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A horticultural study of Liriope and Ophiopogon: nomenclature, morphology, and culture

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A HORTICULTURAL STUDY OF *LIRIOPE* AND *OPHIOPOGON*: NOMENCLATURE, MORPHOLOGY, AND CULTURE

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Dedicated to Mirza and Vernon Broussard
Who gave me roots
and
Melva Ligon Tessier
Who gave me wings

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ABSTRACT

Liriopogons are evergreen perennials with a confusing taxonomy. New cultivars are being rapidly selected and named. The landscape industry uses them extensively and they are being planted in improper sites. Morphological studies were done at Louisiana State University in Baton Rouge, Louisiana to identify 19 cultivars by comparing plants to botanical keys. Cultural studies were done at Burden Station in Baton Rouge, Louisiana by comparing cultivars in sun and 63% shade, and by greenhouse fertilization experiments, and pruning experiments. Plants were harvested, studied, dried and mounted in the Louisiana State University Herbarium as permanent record.

Of the 19 cultivars of *Liriope* and *Ophiopogon* studied, there were two genera and eight species identified. These were studied for flower morphology on dissected flowers under microscope. Aztec grass, which had been labeled *Ophiopogon jaburan* was discovered to be *Ophiopogon intermedius. Liriope muscari* 'Big Blue' is a *L. muscari* but some plantings in landscapes are *L. exiliflora*. The cultivar 'Samantha' has been classified *L. muscari* and cf. to *L. exiliflora*, according to the rhizomatous root system and spaces between flowers. 'Evergreen Giant' and Supergreen Giant were both called cultivars of *Liriope muscari* and they are morphologically *Liriope gigantea* 'Evergreen Giant' and 'Merton Jacobs' Supergreen Giant™ respectively.

A three-year study at Burden Center with 19 cultivars, sun and 63% shade treatment and six replications showed the top sun performing cultivar to be *Liriope gigantea* 'Merton Jacobs' Supergreen Giant™. The second was *Liriope muscari* 'Big Blue'. *Liriope muscari* 'Monroe White' and *Ophiopogon japonicus* 'Silver Mist' were the two low sun performers. The top shade

performers were *O. japonicus* and *O. japonicus* 'Nana'. The low sun performers were *Liriope muscari* 'Densiflora' and *Liriope gigantea* 'Evergreen Giant'.

Bib production benefited by 20% pruning in *Ophiopogon intermedius* but did not have significant effects on any other cultivar.

Plant height, quality, N and P were the most influenced variables for all combinations of liquid fertilization + controlled-release and liquid fertilizer alone over any of the controlled-release rates of fertilization.

Index words: liriopogons, lilyturf, *Liriope, Ophiopogon*, mondo, Aztec grass, monkey grass, cultural practices, nomenclature, morphology.

CHAPTER 1
INTRODUCTION

The wholesale nursery industry in the Southeastern United States is involved in a two hundred and seventy five million dollar business supplying groundcovers for residential and commercial landscapes (Anonymous, 2004). In the Southeastern United States, groundcovers account for 18.4% of the total wholesale production sales annually in Louisiana, 13.5% in Georgia, 9.2% in Mississippi, and 7.9% in Florida (Brooker et al., 2005*). Liriope* and *Ophiopogon* far exceed other plants in groundcover sales and are represented by numerous species and cultivars (Bailey, 1929). Because of the increasing use of liriopogons (*Liriope and Ophiopogon*) for groundcovers and borders in the Southeastern United States, there is a need for accurate plant identification and specific cultural practice recommendations (R. Odom, personal communication, 2004). In the lower south, particularly in gardens of the coastal towns of the Atlantic and Gulf of Mexico, these plants have been used more extensively than elsewhere, perhaps introduced long ago by sailors who touched at different ports (Hume, 1961). The plants are commonly misnamed in nurseries and catalogues, pictures in books are not reliable; specimens are likely to be wrongly determined in herbaria (Bailey, 1929). Binomials are intended to convey information beyond distinguishing one plant from another. The names reflect relatedness among groups of plants which are ignored if the appropriate taxonomic name is not used (Denny and Arnold, 2007).

Groundcovers are low-growing plants that spread quickly to form a dense cover in areas where grass either won't grow or is not desired. They come in a variety of textures and colors with special landscape attributes such as flowers and/or berries. A major advantage is that once established, they need less water and maintenance than turfgrass (Balge, 1997).

In Louisiana and other areas of the Southeastern United States, *Liriope, Ophiopogon* and *Trachelospermum asiaticum* (Asian Jasmine) are the three most common groundcovers in landscapes (A.D. Owings, personal communications, January 23, 2006). *Liriope* and *Ophiopogon* have been used in mass plantings on the Louisiana State University campus in Baton Rouge, Louisiana (USDA Hardiness Zone 8B) as a groundcover and also as a bordergrass.

Liriopogons (*Liriope, Ophiopogon*) are acaulescent plants with grass-like leaves and small lilac to violet or white flowers clustered in fascicles on scapes among the foliage. Leaves may be green or variegated with marginal bands, longitudinal stripes, or, occasionally, with transverse bands of creams, yellows, white, or silver (Fantz 1993). They have been shown to be hardy, heat and sun tolerant as well as cold tolerant to different degrees. There are numerous species and cultivars of *Liriope* and *Ophiopogon* with variations in their responses to sun, shade, drought, low fertility, high fertility, and pruning (Devine, 1997).

Many *Liriope* and *Ophiopogon* have been found to be marketed and sold under incorrect names by reputable nursery growers in the United States. A nursery in Greenville, Georgia has *Liriope gigantea* 'Evergreen Giant' listed as an *Ophiopogon jaburan* (Anonymous, 2004). Other nurseries list it under *Liriope muscari* (Anonymous, 2002). Aztec grass has been referred to as a *Liriope* sp., *Ophiopogon intermedius*, and *Ophiopogon jaburan* by horticulturists and nursery professionals (Anonymous, 2004).

Because liriopogons have become a popular and economically important groundcover, it is important to develop a correct botanical identification system for these cultivars and to determine how the different cultivars respond to varying environmental conditions (J. Berry, personal communication, August 2005).

Studies of these plants by Dr. L.H. Bailey culminated in his publication "The Case of *Ophiopogon* and *Liriope"*. This discussion emphasized botanical features and relationships of these plants. In the interim, a considerable number of garden varieties have been selected and propagated and more has been learned about their behavior in gardens in the last 30 years than was known prior to that date (Hume, 1961).

It was not until the mid-20th century that *Liriope* and *Ophiopogon* became recognized as a possible ground cover and border plant in the Southeastern United States. Since 1960, there has been an increase in the use of these genera and now they are a major part of garden landscapes. In this country, the state with the highest percentage spending on vines and groundcovers is Louisiana (Brooker et al., 2005). In America, *Liriope* and *Ophiopogon* have been cultivated in gardens of the Old South for the longest time and it is within this region that most of the named flowering selections have originated as chance seedlings. The seed is carried by birds, and young plants will appear in many unlikely places (e.g., the middle of a patch of another variety) (Skinner, 1971).

It is important but difficult to maintain correct botanical names of these plants because of the nursery practices of sexual propagation of cultivars, plant substitution, mislabeling of cultivars, and seedling invasion into cultivar stock which leads to cultivar degradation (Fantz, 1993).

NOMENCLATURE

Botanically, liriopogons may be either *Liriope* or *Ophiopogon*. Both genera are in the family Convallariaceae, native to East Asia. They are also found under Ruscaceae and Liliaceae (Watson and Dallwitz, 1992). Modern botanists and taxonomists with the aid of DNA and other technology have reclassified new groups for some members of the Liliaceae family. One of the

new groups is Convallariaceae. Convallariaceae has one trace tepal (one vascular bundle) instead of three as in Liliaceae, and there are different mychorriza fungi associated with the roots. Convallariaceae is a monocot. The foliage are narrow with parallel veins; flower components occur in multiples of three, identical in size and color; sepals and petals are indistinguishable and are known as tepals; usually six stamens; fruit is a three-celled capsule or berry; vascular bundles are scattered in random bundles throughout the stem; and, because they lack stem cambium (actively dividing cells that produce wood), they are herbaceous (Watson and Dallwitz, 1992).

Harold Hume (1961) entitled an article "The *Ophiopogon – Liriope* Complex" because botanists, who have written about the plants, have sometimes placed the two genera *Ophiopogon* and *Liriope*, related plants of this family, into a single genus and have applied a number of different generic names to them. "The species belonging to them have also been given, in some instances, a number of different names" (Hume, 1961).

Some of the confusion regarding correct naming of these plants is due to the difficulty distinguishing them, as many liriopogons look similar vegetatively. In the nursery trade they are referred to as lilyturfs, mondo grass, Aztec grass, *Liriope,* bordergrass and monkey grass (Fantz, 1993).

PLANT DESCRIPTIONS

The most distinctive features used to classify species are the reproductive structures. Plant groups have identifying characteristics that range from gross morphology of flowers to details of pollen and seed shapes, pollination systems and mode of embryo development. Added to the list of items making up a species description are habitat preferences, physiological traits, unique biochemical properties, chromosome numbers in cell nuclei, leaf shape, vein pattern, leaf and stem anatomy and the structure of epidermal hairs (Capon, 1990).

The Royal Botanical Dictionary of Gardening, Huxley (1992) gives the following information: *Liriope* Lour (after the nymph Liriope). Lilyturf. Liliaceae (Convallariaceae). Some five species of perennial, evergreen, stemless, tufted or occasionally rhizomatous herbs, to 45 cm. Leaves are grass-like. Flowers white to dark mauve, grape-like, clustered in a scapose, elongated spike or raceme; tepals six, free; stamens six; ovary superior (cf. *Ophiopogon*), closely related except for half inferior ovary. Fruit black, seeds one or two, fleshy. Japan, China, Vietnam.

Ophiopogon Ker Gawl. (From Greek sphis, serpent, and pogon, beard.) Liliaceae (Convallariaceae). Four species of perennial, evergreen herbs. Leaves linear, grasslike, usually sessile. Flowers white to lilac, numerous in racemes; tepals six, overlapping, white, blue, lilac or lilac-tinted, tube obconical, adnate to inferior ovary (cf. *Liriope*); stamens six, joined at base to tepals, filaments very short, anthers pointed. Fruit blue, berry-like. (Huxley, 1992).

CULTURAL FACTORS

Liriope is native to eastern Asia (mostly China), Japan, and Vietnam. *Ophiopogon* is a native of Japan and Korea and is a good, temperate garden perennial (Bailey, 1929).

Liriope and *Ophiopogon* are both well adapted to USDA hardiness zones 5-11 and AHS heat zones 8-3 (Cathey, 1998). Some sources describe *Liriope* and *Ophiopogon* as tender and best planted in the South. This may be a bit too cautious as *Liriope* does well from Southern New England (zone 5) to Southern Florida (zone 10). *Ophiopogon* is a bit more cold-sensitive, performs well from the Mid-Atlantic States southward to Florida (zones 6-10) (Devine, 1997).

Many factors besides minimum winter temperature affect the success of any plant. Cultural factors such as soil, fertilization, weeds, pathogens, moisture conditions, humidity, night

time and day time temperatures, and light affect how a plant responds to seasonal highs and lows (Devine, 1997).

Often plants are selected for landscape design without considering the cultural aspects such as sun or shade exposure, soil, moisture, pruning, pest problems, and growth rate. When plants are placed in an unsuitable environment, constant maintenance problems will occur.

The terms sun, part shade, or shade refer to the quality of light in which a plant grows best. Some plants cannot endure sun, while others require full sun for best display (Halfacre and Shawcroft, 1989).

Sun/Shade

Intensity, quality, and duration of light regulate plant growth and development. As a general rule, the farther south liriopogons are grown, the more shade is needed Yet, even in the deep south, they can withstand almost full sun, as long as water is provided (Devine, 1997). Although liriopogons grow relatively well in full sun, the direct sunlight of hot summer burns foliage (Odenwald and Turner, 1996).

Physiologically, liriopogons are C3 plants (Appendix A) (Broussard, 2007). Plants that survive solely on C3 fixation tend to thrive in areas where sunlight intensity is moderate, temperatures are moderate, and carbon dioxide concentrations are around 200 ppm or higher. These plants fix CO_2 only by the Calvin cycle (Hall, 1987).

Weed Control

Liriope is prone to be highly infested with weeds and grasses when growing in full sun. Post emergence control of yellow nutsedge (*Cyperus esculentus* L.) is a problem in landscape beds of the southeastern United States. Studies have shown that there are herbicides that will kill weeds in these groundcovers without significant damage to the bordergrass or groundcover.

Herbicides proven effective in killing nutsedge without harming *Liriope* and *Ophiopogon* are trifloxysulfuron-sodium and sulfosulfuron (R. Strahan, personal communication, November, 2006). Other herbidides labeled for *Liriope* are fenoxapropethyl, prodiamine, bentazon, dithiopty clethodim, fluazifop-P-butyl, isoxaben, imazaquin, snapshot, S-metolachlor, and pendimethalin (A. Owings and J Griffin, personal communication, Dec. 2006).

Insects and Diseases

Pinnaspis caricis Ferris (*Liriope* scale), is one of the most injurious insect pests of commercially grown liriopogon plants. Heavy infestations yield chlorotic spotting and foliar necrosis (Reynolds, 1993). During warm seasons, living scale insects can be observed on all surfaces of the liriope blades; however, greatest concentrations are found in the blade sheaths. Egg production is constant, being greatest in the months of March-April and July-August. Cultural practices such as heavy irrigation and fertilization during crawler production can greatly reduce infestation (Reynolds, 1993). Cutting the foliage back severely during the late winter is the most practical means to control the problem (Midcap and Clay, 1988).

A severe leaf and crown rot in the Southeast has affected *L. muscari* in landscapes, as well as nursery operations. 'Evergreen Giant' appears to be the most susceptible to the disease, possibly because it is the most frequently used in the landscape (Strandberg, 2001).

Several fungi, particularly *Fusarium* spp., have been reported to infect the leaves, roots, and rhizomes of *L. muscari*. *Phytophthora palmivora* and *P. nicotiana* are fungal pathogens found in nurseries and greenhouses.

Liriope is susceptible to fungus foliage blight *Colletotrichum* sp. (anthracnose) which causes leaves to turn brown and die back. Remediation consists of pruning the diseased growth back to a height of about three inches before new growth appears (Killebrew, 1999).

Pruning

Pruning is an excellent maintenance and sanitation technique used to clean dead and discolored foliage through the late fall and winter months. This is one of the suggested techniques for control of *Pinnaspic caricis (Liriope* scale) as well as the fungi *Fusarium* spp. and *Phytophthora* spp. (Killebrew, 1999). The leaves should be thrown away to prevent further infestation or infection.

When not pruned, the plants look untidy in the spring before new growth begins. The leaves sometimes turn brown, but they are inconspicuous and disappear after the new growth begins (Rackemann, 1987).

Propagation

Liriope and *Ophiopogon* are propagated by seed, division, and tissue culture. Division is faster and easier and results in bigger plants in a shorter time frame (Devine, 1997). Division is a method of asexual or vegetative plant propagation. It involves propagating a new plant from a vegetative part or section of a plant. As with other methods of vegetative propagation, the propagated plant will have the same characteristics as the parent plant. Division is a common means of multiplying plants in the residential landscape and the commercial landscape plant industry (Ingram, 2001). The optimum time to divide plants is during the dormant season just before the new growth. Plants that produce multiple stems and suckers are the best candidates for propagation by division.

Division produces the identical plant as the mother plant; therefore, it is important to the nursery industry to have correctly identified plant material.

It has been a practice of nursery producers to name a plant that has been propagated at their nursery without considering the confusion in the industry if the plant already has a name.

Some of the mistaken identity problems with liriopogons that are currently being recognized were noted by Dr. Paul Fantz at North Carolina State University. "Some cultivars will originate through misidentification. Nurserymen have material that seems different from others in the species and they name a new selection, not realizing that the differences may be species differences (Fantz, 1993).

Since propagation is easily done by division, some growers never grow lilyturf from seed. However, seeds with all flesh removed may be planted in sandy peat in flats in a greenhouse or cold frame. The seeds should be planted soon after they are collected from the plant (Rackemann, 1987). An informal observation by the author found the germination rate to be approximately ten percent in the summer of 2005.

Tissue culture is another propagation technique: growing parts of plants aseptically on an artificial medium under controlled environmental conditions (C. Johnson, personal communication, March, 2006). *Liriope muscari* 'Variegata' displayed the greatest propensity for growth in tissue culture in a study at the University of Georgia (Frett and Dirr, 1983). No organogenesis occurred after eight weeks in culture with *L. muscari* 'Christmas Tree' and *L muscari* 'Monroe White'. *O. jaburan* produced callus in primary culture only (Frett and Dirr, 1983).

