stem cuttings as well as tissue culture.

***Tagetes* spp.** Marigold (223). Tender annuals. Plants are used as bedding plants and cut flowers. Seeds germinate readily within 1 week at 21 to 24°C (70 to 75°F). Can be sown in place in spring after frost in mild climates. *T. erecta* (African marigold) has been micropropagated from leaf segments (180). Somatic embryos have also been developed (37).

***Tanacetum coccineum* (formerly *Chrysanthemum coccineum*).** Painted daisy. Hardy perennial for the flower border. Can be propagated by seeds that emerge in 2 weeks at 16 to 21°C (60 to 70°F). Most often propagated by division or basal stem cuttings.

***T. parthenium* (formerly *Chrysanthemum parthenium*).** Feverfew. Hardy perennial usually grown as an annual. Seeds germinate in about 1 week at 20°C (68°F) in light. Plants easily self-seed and can be divided.

***T. ptarmiciflorum*.** Dusty miller. Tender perennial grown as an annual. Propagated from seeds that emerge within 2 weeks at 22 to 24°C (72 to 75°F) in light.

***Teucrium* spp.** Germander. Herbaceous and woody perennials grown mainly for their green or silvery foliage. Often pruned into garden borders or used in knot gardens. Seeds germinate at 18 to 21°C (65 to 70°F). Commonly propagated by stem cuttings using mist or high humidity with bottom heat.

***Thalictrum* spp.** Meadow rue. Hardy perennial. Seeds germinate at 20°C (68°F). May benefit from 1 week of chilling stratification. Plants can be multiplied by dormant divisions in spring or fall.

***Thermopsis caroliniana*.** Hardy perennial. Seeds have hard seed coats and require scarification. Seeds germinate at 21°C (70°F). Plants can be divided, but it is best to leave them undisturbed for garden performance.

***Thunbergia* spp.** Clockvine. Tender annual and perennial vines. *T. alata* (black-eyed Susan) and *T. gregorii* are grown as summer annuals on a garden support or as a ground cover. *T. grandiflora* (Blue trumpet vine) and *T. mysorensis* are usually used as perennial vines in greenhouse displays for spring or fall blooms. Seeds germinate at 21 to 24°C (70 to 75°F), but seedlings grow slowly. Softwood cuttings taken from new shoots root readily with bottom heat.

***Thymus* spp.** Thyme. Hardy creeping perennials grown as ground covers for small spaces or in containers. Leaves are fragrant. Seeds germinate at 21°C (70°F). Germination may be promoted by light. Can also be increased by division or by softwood cuttings taken in summer. Plants have been micropropagated (121).

Ti. See *Cordyline terminalis*.

***Tiarella cordifolia*.** Foamflower. Hardy perennial grown as a ground cover in the shade. Can be propagated from seed or division. Seeds emerge within 2 weeks at 18°C (65°F). *Tiarella* is commercially micropropagated from shoot explants (175).

***Tigridia pavonia*.** Tiger flower (92). Tender bulbous perennials. Plant bulbs in spring and dig in fall when leaves die. Increase by removal of small bulblets. Easily started by seed.

***Tillandsia* spp.** See Bromeliads.

***Tithonia rotundifolia*.** Mexican sunflower. Tender perennial with large composite flowers grown as an annual. Seeds germinate at 21°C (70°F).

***Tolmiea menziesii*.** Piggyback plant. Tender perennial used as an indoor foliage plant. New plantlets form on upper surface of leaves. Plantlets can be removed and rooted. Also propagated from stem (rhizome) cuttings.

***Torenia fournieri*.** Wishbone flower (272). *Torenia* is a tender perennial grown as an annual for semi-shady garden areas. Seed germination is at 21 to 23°C (70 to 75°F) with light. Plants are also propagated from terminal cuttings treated with 2,500 ppm IBA under mist (99).

***Trachymene coerulea*.** Laceflower. Tender perennial grown as an annual for display or cut flowers. Seeds germinate at 20°C (68°F).

***Tradescantia* spp.** Spiderwort. Hardy perennial grown for their foliage color or their long-blooming blue, pink, or white flowers held above grass-like

foliage. Seeds germinate at 21°C (70°F). Cultivars are propagated from dormant divisions in spring or autumn. Stem cuttings root easily under mist or high humidity without auxin.

***Tricyrtis* spp.** Toad lily. Hardy perennial. Unique flowers produced in the early autumn. Plants prefer shade. Propagation is from seed, division, or stem cuttings. Seeds require stratification. *Tricyrtis* has become widely available partly due to its ease of micropropagation.

***Trillium* spp.** Trillium, wake robin. Hardy herbaceous perennials grown in the woodland garden. Plants produce white, yellow, or red flowers with three pigmented petals. Seeds are covered with an aril called an elaisome that attracts ants, which disseminate the seed. Seeds should be sown as soon as the seed ripens. Maintain even moisture levels until seedlings emerge. Seeds have morphophysiological dormancy where the radicle emerges after the first chilling stratification and the epicotyl emerges after a second chilling stratification, which means two seasons are required for seedling emergence (49, 273). Many trillium produce shoots from rhizomes. The rhizome can be notched behind the apical shoot bud to induce numerous new buds near the wound site. After 1 year, these new shoots can be separated, including a piece of the rhizome (41). Some trillium species have been micropropagated (232).

