Crop Reports

Stokes Aster

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Stokes aster [*Stokesia laevis* (J. Hill) Greene] is an underused herbaceous perennial that has great potential use as a landscape ornamental and as an industrial oilseed crop. It has large, showy flowers and is available in several attractive cultivars. Grown primarily for its flowers (Bailey, 1949), it has been described as a species of minor ornamental importance in the southeastern United States (Gunn and White, 1974). Huxley (1992) recommended its use both as a cut flower and as an ornamental landscape plant.

Stokes aster also has potential use as an oilseed crop because its seeds contain large amounts of vernolic (12,13-epoxy-cis-9-octadecenoic) acid, a fatty acid that is converted to epoxy oil products for use in the manufacture of plastics and adhesives (Campbell, 1981; Kleiman, 1990). Oil content in seeds can be as high as 40%, with about 70% of this oil being vernolic acid (Gunn and White, 1974). In the 1980s, the annual global market for seed-derived epoxy oils was between 45 and 90 billion tons (40.8 and 81.6 $\times$ 10^9 t) per year (Campbell, 1981; Princen, 1983). The United States alone currently uses between 50 and 75 billion tons (45.4 and 68.0 $\times$ 10^9 t) of epoxy oil on an annual basis (Cunningham, 1997). Most of this is derived from traditional petrochemicals and the processing of linseed and soybean oils. Cultivation of stokes aster as an oilseed crop could reduce the amount of petrochemicals used in this process while providing an alternative, sustainable source for raw material (Gunn and White, 1974; White, 1977).

Classification, origin, and environmental requirements

Stokes aster initially was described and classified as *Carthamus laevis* by J. Hill in 1769. The genus *Stokesia* was described by L'Héritier de Brutelle (1788), who proposed that the type specimen used by J. Hill to describe *C. laevis* should be selected as the type specimen for the new genus *Stokesia*. L'Héritier de Brutelle (1788) also referred to *S. cyanea* but failed to describe the species; therefore, the name *S. cyanea* is illegitimate. The final authority regarding the nomenclature of stokes aster is Greene (1893), who stated that the proper binomial for the specimen called *C. laevis* by J. Hill and *S. cyanea* by L'Héritier de Brutelle should be *Stokesia laevis*. The genus is named for the English botanist Jonathan Stokes (1755-1831).

Stokesia is one of about 950 genera in the aster family (Asteraceae Dumont) and is monotypic, with *S. laevis* the only species (Bailey, 1949; Els, 1994; Greene, 1893; Gunn and White, 1974). *Stokesia* belongs to the subfamily Tubiliflorae within the tribe Vernonieae Cass. Vernonieae has two other genera—*Elephantopus* L. and *Vernonia* Schreb. *Stokesia* is the only member of the Vernonieae tribe that is restricted to the United States. *Stokesia* can be separated from the other genera in the tribe based on the large 3- to 4-inch (7.6- to 10-cm)

Fig. 1. Plant of stokes aster 'Purple Parasols' in flower.

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diameter inflorescence and enlarged marginal flowers; in addition, the pappus of *Elephantopus* and *Vernonia* is permanent, while the pappus of *Stokesia* is early deciduous (Gunn and White, 1974).

Stokes aster is indigenous to southeastern North America (Bailey, 1949; Gunn and White, 1974). Native populations are concentrated in South Carolina, southern Mississippi, Louisiana, southern Alabama, and Florida (Bailey, 1949; Gunn and White, 1974; Huxley, 1992). Isolated colonies in southern South Carolina, central Georgia, and the Florida Panhandle are found in areas that are damp to wet for at least part of the year (Gunn and White, 1974). L'Héritier de Brutelle (1788) stated that the specimen he called *S. cyanea* is native to South Carolina. Stokes aster is classified as hardy in USDA hardiness zones 5–8 (Brickell, 1992) and American Horticultural Society heat zones 4–8 (Cathey, 1998). DeFreitas (1987) stated that stokes aster can thrive into southern Florida (USDA hardiness zones 10B–11). Brickell (1992) stated that stokes aster is fully hardy, meaning the species can withstand subfreezing temperatures during the winter without significant damage, but Coughlin (1991) recommended that protective measures, such as the application of several inches of mulch, be taken in regions that experience freezing and thawing.