Fertilization

Fertilizer materials are applied to plants either to prevent nutritional differences or to correct existing differences. Plant nutrients are commonly applied to the soil or rooting medium for uptake by roots, and in certain circumstances can successfully be applied to plant tops for foliar uptake. Maximum vigor is obtained in liriopogons by applying a broadcast general lawn or shrub fertilizer in early spring and again in mid-summer (Midcap and Clay, 1988). The

appropriate form, amount, timing, and placement are important in the proper management of fertilizer in order to achieve good productivity without causing potential environmental contamination (Mills and Jones, 1996).

RESEARCH OBJECTIVES

Objectives of this research were to establish accurate nomenclature and recommended cultural practices for 19 cultivars of *Liriope* and *Ophiopogon***.** Cultural practices for individual plants can be different, affecting their growth and response. Research objectives of this study are listed below:

I. Establish the morphological difference in 19 cultivars of *Liriope* and *Ophiopogon* with general descriptions and pictures of the mature plants. Collect and mount 19 different cultivars of *Liriope* and *Ophiopogon* in the LSU Herbarium as a permanent record of the plants collected and studied.

II. Determine the effect sun and shade growing conditions have on landscape performance of 19 cultivars of *Liriope* and *Ophiopogon.*

III. Determine the effect of five pruning percentages on bib production of seven cultivars of *Liriope* and *Ophiopogon*.

IV. Determine the effect of rates and methods of fertilization on cultivars of *Liriope* and *Ophiopogon* in a nursery production setting.

CHAPTER 2
REVIEW OF LITERATURE Error! Bookmark not defined.

NOMENCLATURE, THE HISTORICAL PERSPECTIVE

Liriopogons are originally native to Eastern Asia (China, Japan, Korea, and Vietnam) and reports indicate it was introduced to the west over 200 years ago. In 1712, Engelbert Kaempfer, a German doctor with the Dutch East India company, in his book Amoenitatum Exoticarum, illustrated and described *Ophiopogon japonicum,* which he called *Rjuno Fige* meaning snakes beard or bearded snake, in Japanese (Hume, 1961). The present confusion with the nomenclature of these plants is because botanists, who have written about them, often combined the two genera *Ophiopogon* and *Liriope* into a single genus and then applied them to a number of different genera. The related species have often been given a number of different names (Hume, 1961). Skinner (1971) saw part of the misidentification of these plants as due to them having been named with lavish abandon. Fantz (1993) recognized the problem with misidentification of liriopogons in the industry as well as in academia, as a large taxonomic mixup.

In 1763, Michael Adanson, a French Botanist, published his *Familles naturelles des plantes.* In this book, he referred to the plant as *Mondo* (Bailey, 1929). Mondo has been a commonly used name since that time.

Carl Peter Thunberg, a Swedish naturalist, wrote Flora Japonica in 1780 and in it he described *Convallaria japonica*, the plant now known as *Ophiopogon japonicus* (Bailey, 1929). Convallariaceae is one of the families where *Ophiopogon* and *Liriope* can be found at present.

Joao de Loureiro, a Portugese botanist, in 1790 named *Liriope* after the mother of Narcissus in Greek mythology. *Liriope* is native to Cambodia, Laos, and Vietnam. The plant he named was what we now know as *Liriope spicata* (Fantz, 1993).

John Bellenden Ker Gawl, a botanist from the United Kingdom, in 1807 proposed the name *Ophiopogon* for the genus based on the species named by Thunberg. Ker Gawl is the author of *Ophiopogon* (Fantz, 1993). As can be seen in the history by Fantz and Bailey, the name evolved over a period of 100 years as it was studied by other European botanists.

In 1830, Phillip Franz von Siebold described *Slateria jaburan* from Japan. He studied Japanese flora as a physician and scientist (Fantz, 1993).

George Loddiges, in 1832, assigned Siebold's species to *Ophiopogon* thus changing *Slateria jaburan* to *Ophiopogon jaburan* (Bailey, 1929).

French botanist and agronomist Joseph Decaisne, in 1868, described the species *Ophiopogon muscari*, presently called *Liriope muscari* (Fantz, 1993). Though *Liriope* was named by Loureiro in 1790, genera of the plants were often called *Ophiopogon* in the 1800's.

Japanese botanist Takenoshin Nakai in1920, described *Ophiopogon planiscapis*, the black liriopogon (Fantz, 1993). This plant has sometimes been referred to as the designer liriopogon because of the dark black leaves and white to pinkish flowers that bloom in mid summer. *O. planiscapis* provides color contrast when used in conjunction with other brightly colored plants (Howe, 2004).

In 1921, American botanist Oliver A. Farwell reported that Adanson's *Mondo* had priority over *Ophiopogon* and transferred all species to the genera *Mondo*. Because there were no common names for these plants this may have been how they became known as mondo grass (Bailey, 1929). Mondo has remained a common name for *Ophiopogon japonicus*.

Liberty Hyde Bailey (1858-1954) was an American horticulturist, botanist, and cofounder of the American Society for Horticultural Science. In 1929, he gave the vernacular name lilyturf to the combination of *Ophiopogon* and *Liriope*. He also summarized their cultural uses and

nomenclatural history. He noticed that some authors combined them under one genera, but his studies brought him to the conclusion that there were two. He provided a taxonomic key to the seven species of *Mondo* and two of *Liriope* that were recognized at the time (Hume, 1961).

Two genera were accepted as cultivated plants for the purposes of his paper: *Mondo* and *Liriope.* The species were *M. japonicum* Farwell, *M. wallichianum*, *M. intermedium, M. jaburan, M. dracaenoides* Farwell, *M planiscapum* Nakai and *Mondo* sp. *L. muscari* and *L. spicata* (Bailey, 1929).

In his study 'The Case of *Ophiopogon* and *Liriope*' Bailey noted that the dwarf mondo or lily-turf, known as *Ophiopogon japonicus*, came into cultivation in Europe toward the end of the eighteenth century and early in the past century it began to receive the attention he thought it deserved. He recognized the devious botanical history in six genera: *Mondo*, *Convallaria, Polygonastrum, Ophiopogon, Flueggea, Slateria,* and even *Chloopsis* of Blume, in 1827.

In 1935, the sixth International Botanical Congress met in Amsterdam. A number of generic names were conserved over synonyms and earlier published generic names. A conserved name or *nomen conservandum* is a scientific name that enjoys special nomenclatural protection. The generic name *Ophiopogon* was conserved over the name *Mondo*. This is important for the botanical community, however, landscape professionals and nurserymen use the common name often when referring to liriopogons without concern for the conserved names. Liriopogon is the alternative common group name given by Skinner. The two species are likely to remain separate, yet to classify a plant with inflorescence like that of 'Christmas Tree'as a turf, is not appropriate (Skinner, 1971). The group common name 'lilyturf' given by Bailey is presently called liriopogon, though lilyturf is still accepted and acknowledged in the nursery community. Current generic names seem to be permanent. *Liriope* seems established for those plants with upturned

flowers and superior ovaries; and *Ophiopogon* has become a conserved name for the species with nodding flowers and sub-inferior ovaries (Skinner, 1971).

H. Harold Hume, Canadian born botanist, inventoried the lilyturfs in the 1960s and attempted to moderate the confusion in the nomenclature at the species level. Hume and Benjamin Morrison wrote about the importance of lilyturfs in landscapes, as well as used for bordergrass, pot plants, and cut flowers. In their articles, they covered the culture of the plants available at that time (Skinner, 1971). Since those writings, hybrids have appeared in gardens, propagated, and given cultivar names without necessarily having the correct identity of the genera and species. This has further complicated the problem of misnamed species in the landscape industry. As noted in Hartman, plants can hybridize naturally and the resulting plants do not resemble the original species. A botanist could have difficulty identifying the new progeny as variations within populations of these plants could be slight or major (Hartmann et al., 1997).

The Royal Botanical Gardens, Kew, has records of a world checklist of selected plant families. Within this checklist, names and their synonyms have been recorded. This checklist was verified in the herbarium in 2002, and notes from this visit to the herbarium are recorded in Appendix B. Synomym is defined in botany as an established name that is not the accepted name (Brickell, 2004). Deputy (1999) wrote that *Liriope muscari*, whose species name has recently been changed to *platyphylla,* has many popular varieties. At present, the *muscari* species designation is still the most commonly used name in the trade. Below is a list of scientific names and their synonyms as reported by the Herbarium at Kew Botanical Gardens in London and the United States Department of Agriculture Germplasm Resources Information Network (GRIN).

Table 2.1 Synonyms of *Ophiopogon* and *Liriope* species.

Scientific name	Synonyms (Historically)	Common names
Ophiopogon japonicus (L.f.) Ker-Gawl	*Convallaria japonica* L.f., Suppl. Pl. (1782) 204 APN	Langigit (Philippines)
	Flueggea japonica Rich. In Schrad. Neues J. 2 (1807) 9	Mach mon (Viet Nam)
	Slateria japonica Desv. In J. Bot. 1 (1808) 224 APN	English dwarf lily-turf
	Chloopsis acaulis Blume, Enum. Pl. Javae (1827) 14 APN	English lily turf
	Flueggea anceps Raf., Fl. Tellur. 4 (1838) 18 APN	English monkey grass
	Flueggea wallichiana Kunth, Enum. Pl. 5 (1850) 303 APN	English Liriopogons
	Slateria coerulea Siebold ex Miq. In Ann. Mus. lugd.-bat. 3 (1867) 143	English Japanese snake's beard
	Ophiopogon umbraticola Hance in J. Bot. 6 (1868) 115	French Herbe aux turquoises
	Mondo japonicum (L.v.) Farw. In Amer. Midl. Nat. 7 (1921) 42	French Muquet du japon
	Ophiopogon merrillii Masam. In Bull. Soc. Bot. Fr. 84 (1937) 90	German Japanischer Schlangenbart Japanese Ja-no-hige Korean
Liriope muscari (Dcne.)	*Liriope platyphyllis* Wangenh & Tang	English liriopogon English lily turf English green liriope
Ophiopogon intermedius	*Flueggea intermedia* (D. Don) Kunth, Enum. Pl. 5: 306 (1850).	Aztecgrass
	Ophiopogon japonicus var. intermedius (D. Don) maxim., Bull. Acad. Imp. Saint-Petersbourg 15:89 (1871)	
	Mondo intermedium (D. Don) L.H. Bailey, Gentes Herb. 2:25 (1929).	
Liriope exiliflora	*Liriope muscari* (Dcne.) Bailey var. *exiliflora* L.H. Bailey	
Liriope graminifolia ((L.) Baker) variety *densiflora* Baker	*Liriope muscari* (Dcne.) Bailey var. *densifolia* Baker	

HERBARIA

An herbarium is a collection of dried plant specimens essential for systematic research. Our understanding of the pattern of variation in nature mostly comes from herbarium specimens.

Morphological variability of population, species, and higher taxa, their geographical distribution, and their ecological characteristics are documented by these collections. A systematist can determine fruiting and blooming time by studying numerous specimens from a geographic range. Also, small portions of a specimen can be removed (with permission) to study palynology, ultrasturcture, micromorphology, anatomy, and possibly DNA. Dried plant specimens are scientific vouchers documenting the presence of a species to a particular locality (Judd et al., 1999).

Herbarium specimens are useful as references for plant identification and for determination of plant locations and ranges, abundance, habitat, and flowering and fruiting periods.

Bailey (1929) noted that unfortunately, not many herbaria have incorporated adequate material of carefully determined cultivated plants and that cultivated varieties have received too little systematic study. Fantz (1994) agreed with this; part of his recommendations for solving the problems of incorrectly named liriopogons was to have more of them correctly identified, dried, and mounted in herbariums for permanent records.

"The most important element in botanical collecting is the permanent record produced, which is a specimen or a suite of specimens representing a living plant. For most purposes, an identifiable specimen can be defined as one with either flowers or fruit, or both, because most botanical literature discusses the differences in kinds of plants in terms of reproductive structures" (Smith, 1971).

An herbarium collection of plant samples is preserved for long term study. There are over 300 million specimens worldwide preserved for research in the form of pressed and mounted

plants, seeds, wood sections, pollen, microscope slides, frozen DNA extractions and fluid preserved flowers and fruits (Holmgren and Holmgren, 1998).

NOMENCLATURE AND MORPHOLOGY

Nomenclature is defined as a set or system of names or terms, as those used in a particular science (Random House Dictionary of the English Language, 1987).

"Morphological characters are features of external form or appearance. They currently provide most of the characters used for practical plant identification and many of those used for hypothesizing phylogentic relationships. These features have been used for a longer time than anatomic or molecular evidence and have constituted the primary source of taxonomic evidence since the beginning of plant systematics" (Judd et al., 1999).

Anatomical characteristics are those related to internal structures of plants and are useful in both practical identification and determination of phylogenic relationships. These are investigated by light microscope study (Judd et al., 1999). In his study of the vegetative anatomy of Ophiopogoneae, Cutler (1992) first described the tribe Ophiopogoneae as consisting of three genera, *Ophiopogon* Ker Gawl., *Liriope* Lour. and *Peliosanthes* Andr. He went on to say that the morphological characters separating *Liriope* and *Ophiopogon* are rather slight and that is why some species have synonyms in both genera. Cutler (1992) concluded from his vegetative anatomical study of the tribe Ophiopogoneae that anatomical features of *Liriope* and *Ophiopogon* show close affinity and he did not feel compelled to separate the taxa.

Molecular systematics is the application of nucleic acid data to problems in systematics. This is the use of DNA and RNA to infer relationships among organisms. There are more molecular characteristics available than morphological characteristics and their interpretations are easier. Molecular data are now used for generating phylogenetic hypothesis (Judd et al.,

1999). Mcharo et al., (2003) in a molecular investigation of *Liriope* and *Ophiopogon* concluded that the molecular marker data did not substantiate the existence of two genera. These were preliminary data suggesting a close genetic affinity existing among the representative *Liriope* and *Ophiopogon* spp. taxa.

Appropriate classification of taxa is important in ecological and environmental studies because they attempt to investigate the geographic component to genotypic variation. If incorrect taxonomic classification is used, erroneous conclulsions may be drawn (Denny and Arnold, 2007). Denny and Arnold (2007) went on to explain that though horticulturists are often irritated and sometimes baffled by seemingly arbitrary nomenclatural changes taxonomists make to plants, correct updated taxonomic names are important to convey relatedness among plants.

Liriope and *Ophiopogon* belong to the lily family (Liliaceae), not the grass family (Hume, 1961). In the 1960s and 70s taxonomists met in London to determine an acceptable system to split Liliaceae. The following liliaceous family names are now in common use: Alliaceae, Agavaceae, Aloeaceae, Alstroemeriaceae, Amaryllidaceae, Aphyllanthaceae, Asparacaeceae, Asphodelaceae, Campynemaceae, Colchicaceae, Convallariaceae, Dracaenaceae, Doryanthaceae, Hemerocallidaceae, Hostaceae, Hyacinthaceae, Melanthiaceae, Ruscaceae, Smilacaceae, Tecophilacaceae, and Xanthorrhoeaceae (Gledhill, 1985). Ruscaceae is one of the subfamilies into which some classification systems subdivide the Liliaceae but is not widely accepted (Watson and Dallwitz, 1992). Liriopogons have been found in the literature under several of these families. The herbarium at the University of Gainsville, Florida has *Ophiopogon* listed under Ruscaceae, the herbarium at Kew Gardens in London, England has Asparagaceae listed as a family name for some *Liriope* spp.

Scientific names of species are binomials and the system of nomenclature was first consistently used by Carolus Linnaeus in his *Species Plantarum* (1753). The first word of a species is the name of the genus to which the plant is assigned. The second word is an adjective modifying the generic name and is the specific epithet. The specific epithet is followed by one or more authorities; the name (or names) of the person (or persons) who were the first to describe the species. Increased knowledge concerning the phylogenetic relationship of a species can result in a name change. When this happens the describing authority's name is placed in parenthesis and is followed by the transferring authority name (Judd et al., 1999).

Bailey (1933) defined species as a kind of plant that is distinct from other kinds in essential features, has good characters of identification, and is assumed to represent in nature, a continuing succession of individuals from generation to generation. He also said it is impossible to accurately define what is meant by species as nature is not laid out in formal lines. It becomes an unconscious part of the attitude of the naturalist which is acquired over time (Bailey, 1933). In 1929 he gave a number of genera from which certain individual species were part of the Liriope-Ophiopogon group. In his opinion *Asparagus, Convallaria, Chloopsis, Dracaenaceae* and *Polygonastrum* were included as synonomy or as a new species.