***Trollius* spp.** Globeflower. Hardy perennial grown for their striking orange-yellow flowers. Seeds show endogenous dormancy and should be stratified or planted in fall to produce plants that flower by next spring (49). Plants are also increased by crown division.

Tropaeolum majus. Nasturtium. Tender perennial grown as an annual. Seeds germinate at 18 to 21°C (65 to 70°F). Plants can be difficult to transplant and are often seeded in place. Double-flowering kinds must be propagated vegetatively, usually by softwood cuttings.

***Tulipa* spp. and Hybrid Cultivars.** Tulip (192). Hardy perennials from tunicate bulbs. Tulips are used for seasonal bedding plants, pot plants, and cut flowers. Plant bulbs in fall for spring blooms. Seeds are used to reproduce species and for breeding new cultivars. They germinate readily after chilling stratification. Vegetative methods include removal of offset bulbs in the fall. Different bulb sizes are planted separately, since the time required to produce flowers varies with size. For details of procedure, see Chapter 15. Tissue culture of tulip is possible but results are variable and success rates are low. Additional work is needed to develop a commercial micropropagation system (4).

Tweedia caerulea. (synonym *Oxypetalum*). Hardy perennial grown for its pale blue flowers that make long-lasting cut flowers. Seeds germinate within 2 weeks at 21°C (70°F) in light.

Valeriana. See *Centranthus*.

***Verbascum* spp.** Mullein. Hardy perennials and biennials grown for their showy spikes of flowers. Seeds germinate at 18 to 21°C (65 to 70°F). Propagate named cultivars by root cuttings taken in early spring before vegetative growth begins.

***Verbena* spp.** Verbena. Tender perennials grown as an annual. Seeds germinate at 24 to 27°C (75 to 80°F), but germination can be erratic (65). Seeds are sensitive to overwatering (60). Hardy kinds can be propagated by division or from softwood cuttings taken in summer. Stem cuttings are treated with 1,000 ppm IBA and rooted under mist (99).

***Veronica* spp.** Speedwell. Diverse group of hardy perennials producing white or blue flowers on upright or spreading plants depending on the species. Seeds germinate at 18 to 24°C (65 to 75°F) with light. Plants are increased by division in spring or fall or by softwood cuttings taken in the spring or summer. Plants can be micropropagated (280).

Vinca. See *Catharanthus*.

Vinca major. Tender perennial grown as a ground cover. Propagated by division or by softwood cuttings treated with 1,000 ppm IBA under mist (99).

V. minor. Periwinkle. Hardy perennial. Seeds germinate at 20°C (68°F). Easily propagated by softwood cuttings or by division. *V. minor* can also be micropropagated (278).

***Viola* spp.** Violets. Many hardy perennial kinds. Species violets can be propagated by seeds, but germination may be slow and seeds are best exposed to chilling stratification before planting. Many species produce seeds in inconspicuous, enclosed (cleistogamous) flowers near the ground, whereas the conspicuous, showy flowers produce few or no seeds. These plants can also be reproduced by cuttings or by division (80).

Viola cornuta. Horned violet, tufted pansy. Hardy perennial. Seeds germinate at 18 to 21°C (65 to 70°F). Seeds of some cultivars need light. Vegetative propagation is by cuttings taken from new shoots obtained by heavy cutting back in the fall. Clumps may also be divided.

V. odorata. Sweet violet. Tender to semi-hardy perennials. Grows by rhizome-like stems, which can be separated from others on the crown and treated as a cutting with some roots present.

V. tricolor. Johnny-jump-up. Hardy or semi-hardy, short-lived perennial. Usually propagated by seeds as described for *V. cornuta* but may also be increased by division.

Viola xwittrockiana. Pansy. Short-lived perennial grown as an annual. Popular as an autumn and early spring bedding plant. Propagation is by seed. Seeds germinate at 18 to 21°C (65 to 70°F) with light. Pansy seed experiences thermoinhibition at temperatures above 30°C (86°F) and fails to germinate. These temperatures are common in summer greenhouses when pansy seed is normally sown, but seed priming alleviates this problem (58). Pansy seed is commonly sold as primed seed from the seed company.

Vriesea. See Bromeliads.

***Yucca* spp.** Yucca. Tender to semi-hardy perennials. Seeds germinate at 20°C (68°F) but require several years to flower. Plants are monocots; some are essentially stemless and grow as a rosette, while others have either long or short stems. Offsets growing from the

base of the plant can be removed and handled as cuttings; sometimes entire branches or the top of the plant can be detached a few inches below the place where leaves are borne and replanted in sandy soil. Sections of old stems can be laid on sand or other medium in a warm greenhouse, and new side shoots that develop can be detached and rooted. *Y. elephantipes* is rooted by long canes (239).

***Zantedeschia* spp.** Calla (120). Tropical perennials used as cut flowers and seasonal pot plants. Plants are propagated by seed, division, and tissue culture. Plants grow by thickened rhizomes (or tuber) that produce offsets or rooted side shoots; these are removed and planted. Calla are also commercially micropropagated (79, 160).

Zebrina pendula. Wandering Jew. Tender perennial. Easily propagated at any season by stem cuttings.

***Zephyranthes* spp.** Zephyr lily (92). Tender perennial produced from a bulb. Used as a seasonal pot plant or annual display. Multiplied by offsets of the bulb.

Zinnia elegans and other species. Zinnia (223). Half-hardy hot-weather annuals used as bedding plants or cut flowers. Greenhouse germination is rapid (within 1 week) for seeds sown at 21°C (70°F).

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