Established colonies of stokes aster appear to tolerate a wide range of moisture levels. Coughlin (1991) recommended its use as a drought-tolerant perennial, while Brickell (1992) merely called for well-drained soil. However, Gunn and White (1974) and Bell and Taylor (1982) observed that stokes aster naturally inhabits moist or poorly drained regions at the southernmost end of the plant's range. The dichotomy in moisture tolerance is most likely a function of climate, as increased hydration can sometimes compensate for accelerated evapotranspiration that typically accompanies high air temperatures found in extreme southern regions.

Stokes aster is thought to be a shade-tolerant sun species; full sun is preferable, but some shade is tolerated. Seedlings of stokes aster typically produce only vegetative growth the first year (Callan and Kennedy, 1995; Campbell, 1981). Stokes aster flowers from late spring through summer (Bell and Taylor, 1982; DeFreitas, 1987; Radford et al., 1964), and is thought to be a facultative intermediate-day plant (Clough et al., 1999). Facultative intermediate-day plants achieve most consistent and rapid flowering when exposed to a photoperiod of 12 to 13 h. Conflicting information is published in the literature and popular press regarding the conditions necessary to induce floral initiation. Campbell (1984) suggested that vernalization may be necessary for floral development and that plants placed in the landscape in spring may not produce flowers until summer of the following year. Clough et al. (1999) stated that seed-derived plants of stokes aster will not produce flowers during the initial year of growth due to a period of juvenility. They also reported that a cold treatment is not necessary for floral development in mature plants, and optimum flowering is dependent upon photoperiod. Highest flowering percentage of stokes aster occurred when plants were grown with a photoperiod of 12 to 13 h. Floral initiation in seed-derived breeding populations is highly variable (Werner and Gettys, unpublished data). Some genotypes were actively flowering 5 months after seeds were sown, while others required more than 1 year to flower.

Botanical description

Stokes aster is an acaulescent, herbaceous perennial with alternate leaves that form a basal rosette (Fig. 1). At maturity, plants may be up to 28 inches (70 cm) tall (Gunn and White, 1974; Liberty Hyde Bailey Hortorium, 1976), but most cultivars grow to a height of 1 to 2 ft (30-60 cm). The elliptic to lanceolate leaves are entire, thick, and range from 4 to 12 inches (10 to 30 cm) long by 0.3 to 2.0 inches (0.8 to 5.0 cm) wide. Leaves are grayish-green. Peduncles are pubescent to woolly and may become glabrate with age. Peduncle length varies among genotypes but most cultivars have peduncles that bear flower heads in or slightly above the vegetative canopy.

The composite inflorescences of stokes aster (Fig. 2) have multiple perfect flowers forming each capitulum. Flowers in native populations range in color from blue to bluish-purple or bluish-violet to white (Bailey, 1949; Gunn and White, 1974). Gunn and White (1974) reported that white-flowered taxa are seldom found in natural populations. The composite flower heads of stokes aster are typically 3 to 4 inches in width (Bailey, 1949; Liberty Hyde Bailey Hortorium, 1976). In vivo pollination of stokes aster is entomophilous, with pollen transferred primarily by bees. The cypsela (more commonly referred to as the seed) is the product of an inferior ovary.

Disagreement exists as to whether the capitulum, or composite inflorescence, is composed of disc flowers only or of both ray and disc flowers. Bailey (1949) and Steyermark (1963) stated that all plants in the Vernonieae tribe, of which stokes aster is a member, have disc flowers only. Bailey (1949) also stated that enlarged disc flowers along

Fig. 2. Mature inflorescence of stokes aster 'Klaus Jelitto'.

the margin of the capitulum may resemble ray flowers. Greene (1893) described members of the Vernonieae as being destitute of ray corollas. Gunn and White (1974) stated that stokes aster has consistently been placed in the Vernonieae; however, they also reported that capitula of stokes aster possess linear-lanceolate ray flowers that are 1.0 to 1.6 inches (2.5 to 4.0 cm) long and tubular disc flowers that are 0.4 to 0.8 inch (1.0 to 2.0 cm) long. The description of ray flowers in stokes aster conflicts with the Vernonieae tribal requirement for inflorescences that are composed solely of disc flowers.

The receptacle of the capitulum of stokes aster is flat, fleshy, and naked. Flower heads are showy and borne in corymbs of one to seven capitula on long, leafy peduncles (Gunn and White, 1974; Huxley, 1992). Six sets of bracts are imbricate or tiled around the base of the capitulum, tipped with spines, and may become inflexed at maturity to facilitate cypsela retention (Gunn and White, 1974). Bract inflection and cypsela retention is variable and may differ considerably among dissimilar genotypes. The outermost bracts are foliaceous and not persistent after flowering. Two sets of outer bracts are also foliaceous; these are elliptic to lanceolate and range from pubescent to glabrate. Two sets of inner bracts are toothed to entire; the apex may be covered with tawny, crinkled hairs or may be glabrous with ciliate margins. The innermost bracts are similar to the inner bracts, but are narrow with an entire margin.