Charles Darwin (1859) defined species as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other, and that it does not essentially differ from the term variety, which is given to less distinct and more fluctuating forms. The Random House Dictionary of the English Language (1987) defines species as the major subdivision of a genus or subgenus, regarded as the basic category of biological classification, composed of related individuals that resemble one another, are able to breed among themselves

but are not able to breed with members of another species. This is the acceptable definition of species for the purposes of this research.

Cultivar descriptors are a subset of phytographic categories found useful for cultivated varieties. While a botanist may be concerned with ovary position or stem anatomy, such traits are not often useful when the genus or species is already known (Hatch, 1986).

According to the International Code of Nomenclature for Cultivated Plants cultivars are defined as an assemblage of plants selected for a particular attribute or combination of attributes. The characteristics are clearly distinct, uniform, and stable, and when propagated, appropriately retain those characteristics. The category variety is not equivalent to cultivar and must not be treated as an equivalent. Cultivars differ in their mode of origin and reproduction and only those plants which maintain the characteristics may be included in that cultivar. A clone may form a cultivar (Brickell, 2004).

Fantz (1996) proposed that the American Society for Horticultural Science should require basic information on new cultivars that includes derivation of the name; uniqueness; origin; a quantitative description; segregation from similar cultivars; cultural information, including propagation, vouchering, or registration; and availability. His proposal was in response to comments in HortScience on new cultivar documentation which gave the impression that it has been considered inadequate, substandard and of poor quality.

New cultivars should come with information indicating vouchering of the plant for archival purposes, ensuring preservation of the germplasn for future examination. Herbarium specimens may be prepared and deposited at the herbarium of the originating institution(s) (Fantz, 1996).

Cultivated plants are sometimes retained in separate folders or even in a separate set of cabinets in herbaria. This is so that one interested in only cultivated plants can easily find them (Womersley, 1979).

Problems with nomenclature of *Liriope* and *Ophiopogon* now seem to be more importantly, how many species are involved and are there one or two genera (Fantz, 1994). Conclusions from anatomical and molecular studies by Cutler (1992), Rudall (2000), and Mcharo et al., (2003) indicate that there is such affinity between the genera and it could be considered one. Historically Bailey (1929), Hume (1961), and Skinner (1971) treated these genera as two according to morphological findings. Conrad and Tamuri (1998) in their study of Convallariaceae wrote of the rhizomes of *Liriope* spp. and the tuberous roots of *Ophiopogon* spp. indicating they were morphologically different enough to be distinguished for economic and medicinal purposes.

Some botanists who have studied the morphology of plants separate liriopogons into two genera based on the structure of the flower. In Rudall's key identifying morphological data matrix for cladistic analysis, there were 30 indicators. In *Liriope* and *Ophiopogon,* twenty-four were the same (e.g. fleshiness of seed coats, rupturing of ovary wall, presence of septal nectaries, number of ovules per locule, tepal fusion, fruit type, presence or absence of perisperm and phylloclades, leaf type, leaf habit, leaf anatomy) five were questionable (e.g. presence or absence of parietal cell, root characteristics) and only one, the ovary insertion (hypogynous or hemi-epigynous) was different (Rudall, 2000). Cutler (1992) concluded that *Liriope* and *Ophiopogon* were different from *Peliosanthes* in gross morphology according to his findings on cuticular sculpturing on cells adjacent to stomata. In *Peliosanthes*, no specimens studied exhibited small-medium-sized simple micropapillae mainly in one file per cell, single simple micropapillae in

irregular arrangement, most cells with one or two medium sized micropapillae, micropapillae mainly round stomata, irregular and compound micropapillae, or irregular large papillae. In *Ophiopogon* and *Liriope* these leaf characteristics were observed. Leaf widths of *Peliosanthes* ranged from 8mm to 16.5mm, *Liriope* leaf widths ranged from 2mm to 9mm and *Ophiopogon* mostly in the 3mm to 8mm range with a small percentage 14mm to 17mm. Rudall's description of the ovary insertion of *Ophiopogon* differs from what Bailey (1929) and Cutler (1992) reported. Though Cutler finds *Liriope* and *Ophiopogon* different from *Peliosanthes* in gross morphology, he describes *Peliosanthes* inflorescence characteristics as being closest to *Liriope* but the ovary insertion of *Ophiopogon* and *Peliosanthes* as different. Rudall (2000) described *Ophiopogon* as having a hemi-epgiynous ovary. According to Cutler (1992) flowers droop in *Ophiopogon*; they are erect or ascending or nearly sessile in *Liriope* and ascending or recurved in *Peliosanthes*. Tepals in *Peliosanthes* are fused; they are free in the other genera. *Liriope* is hypogynous, whereas *Ophiopogon*, like *Peliosanthes* is hemiperigynous. In his characterization of *Liriope* and *Ophiopogon* species, Skinner (1971) described *Ophiopogons* as having nodding flowers, sub-inferior ovaries, and generally blue fruit. Hume and Morrison (1963) generalized that *Liriope* and *Ophiopogon* are much alike in general appearances, and though it may be dangerous to generalize, the two genera are evergreen-herbacous plants, either forming caespitose clumps or spreading by underground stolons or rhizomes. Bailey reported after making his case for lilyturfs that the two genera seem to be as well differentiated as most other genera of the Liliaceae (Bailey, 1929). Mcharo et al., (2003) noted of *Ophiopogon japonicus* 'Silver Mist', commonly called variegated mondo, that the ovary is hemi-epigynous and is somewhat intermediate between the two classes in morphology. He also noted that the flowers of other *Ophiopogon* species were mostly absent during that study.

The tribe Ophiopogonae has traditionally consisted of three genera: *Liriope, Ophiopogon* and *Peliosanthes* (Dahlgren et al., 1980). Cutler (1992), in his study of the vegetative anatomy of Ophiopogoneae found that micropapillae are a frequent feature of the intercostal epidermal cells of the abaxial surface in *Ophiopogon* and *Liriope*, but absent from *Peliosanthes*. He also found that *Liriope, Ophiopogon* and *Peliosanthes* are lacking differentiated subsidiary cells in the stomates. Plates of crystals occur in *Ophiopogon* and *Liriope*; they have not been seen outside these genera in any of the other Liliiflorae. Styloids are also very common, and occur in all three genera. In studying the vascular bundles Cutler (1992) found in *Ophiopogon* and *Liriope* the larger and medium-sized bundles away from the margin also exhibit more or less rotation; the xylem poles are rotated towards the 'midrib' bundle. Peliosanthes exhibited a small vascular bundle adaxial and inverted with respect to the 'midrib' bundle.

Cutler (1992) consentrated his anatomical study on the leaves of species of *Liriope*, *Ophiopogon*, and *Peliosanthes* in the herbarium at Kew in London. He mentioned the flowers of each but did not indicate that he studied the flower morphology himself for this paper. From his anatomical work on leaves of genera in the tribe Ophiopogoneae he was not compelled to call Liriope and Ophiopgon two different genera. Bailey (1929), Hume (1961), and Skinner (1971) from morphological work on roots and inflorescence of these plants separated them into two genera.

Skinner (1971) noted that botanical names for genera and species alike have been bestowed with lavish abandon. Besides *Liriope* and *Ophiopogon,* they can be found assigned to *Mondo*, *Asparagus, Convallaria, Dracaena, Polygonastrum*, *Flueggea*, and *Slateria.*

Bailey (1929) recognized that the botany of these plants was in need of clarification. He wrote that the plants are commonly misnamed in nurseries and the pictures in books are not

reliable. He felt compelled to check the names and identities of the kinds in cultivation as he had been studying these plants for many years, even growing them in unheated greenhouses to test their hardiness. He collected species in China and in plantations in the United States, England and tropical America and studied them while they were flowering and fruiting in front of him (Bailey, 1929). Foliage is too much alike to distinguish the genera. The flower structure is the place to find reliable generic distinction (Hume, 1961). Bailey (1929) described *Ophiopogon* flowers as drooping, the perianth more or less attenuate or prolonged at base and bell-shaped or cylindrical, the ovary inferior (joined with the perianth), anthers long-pointed and more or less united about style which is straight or slightly curved (not bent), filaments very short or almost none (Bailey, 1929). Conran and Tamura (1998) describe *Ophiopogon* in the family Convallariaceae as acaulescent or caulescent, caespitose, sympodial herbs, thick rhizomes often lignified, spreading; roots fibrous, often tuberiferous; leaves alternate, linear, sessile to oblong; inflorescence a raceme, more or less curved; flowers perigynous, campanulate to opening flat, drooping to ascending, pedicels articulated; tepals 6, fused basally or free, white or violet; six stamens, sometimes connate, attached to tepals basally, very short filaments, anthers long-pointed, basifixed, adpressed to the style; style 1, long, stigma capitate; ovary 3-locular, ovules basal, 2-6 per locule; 1 seeded fruit that ruptures in early development, exposing the seed; blue fleshy globose seed; x = 18. Hume's (1961) description of *Ophiopogon* supported what Bailey (1929) and Conran and Tamura (1998) described about the stigma and style, but his description of ovary insertion was different but in agreement with the language of Rudall (2000) and Skinner (1971). Hume (1961) described *Ophiopogon* as stemless, caespitose or rhizomatous herbaceous plants; leaves grass-like, roots fibrous; flowers racemose, pendent on curved pedicels, fascicled, each group subtended by a foliaceous bract, perianth attenuate and curved

basally, forming with pedicel the fruit-stalk; ovary sub-inferior; filaments very short, anthers sharp-pointed, closely surrounding the style; style projecting slightly beyond the anthers; ovary 6 celled, fruit single–seeded, blue.

Liriope flowers are erect, or ascending, or nearly sessile; the perianth rotate or wide open and not attenuate at base; two of the segments usually more erect than the others, ovary superior and flattened or depressed on top and 3-lobed; anthers obtuse, not exceeding the filaments or even shorter that the filaments which, like the style, are usually bent in the middle (Bailey, 1929). Conrad and Tamura (1998) described *Liriope* as acaulescent caespitose, sympodial herbs, rhizomes thin, spreading; roots fibrous, often tuberiferous; alternate leaves, sessile; inflorescence a reduced dibotyrum; flowers slightly zygomorhpic and opening wide to flat, erect to ascending or nearly sessile, pedicels articulated; tepals 6, fused basally, white or violet; 6 stamens basically attached to tepals, long filaments curved around style, obtuse anthers, basifixed; 1 long style with capitate stigma, curved; hypogynous ovary, 3-locular, ovules axile, 2 per locule; 1 seeded fruit that ruptures in early development exposing the seed; seed globose, blackish and fleshy; x = 18. Hume's description of *Liriope* supports that of Bailey (1929) and Conrad and Tamura (1998). He said of *Liriope* that it is perennial, stemless, caespitose or rhizomatous herbaceous plants with grass-like foliage; roots fibrous with tuber-like growths; flowers patent, racemose, in fascicles, set at an angle of 45° on erect scapes; style curved, anthers bunched, blunt, filaments curved, longer than the anthers, both stigma and anthers pointing toward rachis; ovary superior with 6 carpels, pedicels straight or slightly curved, fruit drupe-like and black (Hume, 1961).

Devine (1997) gave a description of the two genera saying there are general differences that distinguish the genera. *Liriope* tends to form dense clumps and produces flowers on scapes that rise above the foliage. *Ophiopogon* is generally stoloniferous, spreads easily and produces

flowers that are hidden among the foliage. Bailey (1929) and Hume (1961) would dispute this as too general. Hume (1961) separated species of the genera by different root systems. He described *Ophiopogon* as caespitose or rhizomatous. *Ophiopogon jaburan* is caespitose (tufted), in time forming a large clump, roots without tubers, fibrous (Bailey, 1929).

William G. Farlow had comments on problems of species identification. Farlow (1898) did not think that botanists should delude themselves into thinking they would find absolute standards but they should group and arrange what is known. Species are arbitrary and artificial creations, an aid in classification of facts accumulated over time. Botanists continue to study plants attempting to make rules on absolute standards, however, Farlow has a point in his idea that plants should be grouped and arranged on what is known at the time. Future technology may allow absolute standard.

The International Rules of Botanical Nomenclature, Article 15, states that the purpose of giving a name to a taxonomic group is not to indicate the characters or the history of the group, but to supply a means of referring to it. A more profound knowledge of the facts about a plant or if the name is not in accordance with the rules of nomenclature are the only motives appropriate to change a name and each group can only bear one valid name (Camp et al., 1947). It is not uncommon for the nursery and landscape industry to have incorrect names in their catalogs and publications (R. Odom, personal communication, June 2004).

Taxonomic name changes result in a state of confusion for growers, retailers, home owners, students, professional gardeners, landscape contractors, designers, and botanical gardens as well as others. This group perceives taxonomists as an unknown group of name changers who make these changes randomly and arbitrarily for fun or to justify their existence (Valleau, 2002).

Name changes cause panic among plant producers who fear that the public will no longer recognize the names and will fail to purchase in the retail setting. Growers feel helpless and unconsulted, as well as display an unwillingness to change (Valleau, 2002). Appropriate classification of taxa is important in ecological and environmental studies because they attempt to investigate the geographic component to genotypic variation. If incorrect taxonomic classification is used, erroneous conclulsions may be drawn (Denny and Arnold, 2007). Denny and Arnold (2007) went on to explain that though horticulturists are often irritated and sometimes baffled by seemingly arbitrary nomenclatural changes taxonomists make to plants, correct updated taxonomic names are important to convey relatedness among plants.

The main task of standing committees for nomenclature appointed by the International Botanical Congresses is to approve proposals for eventual stability of plant names, though this is not always understood by those in botanical and horticultural circles. It is hoped that in one hundred years the botanists of the day will not still be troubled by long-lost names being exhumed from 18th and 19th century literature coming back to life again (Brummitt, 1987). A precise system of nomenclature is necessary for botany to make satisfactory progress. Principles, rules, and recommendations are the precepts on which this precise system of botanical nomenclature is based. The object of the rules is to put the nomenclature of the past in order, and bring about uniformity and clearness in the future nomenclature (International Botanical Congress, 1930).

When separating species belonging to two genera, the first consideration should be given to growth habit. The grass-like foliage may appear to be much alike, but close examination reveals that some species grow in clumps and increase in size slowly, whereas others produce

rhizomes and spread. *Ophiopogon jaburan* and *Liriope muscari* are clumping species while *Ophiopogon japonicus* and *Liriope spicata* spread by rhizomes (Hume, 1961).

The Cooperative Extension Service at the University of Hawaii at Manoa, published an article in 1999 that said two species of *Liriope* are in common use in Hawaii (Deputy, 1999). However, *Liriope gigantea* 'Evergreen Giant' is now a recognized species in the industry. *Liriope gigantea*, commonly called evergreen giant, has the largest leaf of all the *Liriope*s growing up to 75 cm tall. Flowers are light violet and the scapes are hidden beneath the canopy (Berry, 1995). This particular *Lirope* is distinct from the other species known to be growing in the United States, yet no description fitting it has been found in the literature. It was found growing in an area near the house at Millpond Plantation in Thomasville, Georgia. The type specimen is No. 81458 in the herbarium, University of Florida, Gainesville, Florida, and was collected July 15, 1961 (Hume, 1961). A type specimen in a herbarium is the specimen upon which botanists have based their descriptions of new species. These are the final reference materials for nomenclatural and taxonomic judgement (Womersley, 1979).

Womersley (1979) provides insight into the problem with synonyms. The same plant is often provided with two or more botanical names by different authors. This happens partly because it is difficult for all botanists to be aware of each other's work, particularly where the same plant occurs over a wide range of countries. In Italy, dwarf *Ophiopogon* is called convallaria, and in France "turquoise". It is an admirable ground cover found in every Italian garden with its characteristic narrow leaves and tiny club-headed mauve inflorescence that grow well in sun or shade (Page, 1962). It sometimes happens that a plant first described in one genus is transferred at a later date to a different genus by another botanist (Womersley, 1979). *Liriope exiliflora* (Bailey) is the same plant that was called *Convallaria spicata* by Thunberg, Flora

Japonica: 141. 1784 (Hume, 1961). *Liriope muscari* (Decne.) L.H. Bailey, Gentes Herbarum 2: 35. 1929 was called *Ophiopogon muscari* Decaisne, flore des Serres 17; 181.1868 (Hume 1961).

Liriope platyphylla Wang and Tang is a synonym of *Liriope muscari* according to records at Kew Gardens. In a family tree on Convallariaceae, Conrad and Tamura (1998) use the name *Liriope platyphylla* instead of *Liriope muscari* indicating that it is a synonym.

Hume (1961) said of *Liriope exiliflora* that it blooms abundantly and the racemes are borne well above the foliage. He went on to say that in the South it is more common than any other species of *Liriope* and very constant in growth habit and raceme form (Hume, 1961). In 'The Case of *Ophiopogon* and *Liriope*' Bailey described *Liriope muscari* var. *exiliflora*, and listed *Convallaria spicata,* Thunb. Fl. Jap.141 (1784) as a synonym of *Liriope muscari* var. *exiliflora*. It was described as a small blue *Liriope* or lily-turf. A more slender form: leaves often only 6 mm broad but sometimes nearly twice as broad: open spike (not crowded), whorls being insertions well separated: flowers 2-4 at each insertion: small bracts. Origin was said to be Japan and China, and it is not infrequent in cultivation (Bailey, 1929).

In his morphological studies, Hume (1961) made distinctions between *Liriope muscari* and *Liriope exiliflora* (Table 2.2) which had been named by Bailey as a variety of *Liriope muscari*. According to Hume, *Liriope muscari* has a root system that always forms large clumps and has no rhizomes. Hume formulated a table of comparisons.

Bailey (1929) described lily-turf flowers as not showy individually, although he noted that flowers of the *Ophiopogon jaburan* are large enough to command attention; collectively in the racemes they make a colorful display. Fantz (2006) (Table 2.3) had distinctions between *Ophiopogon intermedius* and *Ophiopogon jaburan* which have been confused in studies and writings in areas of the South. Aztec grass is used as the common name for both species. Table

2.1 outlines distinctions that Fantz has presented regarding *Ophiopogon intermedius* and *Ophiopogon jaburan* (P.Fantz, personal communication, September 2006).

Table 2.2 Comparison of *Liriope muscari* and *Liriope exiliflora* by H. Harold Hume, Gainesville Fla., September 11, 1958.

Liriope muscari	*Liriope exiliflora*
Caespitose – forming large clumps, no rhizomes.	Rhizomatous – forming dense turf from short rhizomes.
Leaves large, usually 10 to 20 mm. wide, and to 59 cm. long, green	Leaves smaller, narrower, shorter. Usually 8 to 12 mm. wide and to 45 cm. long, dark-green.
Racemes variable in shape of apex, some pointed, others blunt, some cockscomb, in large clumps, rising but little above the decumbent leafage.	Racemes constant in shape, cylindrical with pointed apex, carried well above foliage.
Flower fascicles with 4 to 7 buds and flowers, closely together on rachis, forming compact racemes.	Flower fascicles scattered or widely separated on rachis, mostly 5 buds and flowers in each fascicle.
Perianth without basal projection, the perianth set directly on top of pedicel.	Perianth with well-defined basal projection 1 mm. long.
Color: raceme of buds and flowers dark violet.	Color: raceme light violet.
Flowering season: July and August.	Flowering season: somewhat earlier and shorter than that of *L. muscari*.
Fruits large, not abundant.	Fruits smaller and plentiful.

Table 2.3 Paul Fantz's differentiation of *O. jaburan* and *O. intermedius*.

Ophiopogon jaburan	*Ophiopogon intermedius*
Peduncles 17-25 cm	Peduncles 9-18 cm
Rachis 6-10 cm	Rachis 17-30 cm
Rachis < peduncle	Rachis > peduncle
Fascicles 10-14	Fascicles (30) 37-55
Pedicels 6-8 mm	Pedicels 3-6 mm
Bracts 4-7 mm	Bracts 2-4 mm
Foliar bracts 12-15 mm	Foliar Bracts 6-8 mm
Perianth 6-8 mm long	Perianth 5-6 mm long
Seeds oblong 5 x 3 mm	Seeds subglobular 4 mm diam.

Ophiopogon jaburan is the white lilyturf of Japan. The white flowers are up to ½ inch long, are in short, one sided spikes that are carried above the foliage (Everett, 1980). Skinner described *Ophiopogon jaburan* as a clump-forming species that was used for decoration. The leaves are long and ½ inch or longer. The scapes approach 2 feet in height and have white,

nodding flowers. The wild Japanese form has pale lavender flowers (Skinner, 1971).Hume and Bailey both described *Ophiopogon jaburan* as having a root system that is caepitose (tufted), and without tubers, fibrous; leaves dark green, to 86.7 cm long or more; scape declinate, flat, sharply edged, to 62 cm. long; raceme to 15 cm long, open, one-sided, rachis flattened; flowers white, drooping, to 1.5 cm wide across the perianth, basal extension white, becoming green after flower fades, slender, 1 cm long, curved, forming an arc with pedicel, pedicel 10-12 mm., filaments very short, 1mm. or less, anthers greenigh, sharp-pointed, central in compact circle around the style, style straight, extending about 2 mm. beyond anther-tips; furit ellipsoid, 1-1.5 cm. long, dark violet; seed white, nearly as large as the fruit (Bailey, 1929; Hume 1961).

CULTURE

Culture in botany is defined as the raising of plants with a view to their improvement (Random House Dictionary of the English Language, 1983). Nurserymen need to know the correct amount of light, water, soil, fertilizer, and pruning of liriopogons for production. (R. Odom, personal Communication, 2006). It is important in the industry to understand the growth differences in the species and cultivars because if a crop of one cultivar does not sell, money is lost (D. Farrell, personal communication, 2005). The growers are concerned with consistency in groundcovers. When they sell a truck load of plants they want the buyers to be able to trust that the plants they are buying will produce consistently (R. Odom personal communication, 2005)

Sun/Shade

L.H. Bailey (1929) noted that *Liriope* is probably preferable in strong sunshine because their lilac flowers give them an advantage that *Ophiopogon* does not have.

Liriope tolerates full sun and drought conditions because of its fleshy, tuberous root system. In full sun, water management is critical for optimum growth (Deputy, 1999). In

reference to anatomical features Cutler (1969) wrote that the hypodermis, stomata in channels and the sclerified phloem are frequently associated with xeromorphy. The species with narrow leaves are probably best adapted to periods of water deficiency.

There are species of liriopogons that are planted and even thrive in full sun or full shade (Schonbeck, 2006). This generalization does not determine which species thrive in full sun and which in full shade. The landscape industry would benefit from specific information (R. Odom, personal communication, 2004).

In Landscape Plants of the Southeast, Halfacre and Shawcroft (1989) says of *Liriope* that it grows in the shade, but tolerates full sun. When describing *Ophiopogon* he says that this plant grows in shade or sun.

Ophiopogon japonicus 'Nana' is a persistent grass like groundcover that can cover large areas in the shade in regions that are temperate or tropical. It is excellent for edgings; does not bloom freely (Bailey, 1929). Though *Ophiopogon japonicus* spreads at a fast rate, *Ophiopogon japonicus* 'Nana', the dwarf mondo, is actually found to spread slowly (Rackemann, 1987).

A statement in The New Royal Horticultural Society Dictionary of Gardening, Huxley (1992) indicates that *Ophiopogon* and *Liriope* grow in the sun, where soils remain sufficiently moist during the growing season, or in partial shade, in any moderately fertile well-drained soil. General descriptions of the liriopogons can be found in every book and article written on the subject. It is a concern of the nursery industry to learn specifically how individual species and cultivars perform (R.Odom personal communication, 2005).

Liriopogons will tolerate full sunlight on the south side of buildings, but performance improves in part or full shade. Foliage needs partial shade in summer to maintain color; however, for best flower production, some sun is needed (Skinner, 1971).

A Cooperative Extension Service bulletin from the University of Florida describes the light requirement of 'Evergreen Giant' as part shade/part sun and shade (Gilman, 1999). 'Evergreen Giant' is found growing in full sun on the Louisiana State University Campus as well as in landscapes in and around Baton Rouge, Louisiana.

Pruning

The incidence of disease and insects can be reduced by pruning the old foliage in winter and removing the cut leaves. This must be done before new growth develops (Deputy, 1999).

Hume and Morrison (1963) reported that *Liriope spicata* is best cut back in all areas where used as a groundcover to within an inch or so of the ground. This was advised because the winter cold causes them to become ragged and unkept appearing by spring. New leaf growth recovers the former lush green color. *Liriope spicata* can even be mowed with the rest of the lawn and the plants persist and return with the grass (Hume and Morrison, 1963). *Ophiopogon japonicus* responds differently to mowing. When mowed in the spring after the new leaves are tender, the cut leaf tips show damage of cutting: later mowing does not produce this effect (Hume and Morrison, 1963).

In the landscape, *Liriope* foliage should be mowed with a lawnmower set at the highest possible cutting height in late winter. It is important not to injure the crown and to prune before spring growth begins (Russ and Polomski, 1999). Berry agrees that plantings should be mowed to the ground to eliminate old foliage. Pruning allows vigorous new growth to emerge unimpeded from the crowns. There are exceptions in pruning, *Lirope gigantea* has an upright growth habit and is clean from year to year, not requiring routine pruning (Berry, 1995).

Berry (1995) indicated that for commercial production, during division, most *Liriope* growers prune both the shoot and root system of each bib two to three inches from the crown. In

opposition to this view the same year, Hayes et al., (1999) recommended that growers producing *Liriope* liners should be able to root and sell a crop quicker if shoots are not pruned at division.

It is considered in the interest of best management practices to prune *Liriope* and *Ophiopogon* for their appearance in the landscape and to control insects and disease. What has not been determined is whether or not there is a most effective pruning height, and if it is the same for all cultivars of this groundcover (D. Farrell, personal communication 2002).

In a pruning study at Auburn, it was found that shoot pruning suppressed root growth (Hayes et al., 1998). *Liriope* appears to form new roots faster when shoots are not cut back. Shoot pruning at planting resulted in very little root dry weight increase up to eight weeks after planting indicating a competition inhibition of root growth by new shoot growth (Hayes et al., 1999).

Fertilization

In the landscape, most established liriopogons will live indefinitely without fertilization. Light fertilizer applications in the spring, summer and fall can maintain color and appearance if calculated correctly. Well decomposed compost is suitable as a slow-release or organic formulation. Crowns may be injured by soluble fertilizers (Deputy, 1999).

Growers in the Southern United States are looking for efficient methods of propagating liriopogon bibs in containers. Container medium requires supplemental fertilizer until plants become established in the landscape. To avoid stress and poor development during propagation, it is important that the stock plants be maintained under optimal nutrition prior to harvesting propagules. During propagation, nutrients are generally applied to seedlings and plugs by fertigation (soluble fertilizers added to irrigation water) or with slow-release fertilizers that are

either pre-incorporated into the propagation medium or broadcast (top dressed) across the medium surface (Hartmann et al., 1990).

Incorporating fertilizer into a medium before planting is done primarily to accomplish three things: (1) to provide initial fertilizer for plant establishment, (2) to incorporate fertilizer elements that move slowly through the medium when applied from the surface, and (3) to adjust the medium pH to optimum levels for nutrient uptake (Gilliam and Smith, 1980).

Supplemental fertilizing during the growing season is necessary for optimum growth of most ornamentals in containers. Limited container volume, low cation exchange capacities of commonly used media, limited nutrient reserve and rapid nutrient leaching all contribute to the need for supplemental fertilization (Gilliam and Smith, 1980).

Growth and color effects from the application of water-soluble fertilizer are comparatively short lived, so application of these materials is needed relatively frequently during the growth season. Water soluble fertilizers produce rapid greening, have a low cost per unit of nutrient, are easy to apply and are readily available from a wide range of dealers (Guertal, 1998).

A satisfactory feeding program for growing liners is to incorporate a slow release fertilizer (preplant) in the medium with (post plant) fertigation applied at frequent intervals during the growing season or with controlled release fertilizers added as top treatment as needed (Gilliam, 1980). Deputy (1999) may argue that fertigation may cause injury to the crowns. This is a possibility. In a large wholesale nursery in the south a grower reported that their growth medium is amended with approximately 6 kg per m^3 of 6N : 6P : 6K fertilizer with micronutrients; 3 kg of dolomitic lime, 2.4 kg of calcitic lime, and 12 kg.of 16N :10P : 10K slow release fertilizer. Liriope grows well with NO_3 levels of 30 ppm in the soil solution, however, 0.9 kg per 10 m^2 of 12 N:6:6 K fertilizer can be used to boost NO_3 levels if needed (Berry, 1995).

Nitrogen fertilization increases foliage production, particularly leaf numbers, plant height and fresh weight (Thomas et al., 1998). Most forms of nitrogen, except those that contain free ammonia, can be applied successdully through the irrigation system. Leaves can be damaged by sources containing free ammonia, and much of the ammonia would be lost by volatilization. Common nitrogen salts that can be used when applied at recommended rates are: ammonium nitrate, ammonium sulfate, and potassium nitrete (Davidson et al., 1994).

According to Mills and Jones (1996) the sufficience range presented in their handbook is to be used as a guide with the objective to move the tissue nutrient concentrations to the middle of the sufficiency range for all essential nutrients. This data was collected by logging and tracking and the objective was to regulate cultural practices so as to maintain plant element levels within a set sufficiency range. Nitrogen is available for plant uptake at C: N <20:1. In order to increase nitrogen available for plant uptake, fertilizers containing nitrogen are routinely applied to crop soils. Nitrogen deficiency results in slow growing weak and stunted plants. Leaves are small and foliage is light green. The yield and quality are reduced. In this analysis, phosphorus concentrations in mature leaves range from 0.12 to 0.5 (Table 2.4). Phosphorus content in actively growing plant parts is higher because intense anabolism requires multiple energy-transer reactions involving ATP. Phosphorus deficiency can be caused by low soil temperatures in early spring plantings. Phosphorus deficiency results in retarded growth and lower shoot: root ratio. Symptoms include a darkish green color in older leaves (Mills and Jones, 1996). The following table is a report of nutrient analysis of *Liriope and Ophiopogon* (Mills and Jones, 1996).

Table 2.4 Nitrogen and phosphorus levels in selected *Liriope* and *Ophiopogon* species analysis

Species analysed	Nitrogen	Phosphorus
Liriope muscari-variegated cultivars	1.25-2.57	0.12-0.42
Liriope muscari - green cultivars	1.32-1.95	0.15-0.34
Liriope exiliflora	2.17	0.12
Liriope spicata	1.80-2.47	0.14-0.42
Liriope spicata 'Silver Dragon'	1.65	0.53
Ophiopogon japonicus 'Kyoto Dwarf'	2.39	0.32
Ophiopogon japonicus	1.44-2.65	0.20-0.33
Ophiopogon planiscapus	1.95-2.14	0.29-0.34

CHAPTER 3
MATERIALS AND METHODS

MORPHOLOGICAL DIFFERENCES AND HERBARIUM MOUNTS

Pictures of fresh plants from Doug Young Nursery, Forest Hill, La. and experimental plots at Burden Center, Baton Rouge, La. were taken and general descriptions were included to assist the grower, landscape professional and horticulturist with proper identification.

For the purposes of this study, general descriptions are: plant height and width at two years of growth, average leaf height, average number of inflorescence, ovary insertion, stamen characteristics, root type, flowering time and flower color per Munsell Color Chart.

"The Munsell system is the most widely accepted system of color identification in use in the United States. This system is based on a color solid, or approximately a color sphere, which has a neutral gray central axis grading from white at the top to black at the bottom. The property of lightness or darkness is called "value". Around the circumference of the solid are the ten major hues, each of which is divided into ten numbered divisions, so that 5 marks the middle of the hue, and 10 marks the boundary between one hue and the next. Thus any particular hue can be designated by a number and a letter such as 5R or 10YR. Any single vertical section through the neutral gray axis and a particular hue constitutes a color chart on which the colors grade in value from light at the top to dark at the bottom, and in chroma (degree of saturation) from gray at one edge to the most vivid colors out at the margin. Both value and chroma are numbered so any particular color can be given a numerical designation representing hue, value, chroma (Kuehni, 2000)".

This study used cultivars from Doug Young Nursery, Forest Hill, Louisiana.and PDSI in Loxley, Alabama. Heights and widths of plants were taken at Burden Center by measuring 19 cultivars of plants from time of establishment, quarterly, for two years.

Nineteen cultivars of research plants: common name, scientific name, or cultivar name.