Cultivars

The wild type, or species, of stokes aster bears flowers that are described as lavender-blue or bluish-violet. White-flowered specimens are rarely found in wild populations (Gunn and White, 1974) and a yellow-flowered stokes aster has been found only once. Cultivars were described in the literature and popular press as early as the 1940s (Bailey, 1949); however, information concerning the origin and development of many cultivars is unavailable. Most commercially available cultivars have vegetative growth similar to that of the species and differ only in flower color.

'Alba' bears white flowers (Bailey, 1949; Hay and Synge, 1975; Huxley, 1992; Liberty Hyde Bailey Hortorium, 1976; Phillips and Burell, 1993), as does 'Silver Moon' (Gunn and White, 1974; Huxley, 1992); however, both cultivars appear to have trace amounts of anthocyanin in the petals. Blue-flowered commercially available cultivars include 'Blue Danube', 'Blue Moon', 'Blue Star', 'Klaus Jelitto', and 'Wyoming' (Brickell, 1992; Gunn and White, 1974; Hay and Synge, 1975; Huxley, 1992; Phillips and Burell, 1993). 'Träumerei' and 'Maroon' have flowers that range in color from white tipped with lilac to solid lilac. 'Träumerei' is seed propagated. 'Aba' is generally offered as a seed-propagated cultivar, but some nurseries propagate it vegetatively and market a clonal selection. In addition to the above cultivars, Bailey (1949) listed 'Caerulea' and 'Lilacina' as having blue or lilac flowers, respectively. Neither is found in the trade; it is possible that these cultivars are still available under a different name.

Many cultivars of stokes aster are thought to be selections from wild or garden populations, but no formal documentation exists as to how most cultivars arose. In addition, most cultivars have characters that are only slightly different from the species. Notable exceptions include 'Mary Gregory', 'Purple Parasols', 'Honeysong Purple', and 'Omega Skyrocket'.

'Mary Gregory' is the only known yellow-flowered cultivar of stokes aster and is readily available from commercial nurseries, but no formal publication of the cultivar name was found. It was reportedly found as a seedling in a garden population in Columbia, S.C., by M. Creel of the S.C. Dept. of Natural Resources (M. Creel, personal communication). The patented 'Purple Parasols' was selected in Kentucky and registered by C.S. Warren of North American Lily and Floral in 1998 (Warren, 1998). It is described as having flowers that are light blue initially, then changing to dark-blue, bluish-purple, reddish-purple, and dark hot-pink as the head ages. The parentage of 'Mary Gregory' and 'Purple Parasols' is unknown.

'Honeysong Purple' first was offered commercially in 2000 by Wayside Gardens of Hodges, S.C. (Wayside Gardens, 2000). It is described as being ultrafloriferous and bearing deep-purple flowers. Flower color reportedly darkens as the head ages, which "…highlights the contrasting white stamens and red overtones". It was discovered by Alex and Alan Summers. Plant patent protection is being sought. 'Honeysong Purple' is a seedling selection from an open-pollinated population of stokes aster; therefore, its parentage is also unknown.

'Omega Skyrocket' exhibits a markedly different growth habit from the species and the aforementioned cultivars and is described as bearing lavender-blue flowers on peduncles that may be up to 3.3 ft (1 m) long. At this time, 'Omega Skyrocket' is available only with wild-type (bluish-violet) flower color, but a white-flowered group has also been selected (M. Groves, personal communication).

'Omega Skyrocket' was derived from a wild population of plants found growing in Colquitt County, Ga., near the town of Omega, by R. Determann, S. Determann, and O. Johnson of the Atlanta Botanical Garden (R. Determann, Atlanta Botanical Garden, personal communication). The original population consisted of a group of plants that were morphologically similar to one another, but possessed a growth habit different from the wild type stokes aster. The site where 'Omega Skyrocket' originally was found has since been developed into cultivated pastureland and the original population of plants has been destroyed. Fortunately, seeds were collected from many specimens within the population before habitat destruction; as a result, some level of germplasm preservation was established. 'Omega Skyrocket' is primarily propagated by seed but some nurseries have selected and offered clonal selections.