1) Aztec grass

2) *Liriope muscari* (Dcne.) L.H. Bailey 'Big Blue'

3) *Liriope muscari* (Dcne.)L. H.Bailey 'Christmas Tree'

4) *Liriope muscari* (Dcne.) L.H. Bailey 'Densiflora'

5) 'Evergreen Giant'

6) 'John Burch'

7) Mondo

8) Black mondo

9) Dwarf mondo

10) Variegated mondo

11) *Liriope muscari* (Dcne.) L.H. Bailey 'Monroe White'

12) *Liriope muscari* (Dcne.) L.H. Bailey 'Royal Purple'

13) 'Samantha'

14) *Liriope spicata* Lour 'Silver Dragon'

15) *Liriope muscari* (Dcne.) L.H. Bailey 'Silvery Midget'

16) *Liriope spicata* Lour

17) Supergreen

18) 'Variegata'

19) Webster

Inflorescence was removed from all 19 different research cultivars to match the color according to the Munsell Color System developed by Albert Munsell, Wellesley Hills Mass. in 1921. These flowers were dissected for microscopic view in the Louisiana State University

Herbarium viewed by an Olympus SZX12 compound microscope. Pictures of the ovary insertion were taked with an Olympus Amercia 597809 digital six mega pixal camera and the research stereomicroscope system with a Dell computer. Pictures of the dissected flowers showing ovary insertion and stamen filaments were saved in the herbarium at Louisiana State University using the Olympus microsuite software for imaging applications. Flowering time was taken from the field notes of project three of this research (Effects of Sun and Shade on Growing Conditions on Landscape Performance) where data was collected in the spring, summer, fall and winter for three years. Leaf height and number of inflorescence were measured and counted at Doug Young Nursery. Thirty plants were chosen from each plot of cultivars by walking through the plot and randomly choosing the plants to measure, and 30 leaves were chosen randomly for measurement and the results were averaged. Thirty plants were chosen randomly from each cultivar plot by walking throught the plot and choosing the plants to measure; height of inflorescence were measured and the results were averaged. Root type was determined when plants were harvested and dried for the herbarium mounts.

Eighteen cultivars of *Liriope* and *Ophiopogon* were collected at Doug Young Nursery, Forest Hill, Louisiana (N 31° 03.716' W 092° 25.582'). One cultivar, *Liriope gigantea*, 'Merton Jacobs' Supergreen Giant™ was collected from PDSI Nursery, Loxley, Alabama. The entire plant, including leaves, roots, inflorescence, and sometimes berries were taken out of four inch or one gallon nursery containers. The soil was shaken from the plant. The plant was labeled with the scientific name, date of collection, location, then pressed and dried using a plant press. They were pressed while fresh.

The plant press consisted of 21 inch x 18 inch pieces of plywood (press panels); two press straps (or ropes); which were used to tighten the press; herbarium blotters, which absorb

moisture from the plant specimens; and corrugated ventilators (cardboard), which provide air passage through the press. The freshly harvested plant specimen was placed in a folded piece of newspaper on which the specimen name and number were written. Plants were arranged so upper and lower leaf surfaces, flowers, and fruit were visible. Plant material was sufficient to cover the surface of the newspaper and stay within the edges. For tiny plants, several were gathered. Press was assembled as follows: press frame, corrugated ventilator, blotter, newspaper (with fresh plant specimen), blotter, corrugated ventilator, blotter, newspaper (with plant specimen), blotter, corrugated ventilator, blotter, newspaper (with plant specimen) until the collector decided there were sufficient plants for one press and then it was finished with the second press frame. Press was tightened with two straps or ropes.

Once in the plant press the plants were dried in a plant drier. This is a box like structure that suspends the press over a source of heat. The press and dryer allowed warm air to flow through the plant press and remove moisture. Plants dried within four days and the plant material was rigid when dry.

When plants were removed from the dryer they were placed in a box in the herbarium freezer for 72 hours to kill pathogens.

Specimen labels were made with the plants name, geographic locality at which it was collected, habitat, date of collection, collectors name and collection number. The label was glued in the lower right hand corner to the 11 inch x 16.5 inch sheet of archived quality paper. Valuable loose plant parts, such as seeds, fruits, or flower parts were placed in small folded packets and glued to the herbarium sheet.

The plant was mounted to the paper with glue and linen adhesive strips. When complete, the collection was catalogued by family name and placed in the Louisiana State University

Herbarium cabinets. A scan was made of each mount using the Epson expression 10,000 XL Scanner and these were saved on the Dell Computer in the Louisiana State Univesity Herbarium. These vouchers of *Liriope* and *Ophiopogon c*an be found on the LSU Herbarium website. Leaf widths were measured at the widest parts of the leaf from the mature leaves of all 19 cultivars from the herbarium vouchers. These were measured looking through a Bausch and Lomb dissecting microscope. Six leaves of each herbarium voucher were measured and averaged for comparison of genera and species.

EFFECTS OF SUN AND SHADE ON GROWING CONDITIONS ON LANDSCAPE PERFORMANCE

Whether a specific cultivar performs best in sun or shade was determined by a study that rated plant performance in sun and shade by visual quality ratings.

This experiment was performed at Burden Center in Baton Rouge, Louisiana (30° 24.520'N 091° 06.302'W) over a three-year period. There were two treatments: 1) shade (63% shade cloth) and 2) sun. Six replications were used.

Nineteen cultivars of research plants: common name, scientific name, or cultivar name. Pictures of plants are in Appendix C.

1) Aztec grass

2) 'Big Blue'

3) 'Christmas Tree'

4) 'Densiflora'

5) 'Evergreen Giant'

6) 'John Burch'

7) Mondo

8) Mondo black

9) Dwarf mondo

10) Variegated mondo

11) 'Monroe White'

12) 'Royal Purple'

13) 'Samantha'

14) *Liriope spicata* 'Silver Dragon'

15) 'Silvery Midget'

16) *Liriope spicata*

17) Supergreen

18) 'Variegata'

19) 'Webster'

Six shade huts 20 X 4 X 4 feet were constructed using ½ inch polyvinyl chloride pipe and 63% shade cloths. The shade cloth is woven polypropylene, custom cut and grommeted by J. M. Industries in Ponchatoula, Louisiana. Nineteen cultivars were randomized by selecting numbers and planted in the shade and sun (Appendix D). Placement of shade huts was also randomized. These six blocks were planted on two-200 linear foot rows that were 48 inches wide, in Olivier silt loam soil. The rows were topped and initially treated with glyphosate two weeks prior to planting. Drip irrigation was provided for establishment. Six bales of pine straw mulch per block and hand weeding were used post planting, quarterly, for weed control. Planting was completed in August 2000. No fertilization was applied during the experiment. Light readings were taken monthly for a year at noon on the first Friday of the month with a biologically weighted UV-B detector for outdoor use (PMA2102) to establish that the all of the cloth was 63 % shade. Quality ratings for plants were begun once they were established in May 2001. Quality ratings were

taken seasonally (Spring, Summer, Fall/Winter) over a three year period on a scale of 1-5 (1=dead, 2=below average landscape performance, 3=average landscape performance, 4=above average landscape performance, 5=superior landscape performance). Visual quality rating takes into account the overall plant vigor, growth habit (typically compactness and uniformity is favored over tall, leggy growth and lack of uniformity), and flower characteristics (size, uniformity across the plant and from one plant to another plant, color retention) (LSU Agcenter, Research and Extension). Height and width measurements were taken on a north-south and east-west direction at establishment and at maturity. The widths were averaged for one measurement. Chlorophyll readings were taken in May and July 2004 with a Minolta SPAD 502 meter from Spectrum Technologies, East Plainfield Illimois. The SPAD Chlorophyll Meter instantly measures the amount of chlorophyll content. The project ended in July 2004. Chlorophyll results are available in Appendix E.

This experiment was a randomized block design with treatment, variety and season. Data was analyzed using Tukey Kramer adjustment to control the experiment wise error rate. In repeated experiments, it controls the proposition of experiments in which at least one difference in means is found to be significant when there are no real differences. For any given level of significance a minimum significant difference (MSD) is calculated. It is greater than the corresponding LSD. Whereas the LSD does not depend on the number of treatments, the MSD increases with the number of treatments (Cleaver, 2001).

Cultural factors of landscape plants require knowledge of sun and shade requirements as well as fertilization requirements and also pruning for optimal production and performance. Research on pruning percentages was done to complete the cultural factors determinations for *Liriope* and *Ophiopogon.*

EFFECTS OF FIVE PRUNING PERCENTAGES ON BIB PRODUCTION

A pruning experiment to determine most optimum percent pruning for bib performance was done at Burden Center in Baton Rouge, Louisiana. The duration was 4 months. Pruning and planting were done January 15, 2000 and plants were harvested May 15, 2000.

Seven cultivars within 3 species, five treatments and 10 replications were used. Species and cultivars were: 1) *Ophiopogon intermedius* 2) *Liriope muscari* 'Big Blue', 3) *Liriope gigantea* 'Evergreen Giant', 4*) Ophiopogon japonicus*, 5) *Liriope muscari* 'Royal Purple', 6) *Liriope spicata*, and 7) *Liriope muscari* 'Variegata'. The treatments were 1) 0 % pruning, 2) 20% pruning, 3) 40% pruning, 4) 60% pruning, and 5) 80% pruning.

Media consisted of 90% pine bark and 10% sand amended with Osmocote 14-14-14, dolomitic lime applied at 8 lbs/yd^3 and micromax at 1.5 lbs/yd^3. Bibs were pruned by measuring and removing the treatment percentages then planted in four inch liners of PB and sand amendments. This experiment was a completely randomized design. The bib containers were color coded, randomized and placed in the greenhouse with ten replications for each treatment. The bibs were irrigated daily as needed throughout the experiment.

Bib production was measured by height of new growth taken at six weeks and at sixteen weeks. At termination of the experiment height and quality ratings were taken and shoots and roots harvested for dry weight. They were harvested, bagged in labeled brown bags, then dried at 60° C for 48 hours, ground in a Wiley Mill Grinder, and weighed to obtain the weight of the dry shoot and root material.

The data was analyzed using Tukey Kramer adjustment.

EFFECTS OF RATES AND METHODS OF FERTILIZATION IN NURSERY PRODUCTION

To achieve optimum production, nutrient levels can be adjusted. This study determined what effect varying rates and regimes of incorporated fertilizer and liquid fertilizer have on the production of lilyturf bibs.

This experiment was performed at Burden Center in Baton Rouge, Louisiana. Nine fertilization treatments of controlled-release fertilizers (CR) and liquid fertilizer (LF) and four liriopogons (*Liriope muscari* 'Big Blue', *Liriope spicata*, *Ophiopogon intermedius* and *Liriope gigantea* 'Evergreen Giant') were used in the study. The fertilizer treatments were:1) no fertilizer (control) 2) LF 1X/wk 450 ppm 3) LF 3X/wk 150 ppm 4) CR-low rate lr 5) CR-medium rate mr 6) CR-high rate 7) LF 3Xwk 150 ppm N+CRlr 8) LF 3X/wk 300 ppm N+CRmr and 9) LF 3X/wk450 ppm N+CRhr. Two bibs were planted into 4 inch plastic nursery containers. Osmocote 14-14-14 was incorporated at low (3lbN/yd^3) (CRlr), Medium (6lbs N/yd^3) (CRmr), and high (12lbsN/yd^3) (CRhr) rates. Dolomitic lime was incorporated at 8lbs/yd^3, and micromax at 1.5lbs/yd^3 to a 90% pine bark, 10% sand mix. LF used was Peters 20-20-20 at 150 ppm, 300 ppm, and 450 ppm N. Plants were arranged in a RCBD with 10 replications and hand watered per regime in the greenhouse. Visual quality was rated on a scale of 1-10 (1=dead; 5.0=commercially acceptable; 10=dark green healthy plants) and were based on the overall appearance and growth habit of the plant. Height (cm), root weight (g), and shoot weight (g) were measured to obtain growth rate differences. Tissue analysis of nitrogen and phosphorus was done on dried (60 degrees for 48 hours) and ground leaves. The analysis was carried out by the LSU Agricultural Chemistry Laboratory. Foliar nitrogen and phosphorus and content was tested with the AOAC (Association of Official Analytical Chemists) 976.06 procedure.

Data for this experiment was analyzed with Duncan's Multiple Range Test.

CHAPTER 4
RESULTS AND DISCUSSION

MORPHOLOGICAL DIFFERENCES AND HERBARIUM MOUNTS

Each cultivar will be individually described as to classification according to the morphological findings in this research which related to the descriptions of Bailey (1929), Hume (1961), Skinner (1971), Fantz (1994), and Cutler (1992). The herbarium mount will follow the plant description after the table of results (Figures 4.3 - 4.21). Pictures of the fresh plants are Appendix C. Morphological characteristics are genera and species specific in the pictures of dissections of *Liriope* and *Ophiopogon* flowers (Figure 4.1 and Figure 4.2). Dissections show ovary insertions and stamen filaments. Through anatomical and molecular studies, Cutler (1992) and Mcharo et al., (2003) respectively, place *Ophiopogon* and *Liriope* as possibly one genus. Morphological characteristics are used in this study for the green industry professionals. The nurseryman wants a technique of identifying genera and species to ensure consistency (R. Odom, personal communication, 2005).

Figure 4.1 *Ophiopogon* flower

Figure 4.2 *Liriope* flower.

According to Hume (1961) and Rudall (2000), ovary insertion for *Ophiopogon* is hemi-epigynous (semi-inferior). This was supported by the dissections done on five species of *Ophiopogo*n. The stamen filaments are less than 1 mm and appear sessile. The anthers are taller than the filaments and pointed. The anthers are greenish yellow, sharp-pointed, central in compact circle around the style, style straight, extending about 2 mm beyond anther-tips (Hume, 1961). Hume's description of stamen was also supported by dissection and examination of five species of *Ophiopogon* under herbarium microscope for this research. Cutler (1992) reported leaf width measurements (Liriope 2-9mm, Ophiopogon 2-8mm with four species outside that range) which are supported by observations in this research of leaf width measurements under dissecting microscope (Liriope 3-11mm, Ophiopogon 2-7mm).

Bailey (1929), Hume (1961), Skinner (1971), Fantz (1994), and Rudall (2000) agree that ovary insertion for *Liriope* is hypogynous (superior). This is supported by dissections performed on four species of *Liriope* for this research. The stamens were also examined upon dissection and found to have stamen filaments longer than the anthers and curved. *Ophiopogon intermedius* has variegated leaves, with a mean height of 58.7 ± 11 cm (Table 4.1). The combined inflorescence and peduncle is shorter than the leaves, with a mean height of 26.3 ± 5.7cm.(Table 4.1). Canopy appears to grow taller and wider when the species is grown in the shade (Table 4.1). White flowers bloom from June to October (Table 4.1). In a dissected flower of *Ophiopogon intermedius* the ovary is hemi-epigynous. The stamen filament is 1 mm or less, so short as to appear sessile. Anthers are taller than filament and pointed (Table 4.1). Roots are rhizomatous (Figure 4.3). A common name for this species is Aztec grass. According to Henry Skinner this species is from North India. It is confused with *Ophiopogon jaburan* also commonly known as Aztec grass. *Ophiopogon intermedius* was not known to be cultivated in America when Bailey

(1929) and Hume (1961) developed their taxonomic keys. Paul Fantz, personal communication, 2006) has described this species. Closer morphological observation of the available flower shows a hemi-epigynous ovary (Table 4.1) which supports Rudall (2000) and Hume (1961). The ovary has been described by Bailey (1929), and Conran and Tamura (1998) as epigynous. Observations of dissections in this research showed *Ophiopogon intermedius* as having a hemi-epigynous ovary. Based on observations, measurements and comparisons to taxonomic keys of *Ophiopogon intemedius* the plant known as Aztec grass in this research has been correctly identified as *Ophiopogon intermedius*. The rachis of the *Ophiopogon jaburan* is shorter than the peduncle and the pedicels are 6 – 8 mm long. The rachis of the *Ophiopogon intermedius* is longer than the peduncle and the pedicels are 3-6 mm in length (P. Fantz, personal communication, September 2006). Leaf width measurements of 5-7 mm were consistent with Cutler (1992) leaf width measurements of 3-5mm. Pictures of *O. jaburan* were published in Bailey (1929). This distinction was also observed on herbarium vouchers of *O. jaburan* at North Carolina State University, Raleigh. The rhizomatous root system is consistent with the description of *O. intermedius* which describes the root system as rhizomatous (Figure 4.3).

Table 4.1 Horticultural description of *Ophiopogon intermedius* D. Don.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	58.6	50.4
Width (cm)	75.4	66.4

[z]Data collected at Burden Center July 2002, means averaged over six replications.

Leaf Length: Mean ± SD[y]	58.7 ± 11.0 cm
Inflorescence and Peduncle Length: Mean ± SD	26.3 ± 5.7 cm
Ovary Insertion	Hemi-epigynous
Stamens	Filaments short, 1mm or less, anthers greenish, compact circle around straight style.
Flower Color (Munsell Color Chart)	R-Y 9/10 8/10
Flowering time	June-October
Root type	Rhizomatous

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.3 Herbarium Mount of *Ophiopogon intermedius*

Liriope muscari 'Big Blue' has dark green leaves, with a mean length of 38.9±4.3 cm. (Table 4.2). The combined inflorescence and peduncle is shorter than the leaves, with a mean length of 30.6±5.1 cm (Table 4.2). Canopy grows taller and wider when the species is grown in the shade (Table 4.2). Purple flowers are abundant in June and July. In a dissected flower of *Liriope muscari* 'Big Blue' the ovary is hypogynous (Table 4.2). The stamen filaments are taller than the anthers and are curved. Roots are caespitose or tufted (Figure 4.4). This species is sometimes confused with *Liriope exiliflora* and can be differentiated by examination of the inflorescence and root system. Description of *Liriope exiliflora* by Hume (1961) is rhizomatous, spreading to form a dense turf. Flower fascicles are widely separated on the rachis. Fruits are smaller and plentiful. *Liriope muscari* 'Big Blue' is caespitose, no rhizomes, flower fascicles closely together on the rachis, forming compact racemes (Figure 4.4). Fruits are large and not abundant. 'Big Blue' as a cultivar has undetermined origins in the South. 'Big Blue' for this research was Doug Young's Big Blue from Forest Hill, La.

Table 4.2 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'Big Blue'.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	34.8	33.8
Width (cm)	68.9	58.8

[z]Data collected at Burden Center July 2002, means averaged over six replications.

Leaf Length: Mean ± SD[y]	38.9 ± 4.3 cm
Inflorescence and Peduncle Length: Mean ± SD	30.6 ± 5.1 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	7.5P 6/4
Flowering Time	June-July
Root type	Caespitose (tufted)

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.4 Herbarium Mount of *Liriope muscari* 'Big Blue'

Liriope muscari 'Christmas Tree' has dark green leaves, with a mean length of 43.6 ± 7.6 cm (Table 4.3). The combined inflorescence and peduncle is shorter than the leaves, with a mean length of 31.9 ± 6.5 cm but is taller than the plant canopy (Table 4.3). During summer flowering, this cultivar presents a showy display because the inflorescence is taller than the canopy of the plant. Canopy appears to grow taller and wider when the species is grown in the shade. Lilac flowers that do not open and are shaped like a christmas tree (Figure 4.5) are abundant June through August (Table 4.3). This cultivar was named because of the shape of the inflorescence. In a dissected flower of *Liriope muscari* 'Christmas Tree' the ovary is hypogynous (Table 4.3). The stamen filaments are taller than the anthers and are curved. Roots are caespitose or tufted (Figure 4.5). 'Christmas Tree' as a cultivar is classified as the species *Liriope muscari* according to the morphological description (Table 4.3) of this research. This cultivar of *Liriope muscari* is also known as Monroe # 2 in the literature. It was originally described by the growers of *Liriope muscari* 'Monroe White' which is also known as *Liriope muscari* Monroe # 2 (B. Tidwell personal communication 2007).

Table 4.3 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'Christmas Tree'.

Plant canopy characteristics	Shade	Sun
Height (cm) [z]	41.0 cm	36.0 cm
Width (cm)	71.0 cm	64.6 cm
[z]Data collected at Burden Center July 2002, means averaged over six replications		
Leaf Length: Mean ± SD[y]		43.6 ± 7.6 cm
Inflorescence and Peduncle Length: Mean ± SD		31.9 ± 6.5cm
Ovary Insertion		Hypogynous
Stamens		Blunt anthers on long filaments
Flower Color (Munsell Color Chart)		5P 7/4
Flowering Time		June-August
Root type		Caespitose (tufted)
[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005. Leaf length and combined inflorescence and peduncle length averaged over 30 replications.		

Figure 4.5 Herbarium Mount of *Liriope muscari* 'Christmas Tree'

Liriope muscari 'Densiflora' has dark green leaves, with a mean length of 44.1 ± 4.1 cm. The combined inflorescence and peduncle is shorter than the leaves, with a mean length of 30.4 ± 4.8 cm (Table 4.4) and shorter than the plant canopy. Canopy grows taller when the species is grown in the shade and wider when species is grown in the sun, these are biologically interesting but not statistically significant. Purple flowers are in bloom June and July (Table 4.4). The ovary of a dissected flower of *Liriope muscari* 'Densiflora' is hypogynous (Table 4.4). The stamen filaments are taller than the anthers and are curved (Table 4.4). Roots are caespitose or tufted (Figure 4.6).This cultivar is sometimes mistaken for 'Big Blue'. Liriope muscari 'Densiflora' may botanically belong in the classification *Liriope graminifolia*. Bailey (1929) and Hume (1961) wrote that a species named *Liriope graminifolia* resembled *Liriope spicata* because of its grass like leaves. Three years of field observations showed a strong resemblance in the leaves of 'Densiflora' and *L. spicata*, however, the root system of 'Densiflora' is tufted (Figure 4.6) unlike that of *Liriope spicata* which is rhizomatous (Bailey, 1929). Notes from Kew Gardens (Appendix B) have several enteries in their herbarium of *Liriope graminifolia* var. *densiflora.*

Table 4.4 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'Densiflora'

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	38.2	35.8
Width (cm)	49.9	57.4

[z]Data collectd at Burden Center July 2002. Means averaged over 6 replications

Leaf Length: Mean ± SD[y]	44.1 ± 4.1 cm
Inflorescence and Peduncle Length: Mean ± SD	30.4 ± 4.8 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	7.5P 4/6
Flowering Time	June-early July
Root Type	Caespitose (tufted)

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.6 Herbarium Mount of *Liriope muscari* 'Densiflora'.

Liriope gigantea 'Evergreen Giant' has leaves with upper surface dark green and lower surface light green. The leaf mean length is 44.1 ± 4.5 cm (Table 4.5). The combined inflorescence and peduncle length is 22.9 ± 3.5 cm and shorter than the leaf canopy (Table 4.5). No difference in height or width of plant in sun or shade (Table 4.5). Dissected 'Evergreen Giant' flowers have hypogynous ovaries. Stamen filaments are longer than anthers and curved. Dark lilac flowers from June through September (Table 4.5). Root system is rhizomatous with stout, widely spreading rhizomes (Figure 4.7). In some references this species and cultivar is a synonym of *Liriope muscari*. Hume (1961) gave detailed descriptive tables with *Liriope muscari* as having a tufted root system. He described *Liriope gigantea* as having a rhizomatous root system. The differences in root morphology would have this species classified as a *Liriope gigantea* (Table 4.5). This species has also been called an *Ophiopogon* but the flower characteristics of this species place it in the genus *Liriope* (Figure 4.2).

This species is grown abundantly in Florida which is where it was originally discovered and named by Hume (1961).

Table 4.5 Horticultural description of *Liriope gigantea* H.H.Hume 'Evergreen Giant'

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	56.4	54.8
Width (cm)	79.0	75.5

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	44.1 ± 4.5 cm
Inflorescence and Peduncle Length: Mean ± SD	22.9 ± 3.5
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	10P 6/4
Flowering Time	June-September
Root Type	Caespitose (tufted)

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.7 Herbarium Mount of *Liriope gigantea* 'Evergreen Giant'.

Liriope muscari 'John Burch' has dark green leaves with a yellow margin. The mean length of the leaves is 51.0 ± 3.9 cm (Table 4.6). The combined inflorescence and peduncle is shorter than the leaves, with a mean length of 26.6 ± 3.9 cm but is taller than the plant canopy (Table 4.6). Canopy appears to grow equally in height and width in the sun and shade (Table 4.6). Dark purple flowers are abundant June through August and are showy over the colorful foliage when flowering. In a dissected flower of *Liriope muscari* 'John Burch', the ovary is hypogynous (Table 4.6). The stamen filaments are taller than the anthers and are curved. Roots are caespitose or tufted (Figure 4.8) and this cultivar is more appropriately planted for borders than groundcover as it does not spread as prolifically as the rhizomatous species and cultivars. The morphological characteristics place this cultivar in the classification of *Liriope muscari* (Figure 4.2). The distinctivness of this cultivar are the dark purple inflorescence and the yellow margins outlining the dark green leaves (Appendix C).

Table 4.6 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'John Burch'.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	22.8	21.4
Width (cm)	31.2	31.8

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	51.0 ± 3.9
Inflorescence and Peduncle Length: Mean ± SD	26.6 ± 3.9
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	2.5P 5/8
Flowering Time	June-August
Root Type	Caespitose (tufted)

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.8 Herbarium Mount of *Liriope muscari* 'John Burch'.

Ophiopogon japonicus has dark green leaves, with a mean of 26.9 ± 4.3 cm (Table 4.7). The combined inflorescence and peduncle is much shorter than the leaves (Table 4.7). There appears to be no distinction of height and width of canopy whether grown in sun or shade. Inconspicuous drooping white flowers can be found close to the crown of the plant in May and June. The ovary of a dissected *Ophiopogon japonicus* is hemi-pigynous (Table 4.7). The stamen filament is 1 mm or less, so short as to appear sessile. Anthers are taller than filament and pointed. Roots are rhizomatous (Table 4.7 and Figure 4.9). Leaf width measurements were 2-3 mm. This was consistent with leaf width measurements by Cutler (1992) reported as 2-3 mm. Common names for this species are monkey gass and mondo. Mondo was historically the genus given to plants that are now known as *Ophiopogon. Mondo* is no longer a genus but a common name. It is not certain how the common name monkey gass came about but is speculated to be used as a definition. Monkey means to mimic and this species does mimic grass (Figure 4.9).

Table 4.7 Horticultural description of *Ophiopogon japonicus*, (L.f.) Ker Gawl.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	25.2 cm	22.4 cm
Width (cm)	37.0 cm	36.6 cm

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	26.9 ± 4.3 cm
Inflorescence and Peduncle Length: Mean ± SD	No flowers when data taken
Ovary Insertion	Hemi epigynous
Stamens	Filaments short, 1mm or less, anthers greenish, compact circle around straight style.
Flower Color (Munsell Color Chart)	R-Y 9/10 8/10
Flowering Time	May-June
Root Type	Rhizomatous

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.9 Herbarium Mount of *Ophiopogon japonicus.*

Ophiopogon planiscapus has black leaves, with a mean length of 20.7 ± 2.2 cm (Table 4.8). The combined inflorescence and peduncle is as tall as the leaves, mean length of 19.1 ± 2.0 cm (Table 4.8). Pinkish gray flowers appear in the summer. In a dissected flower of *Ophiopogon planiscapus* the ovary is hemi-epigynous. The stamen filaments are 1 mm or less, so short as to appear sessile. Anthers are taller than filament and pointed. Roots are rhizomatous (Table 4.8 and Figure 4.10). A common name for this species is black mondo. Howe (2004) described the inflorescence as dainty, bell-shaped whitish pink flowers centered slightly above the foliage on flat, upright scapes and the foliage as grasslike deeply purple leaves 10 inches long. This supports the findings of leaf length being 20.7 cm and the flower appearing taller than the foliage due to the arching statue of the plant. Leaf widths were 2-4 mm not consistent with Cutler (1992) reported as 6-7mm. Flowering time was not determined in our research because of the mortality rate of this species in research plots where flowering time was documented. Howe (2004) noted that *O. planiscapus* flowers in mid summer which would support the fact that it was flowering when the cultivars were measured for leaf height and inflorescence number in July 2004.

Table 4.8 Horticultural Description of *Ophiopogon planiscapus*, Nakai.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	Missing data	Missing data
Width (cm)	Missing data	Missing data
[z]Data was not available for plant canopy characteristics		
Leaf Length: Mean ± SD[y]	20.7 ± 2.2 cm	
Inflorescence and Peduncle Length: Mean ± SD	19.1 ± 2.0 cm	
Ovary Insertion	Hemi-epigynous	
Stamens	Filaments short, 1mm or less, anthers greenish, compact circle around straight style.	
Flower Color (Munsell Color Chart)	GY-G 8/5 7/5	
Flowering Time	Mid-summer	
Root Type	Rhizomatous	
[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005. Leaf length andcombined inflorescence and peduncle length averaged over 30 replications.		

Figure 4.10 Herbarium Mount of *Ophhiopogon planiscapus*

Ophiopogon japonicus 'Nana' has dark green leaves, with a mean of 10.1 ± 1.3 cm (Table 4.9). The combined inflorescence and peduncle is shorter than the leaves. Canopy appears to grow taller and wider when the species is grown in the shade (Table 4.9). Inconspicuous pinkish flowers bloom in May and June close to the crown of the plant. The fruit is dark purple when mature and hidden within the crown of the plant. Ovary of dissected Ophiopogon japonicus 'Nana' is hemi epigynous. The stamen filament is 1 mm or less, so short as to appear sessile (Table 4.9). Anthers are taller than filament and pointed. Roots are rhizomatous (Table 4.9 and figure 4.11). Common names for this species are mondo mini and dwarf mondo. Though this species has a rhizamotous root system it is slow to establish. Once established it appears mat like and very much resembles turf. *Ophiopogon japonicus* 'Nana' has been used successfully between stepping stones in landscapes.

Table 4.9 Horticultural description of *Ophiopogon japonicus*, (L.f.) Ker Gawl 'Nana'

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	11.8 cm	9.4 cm
Width (cm)	20.2 cm	17.8 cm

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	10.1 ± 1.3 cm
Inflorescence and Peduncle Length: Mean ± SD	No flowers when data was taken
Ovary Insertion	Hemi-epigynous
Stamens	Filaments short, 1 mm or less, anthers greenish, compact circle around straight style.
Flower Color (Munsell Color Chart)	R-Y 9/10 8/10
Flowering Time	May-June
Root Type	Rhizomatous

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.11 Herbarium Mount of *Ophiopogon japonicus* 'Nana'

Ophiopogon japonicus 'Silver Mist' has variegated leaves, with a mean of 27.4 ± 3.1 cm (Table 4.10). The combined inflorescence and peduncle is much shorter than the leaves. The canopy appears to grow taller and wider when the species is grown in the shade (Table 4.10). White flowers bloom in May and June (Table 4.10). Flowers are usually inconspicuous and grow close to the crown of the plant (figure 4.12). In a dissected flower of *Ophiopogon japonicus* 'Silver Mist' the ovary is hemi-epigynous (Table 4.10). The stamen filaments are 1 mm or less, so short as to appear sessile (Table 4.10). Anthers are taller than filaments and pointed. Roots are rhizomatous (Table 4.10 and figure 4.12). Common names for this species are variegated monkey grass and variegated mondo. The root system indicates that this cultivar would perform well as a groundcover. This species is colorful due to the amount of white in the leaves. This is also a cultivar that does not perform well in the sun according to field observations for three years at Burden Center (Table 4.20).

Table 4.10 Horticultural description of *Ophiopogon japonicus* (L.f.) Ker Gawl 'Silver Mist'

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	26.4 cm	21.0 cm
Width (cm)	40.2 cm	30.3 cm

[z]Data collected at Burden Center July 2002

Leaf Length: Mean ± SD[y]	27.4 ± 3.1 cm
Inflorescence and Peduncle Length: Mean ± SD	No flowers when data taken
Ovary Insertion	Hemi-epigynous
Stamens	Filaments short, 1 mm or less, anthers greenish, compact circle around straight style.
Flower Color (Munsell Color Chart)	R-Y 9/10 8/10
Flowering Time	May-June
Root Type	Rhizomatous

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.12 Herbarium Mount of *Ophiopogon japonicus* 'Silver Mist'

Liriope muscari (Dcne.) L.H. Bailey 'Monroe White' has dark green leaves, with a mean length of 40.1 ± 4.2 cm (Table 4.11). The combined inflorescence and peduncle is shorter than the leaves, with a mean length of 35.6 ± 2.8 cm but is taller than the plant canopy (Table 4.11). Canopy appears to grow taller and wider when the species is grown in the shade (Table 4.11). White flowers appear in June through August and are a showy display because the inflorescence is taller than the plant canopy. In a dissected flower of *Liriope muscari* 'Monroe White' it shows an ovary that is hypogynous (Table 4.11). The stamen filaments are taller than the anthers and are curved (Table 4.11). Roots are caespitose or tufted (Table 4.11) and have tubers (Figure 4.13). Ovary insertion, stamen filaments and morphology of root sytem indicate that this cultivar is correctly classified as *Liriope muscari.* This cultivar performs best in the shade, leaves and flowers bleach when grown in the sun. *Liriope muscari* 'Monroe White' is synonymous with Monroe # 2 as listed in plant catalogues (Anonymous, 2004).