Pests and pest management

Stokes aster is reportedly susceptible to head blight (*Botrytis cinerea* Pers. ex Fr.) and leaf spot (*Ascochyta* Lib.) (USDA, 1960). Powdery mildew (*Erysiphe cichoracearum* DC. ex Merat) can be problematic (Ellett, 1963; Kilpatrick et al., 1975), as are mosaic virus and bidens mottle virus (Horst, 1990; Logan et al., 1984). Kilpatrick and Uecker (1978) isolated 26 types of fungi growing on stokes aster, but fungal infestations found in their screenings were primarily *Alternaria alternata* Fr. ex Keissler and unidentified species of *Phomopsis* (Sacc.) Bubák and *Phyllosticta* Pers. *Sclerotinia sclerotiorum* (Lib.) dBy. and *Sclerotium rolfsii* Sacc. were also identified as pathogens of stokes aster by Kilpatrick and Uecker (1978), who stated that plants infected by these fungi did not survive. Uecker (1989) described the development of *Diaporthe phaseolorum* (Cooke et Ellis)

Sacc. on stokes aster. Other fungal pathogens include *Stemphylium floridanum* C.I. Hannon et Weber and unidentified species of *Cercospora* Fuckel and *Rhizoctonia* DC. (Alfieri et al., 1984).

Greenhouse pests include aphids (*Myzus persicae* Sulzer and other species) and whiteflies (*Trialeurodes vaporariorum* Westwood and *Bemisia argentifolii* Bellows et Perring). Minor infestations may be limited by allowing adequate airflow around plants, while more serious infestations may be controlled by application of fungicides and pesticides labeled for use on herbaceous perennial plants.

Genetic analysis and reproductive biology

The chromosome number of stokes aster has been established as 2n = 2x = 14 (Gunn and White, 1974; Keeley and Jansen, 1994). All cultivars of stokes aster are closely related to one another, with the exception of 'Omega Skyrocket'. Gettys (2000) used randomly amplified polymorphic DNA (RAPD) analysis (also called DNA fingerprinting) to show that most pairs of cultivars of stokes aster exhibited homology at >85% of the fragments produced from 74 RAPD primers, while 'Omega Skyrocket' was homologous with other cultivars at only 65% to 70% of these fragments. This high degree of homology suggests a limited amount of genetic diversity within the species; however, breeding experiments by the authors produced offspring with distinct traits not previously described, including overall plant size, growth habit, time of floral initiation, flower morphology, and seed set.

Information concerning the reproductive biology of stokes aster is limited. Anthers dehisce and pollen is released before anthesis (unpublished data), but production of viable seeds without cross-pollination is rare. The species is classified as self-incompatible (Campbell, 1981, 1984; Gunn and White, 1974; Kleiman, 1990; Princen, 1983; White, 1977). Studies performed by Gettys (2000) showed that 'Klaus Jelitto', 'Mary Gregory', 'Omega Skyrocket', and 'Silver Moon' are self-incompatible, while 'Alba' is highly self-fertile. However, no formal documentation or experimental evidence exists regarding the mechanism responsible for self-incompatibility in most cultivars and self-fertility in 'Alba'. The possibility of seed production by 'Alba' through apomixis has not been ruled out. Since most cultivars of stokes aster are propagated using asexual methods, self-incompatibility does not hamper production of established cultivars. The requirement for cross-pollination can, however, be viewed as a limiting factor for breeding purposes, as the production of inbred lines for use as breeding stock in a formal cultivar development program is virtually impossible. The self-incompatibility found in most cultivars of stokes aster can also be beneficial, as the system eliminates the need for emasculation of the maternal parent in cross-pollination events designed to produce F_1 hybrids. Seed production and retention are extremely variable and cultivar dependent; also, seeds may require up to four months of ripening after pollination and resultant progeny may exhibit a great deal of variation (Gettys, 2000). These factors make in-house seed production impractical for most growers. In addition, one must remember that most cultivars of stokes aster will not maintain their unique characteristics when propagated by sexual means; 'Träumerei', 'Omega Skyrocket', 'Alba' and the species may be reliably produced from seeds. Therefore, a grower wishing to produce a uniform population of stokes aster plants from seed is limited to a restricted number of cultivars. Seed should be purchased from a reputable dealer.