Table 4.11 Horticultural Description of *Liriope muscari* (Dcne.) L.H. Bailey 'Monroe White'.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	30.0 cm	25.4 cm
Width (cm)	52.5 cm	46.9 cm

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	40.8 ± 4.2 cm
Inflorescence andPeduncle Length: Mean ± SD	35.6 ± 2.8 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	Neutral N9/.5 and R-Y 9/10
Flowering Time	June-August
Root Type	Caespitose (tufted)

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.13 Herbarium Mount of *Liriope muscari* 'Monroe White'

Liriope muscari (Dcne.) L.H. Bailey 'Royal Purple' has dark green leaves, with a mean length of 28.2 ± 2.3 cm (Table 4.12). The combined inflorescence and peduncle and leaves are equally tall, with a mean length for the inflorescence and peduncle of 28.1 ± 3.4 cm and is equal to the height of the plant canopy (Table 4.12). Canopy appears to grow taller and wider when the species are grown in the sun. Purple flowers are abundant June through August (Table 4.12). In a dissected flower of *Liriope muscari* 'Royal Purple', the ovary is hypogynous (Table 4.12). The stamen filaments are taller than the anthers and are curved. Roots are caespitose or tufted (Table 4.12) and have tubers (Figure 4.14). These morphological characteristics correctly classify 'Royal Purple' in the species *Liriope muscari*. This cultivar is known for the showy dark purple inflorescence during the summer months. Three years of field observation found 'Royal Purple' to have foliage that flattens in the late fall and winter months.

Table 4.12 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'Royal Purple'.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	28.8 cm	29.4 cm
Width (cm)	49.9 cm	54.0 cm

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	28.2 ± 2.3 cm
Inflorescence and Peduncle Length: Mean ± SD	28.1 ± 3.4 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	2.5P 4/8
Flowering Time	July-August
Root Type	Caespitose (tufted)

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Erronously named *Liriope muscari* 'Samantha'. Examination of roots and flowers shows that it compares favorably to *Liriope exiliflora*. Hypogynous ovary and erect flowers classify this cultivar in the genera *Liriope.* (Table 4.13). Pink flowers are abundant May through August

Figure 4.14 Herbarium Mount of *Liriope muscari* 'Royal Purple'

(Table 4.13). Flower fascicles are widely separated. Hume (1961) described *Liriope exiliflora* as having a peduncle well above the foliage with widely separarted fascicles.This cultivar has a rhizomatous root system forming dense turf from short rhizomes unlike the tufted root system of *Liriope muscari* (Figure 4.15). 'Samantha' has been called a *Liriope spicata* because the root system is rhizomatous like the root system of *L. spicata* (Table 4.16). The combined inflorescence and peduncle is taller than the *Liriope spicata* combined inflorescence and peduncle. Rhizomatous root system indicates it is not a *Liriope muscari*. *Liriope exiliflora* was described by Hume (1961) growing abundantly in Florida. It has not been described in areas outside of Florida possibly because it is confused with *Liriope muscari* and *Liriope spicata* when the species are not observed closely for the flower and root system morphology. Closer observation of species known as *L. muscari* growing in landscapes and propagated in nurseries would probably reveal an abundance of *L. exiliflora*.

Table 4.13 Horticultural Description of *Liriope* cf. *exiliflora* (L.H. Bailey) H.H.Hume 'Samantha'

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	28.8 cm	30.4 cm
Width (cm)	62.4 cm	58.4 cm

[z]Data collected at Burden Center July 2002

Leaf Length: Mean ± SD[y]	40.5 ± 6.6 cm
Inflorescence and Peduncle Length: Mean ± SD	36.8 ± 3.5 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	10P 8/4
Flowering Time	May-August
Root Type	Rhizomatous

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Figure 4.15 Herbarium Mount of *Liriope* cf. *exiflora* 'Samantha'.

Liriope spicata 'Silver Dragon' is a colorful spreading groundcover. The leaves are white with green stripes with a mean length of 38.4 ± 4.2 cm (Table 4.14). The combined inflorescence and peduncle has a mean length of 20.0 ± 4.3 cm and is partially hidden in the canopy of the plant. Lilac flowers bloom July through September (Table 4.14). In a dissected flower of *Liriope spicata*' Silver Dragon'the ovary is hypogynous (Table 4.14). The stamen filaments are taller than the anthers and curved (Table 4.14). The root system is rhizomatous (Figure 4.16) and this cultivar spreads prolifically, overrunning other species that are growing nearby. According to three years of field observations it was found that the distinctive characteristics of this cultivar are its ability to spread as a groundcover in a short period of time and its striking leaves which are mostly white. However, the same observations reveal a cultivar that has flattened foliage in the winter months.

Table 4.14 Horticultural description of *Liriope spicata* Lour 'Silver Dragon'.

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	27.0 cm	29.4 cm
Width (cm)	84.0 cm	98.0 cm

[z]Data collected at Burden Center July 2002

Leaf Length: Mean ± SD[y]	38.4 ± 4.2 cm
Inflorescence and Peduncle Length: Mean ± SD	20.0 ± 4.3 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	2.5P 8/4 7/4
Flowering Time	July-September
Root Type	Rhizomatous

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and combined inflorescence and peduncle length averaged over 30 replications.

Liriope muscari 'Silvery Midget' has dark green leaves with a yellow margin and a mean length of 27.7 ± 3.6 cm (Table 4.15).The combined inflorescence and peduncle and leaves are equally tall, with a mean length of 30.4 ± 3.9 cm and is equal to the height of the plant canopy

Figure 4.16 Herbarium of *Liriope spicata* 'Silver Dragon '

(Table 4.15). Canopy grows taller and wider when the species are grown in sun. Purple flowers bloom July through August (Table 4.15). In a dissected flower of 'Silvery Midget' the ovary is hypogynous. The stamen filaments are taller than the anthers and are curved (Table 4.15). Roots are caespitose or tufted (Figure 4.17) and are better planted for bordergrass than groundcover. This cultivar is known for the showy inflorescence during the flowering months in the summer. Results from three years of field observations reveal that this cultivar appears to have discolored leaves with red and brown spots in the winter months if not pruned. The foliage does not flatten as much in winter as other cultivars of *Liriope muscari*. According to the morphology of the flowers and roots, 'Silvery Midget' is classified as a *Liriope muscari*.

Table 4.15 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'Silvery Midget'

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	23.0 cm	26.4 cm
Width (cm)	38.6 cm	46.6 cm

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	27.7 ± 3.6 cm
Inflorescence and Peduncle Length: Mean ± SD	30.4 ± 3.9 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	5P 5/6
Flowering Time	July-August
Root Type	Caespitose (tufted)

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005
Leaf length and combined inflorescence and peduncle length averaged over 30 replications

Liriope spicata leaves are green with a mean length of 42.0 ± 5.0 cm (Table 4.16). Combined inflorescence and peduncle has a mean length of 30.0 ± 4.7 cm and is partially hidden in the canopy of the plant (Table 4.16). Lilac flowers bloom May through August (Table 4.16). In a dissected flower of *Liriope spicat*a the ovary is hypogynous (Table 4.16). The stamen filaments are taller than the anthers and curved. The root system is rhizomatous (Table 4.16)

Figure 4.17 Herbarium Mount of *Liriope muscari* 'Silvery Midget'

(Figure 4.18). Leaf width measurements were from 3-5 mm which is consistent with Cutler (1992) leaf width measurements of 2-7 mm. According to notes from three years of field observations at Burden Station in Baton Rouge, Louisiana, this cultivar tends to have discolored tips in a high percentage of the leaves when grown in the sun or the shade. The foliage does not flatten in the winter but grows upright and resembles grass.

Table 4.16 Horticultural description of *Liriope spicata* Lour.		
Plant canopy characteristics	Shade	Sun
Height (cm)[z]	57.2 cm	35.0 cm
Width (cm)	100.0 cm	100.0 cm
[z]Data collected at Burden Center July 2002.		
Leaf Length: Mean ± SD	42.0 ± 5.0 cm	
Inflorescence and Peduncle Length: Mean ± SD	30.0 ± 4.7 cm	
Ovary Insertion	Hypogynous	
Stamens	Blunt anthers on long filaments	
Flower Color (Munsell Color Chart)	10P 7/4 6/4	
Flowering Time	May-August	
Root Type	Rhizomatous	
[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005. Leaf length and combined inflorescence and peduncle length averaged over 30 replications.		

Liriope gigantea 'Merton Jacobs'Supergreen™ has leaves with upper surface dark green and lower surface light green. The leaf mean length is 62 ± 4.5 cm combined inflorescence and peduncle length is 33 ± 3.3 cm and shorter than the leaf canopy (Table 4.17). There is no difference in height and width of plant in sun and shade (Table 4.17). In a dissected flower of *Liriope gigantea* 'Merton Jacobs' Supergreen™ a hypogynous ovary is obvious (Table 4.17). Stamen filaments are longer than anthers and curved. Light violet flowers bloom from June through September (Table 4.17). The root system is rhizamotous (Figure 4.19) with stout, widely spreading rhizomes. This cultivar has been classified in some publications as *Liriope muscari*. They are considered by some to be synonyms.The rhizomatous root system places it

Figure 4.18 Herbarium Mount of *Liriope spicata*

morphologically under the classification *Liriope gigantea*, as Hume described the species in 1961. This cultivar was developed and patented in Loxley, Alabama. The trademark name is Supergreen. Unlike 'Evergreen Giant' this cultivar does not have problems with diseases and chlorotic leaves. Like L. gigantea 'Evergreen Giant' the foliage stays upright throughout the fall and winter and it does not flatten like other species and cultivars of liriopogons.

Table 4.17 Horticultural description of *Liriope gigantea* H.H.Hume 'Merton Jacobs' Patent #=12068 Supergreen Giant™ .

Plant canopy characteristics	Shade	Sun
Height (cm)[z]	57.2 cm	52.4 cm
Width (cm)	87.0 cm	87.0 cm

[z]Data collected at Burden Center July 2002.

Leaf Length: Mean ± SD[y]	62 ± 4.5 cm
Peduncle Length: Mean ± SD	33 ± 3.3 cm
Ovary Insertion	Hypogynous
Stamens	Blunt anthers on long filaments
Flower Color (Munsell Color Chart)	2.5RP 6/4
Flowering Time	June-October
Root Type	Rhizomatous

[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005.
Leaf length and peduncle length averaged over 30 replications.

Liriope muscari 'Variegata' has variegated leaves, with a mean length of 33.4 ± 4.0 cm (Table 4.18). The combined inflorescence and peduncle is shorter than the leaves, with a mean length of 31.2 ± 5.3 cm and is the same height as the plant canopy (Table 4.18). Canopy appears to grow equal in height and width in the sun and shade. Purple flowers bloom June through August (Table 4.18). In a dissected flower of *Liriope muscari* 'Variegata' the ovary is hypogynous (Table 4.18). The stamen filaments are taller than the anthers and are curved (Table 4.18). Roots are caespitose or tufted (Table 4.18 and Figure 4.20). Three years of field obervations indicate that the foliage of 'Variegata' flattens in the winter months. The foliage has discolored leaves in the winter if this cultivar is not pruned and the old foliage discarded.

Figure 4.19 Herbarium Mount of *Liriope gigantea* 'Merton Jacobs' Supergreen™

Table 4.18 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'Variegata'		
Plant canopy characteristics	Shade	Sun
Height (cm)[z]	33.6 cm	31.4 cm
Width (cm)	54.6 cm	54.6 cm
[z]Data collected at Burden Center July 2002.		
Leaf Length: Mean ± SD[y]	33.4 ± 4.0 cm	
Inflorescence and Peduncle Length: Mean ± SD	31.2 ± 5.3 cm	
Ovary Insertion	Hypogynous	
Stamens	Blunt anthers on long filaments	
Flower Color (Munsell Color Chart)	5P 4/6	
Flowering Time	June-August	
Root Type	Caespitose (tufted)	
[y]Data collected at Doug Young Nursery at Forest Hill, La. July 2005. Leaf length and combined inflorescence and peduncle length averaged over 30 replications.		

Liriope muscari 'Webster Wideleaf' has dark green leaves with a mean length of 53.2 ± 5.0 cm (Table 4.19). The combined inflorescence and peduncle is shorter than the leaves, with a mean length of 38.3 ± 4.1 cm and as tall as the plant canopy (Table 4.19). Canopy appears to grow taller when the species is grown in the shade (Table 4.19). Purple flowers bloom June through August (Table 4.19). In a dissected flower of *Liriope muscari* 'Webster Wideleaf' the ovary is hypogynous. The stamen filaments are taller than the anthers and curved. Roots are caespitose or tufted (Table 4.19, Figure 4.21). This cultivar is classified as a *Liriope muscari* according to the caespitose root system and the erect flowers with superior ovary (Table 4.19).

Table 4.19 Horticultural description of *Liriope muscari* (Dcne.) L.H. Bailey 'Webster Wideleaf'.		
Plant canopy characteristics	Shade	Sun
Height (cm)[z]	42.2 cm	37.6 cm
Width (cm)	63.0 cm	64.9 cm
[z]Data collected at Burden Center July 2002.		
Leaf Length: Mean ± SD[y]	53.2 ± 5.0 cm	
Inflorescence and Peduncle Length: Mean ± SD	38.3 ± 4.1 cm	
Ovary Insertion	Hypogynous	
Stamens	Blunt anthers on long filaments	
Flower Color (Munsell Color Chart)	5P 5/6	
Flowering Time	June-August	
Root Type	Caespitose (tufted)	
[y]Data collected at Doug Young Nursery at Forest Hill, La., July 2005. Leaf length and combined inflorescence and peduncle length averaged over 30 replications.		

Figure 4.20 Herbarium Mount of *Liriope muscari* 'Variegata'

Figure 4.21 Herbarium Mount of *Liriope muscari* 'Webster Wideleaf'

EFFECTS OF SUN AND SHADE ON GROWING CONDITIONS

Liriope muscari 'Monroe White', *Ophiopogon japonicus* commonly known as monkey grass, and *Ophiopogon intermedius commonly known as Aztec grass,* were found to perform significantly better in the shade than they performed in the sun (Table 4.20). There were no significant differences in performance in any other cultivars between sun and shade (Table 4.20). This supports the view of Schonbeck (2001) that reported there are species of *Liriope* that thrive in full shade but did not clarify which species or cultivars actually performed better in the shade verses sun. There were no statistical data provided for this study. The findings support Halfacre et al, (1989) that *Liriope* grows in the shade but tolerates full sun. There was no statistical data provided for this study. Of the eighteen cultivars in the final study, fifteen cultivars did not show significant differences when grown in the sun (Table 4.20). Huxley (1992) indicated that *Liriope* and *Ophiopogon* grow in the sun or in partial shade. This is a general statement made in articles written about liriopogons where no statistical data is provided; it does not specify the more shade performing cultivars. Bailey (1929) wrote that *Liriope* probably performed best in full sunshine because of the flowers but this study does not support that concept. One *Liriope* ('Monroe White') out of fourteen liriopogons in this study performed better in the shade (Table 4.20). Odenwald and Turner (1996) wrote that although liriopogons grow relatively well in full sun, the direct sunlight of hot summer burns foliage. Foliage condition was one of the considerations taken into account with visual quality ratings in this research. In the fall, winter and spring of the year there is no flowering. The cultivars with the most outstanding flowers during the summer have flattened discolored foliage during the winter which may explain the lower visual quality ratings. According to my observations and field notes *Liriope muscari* 'Variegata' and *Liriope muscari* 'Royal Purple', *Liriope muscari* 'Silvery Midget', *Liriope muscari* 'John Burch',

Liriope muscari 'Webster Wideleaf', *Liriope muscari* 'Christmas Tree', *Liriope muscari* 'Monroe White' , *Liriope* cf. *exiliflora* 'Samantha', and *Liriope spicata*, ' 'Silver Dragon' have a flattened appearance in the winter months. There were no *Ophiopogon* spp. in the research with flattened foliage in winter. *Liriope spicata* did not have a flattened appearance nor did either of the *Liriope gigantea* sp. There seems to be a differenence in genera in regards to foliage flattening in winter. All of the *Liriope muscari* have a tendency for the foliage to flatten in winter. *Liriope gigantea* 'Merton Jacobs' Supergreen™ did not exhibit flattened foliage in the winter and consistently performed high in the sun and shade while *Liriope gigantea* 'Evergreen Giant' does not exhibit flattened foliage in the winter and consistently performed with low visual quality ratings due to the consistent chlorotic leaves.

Table 4.20 Visual quality ratings of *Liriope* and *Ophiopogon* species and cultivars grown in full sun and shade (63%) landscape settings.