Propagation and crop scheduling

Stokes aster is typically propagated by seed, division, or root cuttings (Brickell, 1992; DeFreitas, 1987; Hay and Synge, 1975; Hosoki et al., 1995). Many of the unique characteristics that differentiate specific cultivars from the species may be maintained only by vegetative propagation; however, the species and selected cultivars may be propagated by seed. Light does not appear to affect germination, and germination is variable in seed populations (Campbell, 1984; Clough et al., 1999; Gettys, 2000). Conflicting information is present in the literature and the popular press regarding optimum temperature conditions for germination of seeds. For example, Jelitto Perennial Seed Co. (Schwarmstedt, Germany) suggested that germination is irregular and may take place over an extended time, and recommended a germination temperature of less than 41 ºF (5 ºC). Thompson and Morgan Inc. (Suffolk, England) stated that germination of stokes aster seed may take up to a year. Specialty Perennial Seeds (Apple Valley, Minn.) and Germania Seed Company (Chicago, Ill.) recommended that seeds be frozen for 5 d, then sown at 60 to 65 ºF (15.5 to 18.3 ºC) for 14 to 21 d to achieve highest germination percentage. Armitage (1994) stated that highest germination percentage occurs when seeds of stokes aster are stratified for 6 weeks at 39 ºF (4 ºC) and germinated at 66 ºF (19 ºC). Campbell (1984) performed studies that showed highest germination percentage was achieved at 68 ºF (20 ºC), and he also stated that seeds did not germinate below 52 ºF (11 ºC). Clough et al. (1999) suggested that seeds of stokes aster germinate without stratification in 12 d at 70 ºF (21 ºC). More recent evidence by Gettys (2000) showed that seeds germinated in 14 to 21 d at 59 to 68 ºF (15 to 20 ºC) and that stratification was neither required nor beneficial. Our studies have shown that seeds harvested in late summer or early fall can be sown immediately in 612 cell packs [individual cell volume 4.5 inch^3 (74 cm^3)] in the greenhouse and may be transplanted to 1-qt (1-L) pots and moved to a protected location outside to overwinter in about 8 weeks (unpublished data). Plants produced in this manner should be large and vigorous enough to sell the following spring.

Vegetative propagation of stokes aster by root cuttings or division is common. Plantlets produced by division will reach marketable size more quickly than those derived from root cuttings; however, a single stock plant may be used to produce far more plants from root cuttings than from division. As much as 30% of the root mass may be removed for use in propagation by root cutting without deleterious effects to the stock plant. Root cuttings may be taken at any time of year; however, cuttings taken in early spring appear to produce plantlets most reliably. Root cuttings taken in fall may be successful if bottom heat is used.

Niche Gardens (Chapel Hill, N.C.) produces plants of stokes aster by root cuttings, and head propagator R. Evinger recommends the following protocol. Thick roots are selected and cut into sections 3 to 4 inches (8 to 10 cm) in length. Flats that are 2 to 3 inches (5 to 8 cm) deep are filled with a standard potting medium to within 1 inch (2.5 cm) of the top of the flat. A trench is prepared in the medium and roots are placed in the trench at a 45º angle. Polarity is maintained so that the proximal end of the root cutting is closest to the surface of the medium. Between 20 and 40 cuttings can be placed in each trench and each flat may contain up to 10 trenches, accommodating several hundred root cuttings. Potting medium is added to cover each trench and bring the surface of the medium level with the top of the flat. Flats are placed in a shade house and hand-watered only two to three times a week, as excessive moisture seems to result in loss of many root pieces. Plantlets of stokes aster produced in this manner are ready to be teased apart and transplanted to 1-qt pots about 3 months after the root cuttings are placed in the flats. The resulting plants are large enough to offer for sale 3 to 6 months after transplanting to 1-qt pots (R. Evinger, personal communication).

Conclusions

Stokes aster has great potential for increased use as a landscape ornamental. The large, showy inflorescences are appealing and numerous cultivars are available, providing a range of colors for growers and consumers. Production requirements are not exacting, as cultivars of stokes aster are easily propagated by root cuttings and require no special equipment, treatments, or handling. These factors make stokes aster a prime candidate for increased attention from growers and propagators, and an attractive perennial flowering plant for inclusion in the landscape.

Stokes aster also has potential for use as an industrial oilseed crop with great implications for the plastics and adhesives industries (Campbell, 1981; Kleiman, 1990). Cultivation of stokes aster as an oilseed crop may reduce the amount of petrochemicals used while providing an alternative, sustainable source for raw material (Gunn and White, 1974; White, 1977). Stokes aster is an attractive native plant that deserves more recognition and attention, whether as a flowering perennial plant in the landscape or as an oilseed crop.

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