Genera	Species	Cultivar [z]	Sun	Shade	Significance
Liriope	*muscari*	'Big Blue'	4.0	4.1	ns
Liriope	*muscari*	'Christmas Tree	3.4	4.2	ns
Liriope	*muscari*	'Densiflora'	3.7	3.8	ns
Liriope	*muscari*	'John Burch'	3.6	4.0	ns
Liriope	*muscari*	'Monroe White'	3.1	4.0	*
Liriope	*muscari*	'Royal Purple'	3.8	4.4	ns
Liriope	*muscari*	'Silvery Midget'	3.7	4.0	ns
Liriope	*muscari*	'Variegata'	3.9	4.5	ns
Liriope	*muscari*	'Wideleaf Webster'	3.9	4.3	ns
Liriope	*gigantea*	'Merton Jacobs' Supergreen Giant™	4.2	4.5	ns
Liriope	*gigantea*	'Evergreen Giant'	3.4	3.7	ns
Liriope	*spicata*		3.7	3.9	ns
Liriope	*spicata*	'Silver Dragon'	3.7	4.3	ns
Ophiopogon	*japonicus*		3.7	4.8	**
Ophiopogon	*japonicus*	'Silver Mist'	3.2	4.0	ns
Ophiopogon	*japonicus*	'Nana'	3.9	4.7	ns
Ophiopogon	*intermedius*		3.5	4.5	*

[z]Means averaged over 6 replications and separated within columns and within cultivars by Tukey-Kramer.

There were no significant differences in any of the cultivars canopy widths in the sun compared to shade (Table 4.21). There were no significant differences in canopy heights of *Liriope* and *Ophiopogon* species in sun or shade (Table 4.21). There are differences in the visual quality ratings of *Liriope muscari* 'Monroe White', *Ophiopogon japonicus* and *Ophiopogon intermedius* (Table 4.20). These three plants significantly performed better in 63% shade compared to full sun. Though quality of the plant was affected by the intense sun (Table 4.20), canopy width and canopy height were not affected (Table 4.21).

Table 4.21 Canopy widths and heights of *Liriope* and *Ophiopogon* species and cultivars grown in full sun and shade (63%) landscape settings.

			Canopy Width[z]		Canopy Height		
Genera	Species	Cultivar	Sun	Shade	Sun	Shade	Significance
Liriope	*muscari*	'Big Blue'	59.8 cm	68.9 cm	33.8 cm[z]	34.8 cm	ns
Liriope	*muscari*	'Christmas Tree'	64.6 cm	71.0 cm	36.0 cm	41.6 cm	ns
Liriope	*muscari*	'Densiflora'	57.4 cm	49.9 cm	35.8 cm	38.2 cm	ns
Liriope	*muscari*	'John Burch'	31.8 cm	31.2 cm	21.4 cm	22.8 cm	ns
Liriope	*muscari*	'Monroe White'	46.9 cm	52.5 cm	25.4 cm	30.0 cm	ns
Liriope	*muscari*	'Royal Purple'	54.0 cm	49.9 cm	29.4 cm	28.8 cm	ns
Liriope	*muscari*	'Silvery Midget'	46.6 cm	38.6 cm	26.4 cm	23.0 cm	ns
Liriope	*muscari*	'Variegata'	54.6 cm	54.6 cm	31.4 cm	33.6 cm	ns
Liriope	*muscari*	'Wideleaf Webster'	64.9 cm	63.0 cm	37.6 cm	42.2 cm	ns
Liriope	*gigantea*	'Supergreen'	87.0 cm	87.0 cm	52.4 cm	57.2 cm	ns
Liriope	*gigantea*	'Evergreen Giant'	75.0 cm	79.0 cm	54.8 cm	56.4 cm	ns
Liriope	*spicata*		100.0 cm	100.0 cm	35.0 cm	57.2 cm	ns
Liriope	*spicata*	'Silver Dragon'	98.0 cm	84.0 cm	29.4 cm	27.0 cm	ns
Ophiopogon	*japonicus*		36.6 cm	37.0 cm	22.4 cm	25.2 cm	ns
Ophiopogon	*japonicus*	'Silver Mist'	30.3 cm	40.4 cm	21.0 cm	26.4 cm	ns
Ophiopogon	*japonicus*	'Nana'	17.8 cm	20.2 cm	9.4 cm	11.8 cm	ns
Ophiopogon	*intermedius*		66.4 cm	75.4 cm	50.4 cm	58.6 cm	ns

zMeans averaged over six replications and separated within columns and within cultivars by Tukey-Kramer.

Liriope gigantea 'Merton Jacobs' Supergreen™ performed significantly better in the sun than *Ophiopogon japonicus* 'Silver Mist' and *Lirope muscari* 'Monroe White' (Table 4.22). *Liriope gigantea* 'Merton Jacobs' Supergreen™ performed best of all cultivars followed by *Liriope muscari* 'Big Blue' (Table 4.22). 'Big Blue' performed significantly better in the sun

than ‘Monroe White’ (Table 4.22). Midcalf and Clay (1988) reported that ‘Monroe White’ was the largest white flowering *Liriope* and that this cultivar performed best in partial shade but there was no statistical data provided in the report. This research found that ‘Monroe White’ performed best in 63% shade but poorly in full sun supporting Midcalf and Clay (1988). Deputy (1999) reported that *Liriope* tolerates full sun which was a general statement that can be supported by this research which was cultivar specific. No statistical data was provided.

Table 4.22 Quality ratings in sun treatment on a scale of 1-5 for various *Liriope* and *Ophiopogon* species.

Cultivar	Quality Ratings [z]
Liriope gigantea ‘Merton Jacobs’ Super Green™	4.2 a
Liriope muscari ‘Big Blue’	4.0 ab
Liriope muscari ‘Webster’	3.9 abc
Ophiopogon japonicus ‘Nana’	3.9 abc
Liriope muscari ‘Variegata’	3.9 abc
Liriope muscari ‘Royal Purple’	3.8 abc
Liriope exiliflora ‘Samantha’	3.8 abc
Liriope spicata ‘Silver Dragon’	3.7 abc
Liriope muscari ‘Silvery Midget’	3.7 abc
Liriope spicata	3.7 abc
Ophiopogon japonicus	3.7 abc
Liriope muscari ‘Densiflora’	3.7 abc
Liriope muscari ‘John Burch’	3.6 abc
Ophiopogon intermedius	3.5 abc
Liriope muscari ‘Christmas Tree’	3.4 abc
Liriope gigantea ‘Evergreen Giant’	3.4 abc
Ophiopogon japonicus ‘Silver Mist’	3.2 bc
Liriope muscari ‘Monroe White’	3.1 c

[z]Means averaged over six replications and separated within columns by Tukey-Kramer at the p=0.05 level. (1=dead, 2=below average landscape performance, 3=average landscape performance, 4= above average landscape performance, and 5= superior landscape performance)

In the shade *Ophiopogon japonicus* and *Ophiopogon japonicus* ‘Nana’ performed significantly better than *Liriope gigantea* ‘Evergreen Giant’ (Table 4.23). *Ophiopogon japonicus* performed significantly better than *Liriope muscari* ‘Densiflora’ and *Liriope gigantea* ‘Evergreen Giant’ (Table 4.23). *L. gigantea* ‘Evergreen Giant’was consistently lower in VQR because of chlorotic leaves according to three years of field observations at Burden Station in

Baton Rouge, Louisiana. The plant has been observed to be medium green with colorful lilac flowers when leaves are not chlorotic.

Chlorophyll testing was also attempted with a SPAD meter but after statistical analysis, the results were inconclusive.The table of chlorophyll readings in sun and shade for eighteen of the nineteen cultivars studied can be found in Appendix E.

Table 4.23 Quality ratings in shade treatment.on a scale of 1-5 for various *Liriope* and *Ophiopogon* species.

Cultivar	Quality Ratings[z]
Ophiopogon japonicus	4.8 a
Ophiopogon japonicus 'Nana'	4.7 ab
Ophiopogon intermedius	4.5 abc
Liriope gigantea 'Merton Jacobs' Supergreen™	4.5 abc
Liriope muscari 'Variegata'	4.5 abc
Liriope muscari 'Royal Purple'	4.4 abc
Liriope muscari 'Webster'	4.3 abc
Liriope spicata 'Silver Dragon'	4.3 abc
Lirope exiliflora 'Samantha'	4.2 abc
Liriope muscari 'Christmas Tree'	4.2 abc
Liriope muscari 'Big Blue'	4.1 abc
Liripe muscari 'John Burch'	4.0 abc
Ophiopogon japonicus 'Silver Mist'	4.0 abc
Liriope muscari 'Monroe White'	4.0 abc
Liriope muscari 'Silvery Midget'	4.0 abc
Liriope spicata	3.9 abc
Liriope muscari 'Densiflora'	3.8 bc
Liriope gigantea 'Evergreen Giant'	3.7 c

[z]Means averaged over six replications and separated within columns and within cultivars by Tukey-Kramer at the p=0.05 level. (1=dead, 2=below average landscape performance, 3=average landscape performance, 4=average landscape performance, 5= superior landscape performance.

EFFECTS OF FIVE PRUNING PERCENTAGES ON BIB PRODUCTION

Ophiopogon intermedius

Of the five root and shoot growth characteristics for production of *Ophiopogon intermedius* only root length and shoot dry weight showed any differences with bib pruning at division and planting. Root length was significantly longer with twenty percent bib pruning over

any other pruning treatments (Table 4.24). Shoot dry weight was significantly higher with twenty percent pruning when compared to eighty percent pruning (Table 4.24). For this cultivar, only twenty percent pruning of bibs at division has any significant effect on bib growth.

Table 4.24. Root and Shoot growth characteristics of greenhouse produced *Ophiopogon intermedius* as influenced by bib pruning percentages.

Pruning %	Root Length[z] (cm)	Root Dry Weight (g)	Shoot Dry Weight (g)	Shoot Height 6 weeks (cm)	Shoot Height 16 weeks (cm)
0%	8.72 b	0.91 a	1.39 ab	14.66 a	17.36 a
20%	17.15 a	2.02 a	2.79 a	14.22 a	12.65 a
40%	12.72 ab	1.34 a	1.64 ab	10.60 a	12.05 a
60%	11.19 b	0.96 a	1.05 ab	11.21 a	10.70 a
80%	7.37 c	1.09 a	0.79 b	10.73 a	7.95 a

[z]Means averaged over ten replications and separated within columns by Tukey-Kramer at the p = 0.05 level. Shoot height measurements taken six weeks after pruning and 16 weeks after pruning.

***Liriope muscari* 'Big Blue'**

Bib growth characteristics were significantly higher with twenty percent pruning treatment in the growth characteristics of shoot dry weight only. No other growth characteristics were affected by any pruning treatment for 'Big Blue' (Table 4.25). This is an indication that for bib development, pruning of this cultivar is not necessary at division and planting. Best management practices suggests pruning to control insects and disease and for cosmetic purposes.

Table 4.25 Root and shoot growth characteristics of greenhouse produced *Liriope muscari* 'Big Blue' as influenced by bib pruning percentages.

Pruning %	Root Length[z] (cm)	Root Dry Weight (g)	Shoot Dry Weight (g)	Shoot Height 6 weeks (cm)	Shoot Heigh 16 weeks (cm)
0%	12.20 a	2.90 a	3.38 ab	23.80 a	24.60 a
20%	11.30 a	2.75 a	3.45 a	22.40 a	24.00 a
40%	14.79 a	1.62 a	1.54 bc	17.10 a	20.60 a
60%	11.20 a	2.13 a	1.29 c	16.50 a	18.55 a
80%	17.46 a	1.82 a	0.94 c	16.55 a	20.60 a

[z]Means averaged over ten replications and separated within columns by Tukey-Kramer at the p = 0.05 level. Shoot height measurements taken six weeks after pruning and 16 weeks after pruning.

***Liriope gigantea* 'Evergreen Giant'**

Of the five growth characteristics for production of *Liriope gigantea* 'Evergreen Giant' only root dry weight and shoot dry weight showed significant differences with different pruning treatments. Root dry weight was significantly lower with eighty percent of the bib pruned than with no pruning (Table 4.26). This supports Haynes et al. (1998) that *Liriope* appears to form new roots faster when the shoots are not cut back. This also supports what Berry (1995) said. The foliage of *L. gigantea* remains upright and clean from year to year and should not be mowed to the ground in late winter. Pruning is indicated for prevention and spread of insect and disease as indicated by best management practices and Killebrew (1999).

Table 4.26 Root and shoot growth characteristics of greenhouse produced *Liriope gigantea* 'Evergreen Giant' as influenced by bib pruning percentages.

Pruning %	Root Length[z] (cm)	Root Dry Weight (g)	Shoot Dry Weight (g)	Shoot Height 6 weeks (cm)	Shoot Height 16 weeks (cm)
0%	11.71 a	4.62 a	4.77 abc	15.79 ab	29.98 a
20%	14.88 a	2.51 bc	5.99 a	23.89 a	26.58 a
40%	14.13 a	3.33 ab	5.25 abc	15.44 ab	26.09 a
60%	11.40 a	2.34 bc	5.84 ab	20.50 ab	24.05 a
80%	12.10 a	1.44 c	3.17 c	18.70 ab	24.60 a

[z]Means averaged over ten replications and separated within columns by Tukey-Kramer at the p = 0.05 level. Shoot height measurements taken six weeks after pruning and 16 weeks after pruning.

Ophiopogon japonicus

There were no significant differences for any pruning treatments for growth characteristics of *Ophiopogon japonicus* (Table 4.27). Data indicates that pruning does not benefit the growth of *Ophiopogon japonicus* bibs. Hume and Morrison (1963) found it important to mow *Ophiopogon japonicus* during winter months so as not to injure tender leaves, however there was no data suggesting that bib production would improve by mowing. Best Management

Practices would dictate to prune this cultivar for maintenance to control the spread of insects and disease. Pruning is also used for cosmetic purposes.

Table 4.27 Root and shoot growth characteristics of greenhouse produced *Ophiopogon japonicus* influenced by bib pruning percentages.

Pruning %	Root Length[z] (cm)	Root Dry Weight (g)	Shoot Dry Weight (g)	Shoot Height 6 weeks (cm)	Shoot Height 16 weeks (cm)
0%	9.14 a	1.57 a	0.92 a	5.50 a	7.06 a
20%	11.30 a	1.39 a	1.19 a	3.21 a	5.86 a
40%	9.75 a	1.19 a	0.74 a	4.60 a	6.74 a
60%	11.10 a	0.89 a	0.46 a	5.40 a	7.20 a
80%	10.45 a	0.44 a	0.23 a	4.60 a	3.94 a

[z]Means averaged over ten replications and separated within columns by Tukey-Kramer at the p = 0.05 level. Shoot height measurements taken six weeks after pruning and 16 weeks after pruning.

***Liriope muscari* 'Royal Purple'**

Root and shoot growth characteristics for *Liriope muscari* 'Royal Purple' were not significantly influenced by any of the pruning treatments (Table 4.28). Data indicates that pruning does not benefit the growth of *Liriope muscari* 'Royal Purple'. Pruning for this species should be done if indicated for insect and disease control and for cosmetic purposes.

Table 4.28 Root and shoot growth characteristics of greenhouse produced *Liriope muscari* 'Royal Purple' as influenced by bib pruning percentages.

Pruning %	Root Length[z] (cm)	Root Dry Weight (g)	Shoot DryWeight (g)	Shoot Height 6 weeks (cm)	Shoot Height 16 weeks (cm)
0%	9.96 a	1.28 a	1.38 a	5.00 a	8.01 a
20%	10.78 a	1.95 a	1.82 a	10.00 a	15.90 a
40%	10.90 a	1.67 a	1.43 a	8.80 a	10.90 a
60%	10.00 a	1.30 a	0.93 a	13.20 a	12.85 a
80%	8.47 a	0.99 a	0.77 a	10.00 a	11.55 a

[z]Means averaged over ten replications and separated within columns by Tukey-Kramer at the p = 0.05 level. Shoot height measurements taken six weeks after pruning and 16 weeks after pruning.

Liriope spicata

Of the root and shoot growth characteristics of greenhouse produced *Liriope spicata* only shoot dry weight showed significant difference with treatment (Table 4.29). Shoot dry weight was significantly higher with no pruning than with sixty percent or eighty percent pruning treatment. This supports Hayes et al., (1999) that *Liriope* does not have to be pruned for better bib production. Pruning is indicated for prevention and control of insects and disease and for cosmetic purposes.

Table 4.29 Root and shoot growth characteristics of greenhouse produced *Liriope spicata* as influenced by bib pruning percentages.

Pruning %	Root Length[z] (cm)	RootDry Weight (g)	Shoot Dry Weight (g)	Shoot Height 6 weeks (cm)	Shoot Height 16 weeks (cm)
0%	10.61 a	2.57 a	2.55 a	19.91 a	18.71 a
20%	14.40 a	1.60 a	0.74 ab	13.25 a	14.45 a
40%	13.50 a	1.24 a	0.72 ab	15.40 a	12.25 a
60%	13.50 a	1.18 a	0.58 b	14.35 a	14.65 a
80%	10.80 a	0.59 a	0.25 b	12.60 a	12.45 a

[z]Means averaged over ten replications and separated within columns by Tukey-Kramer at the p= 0.05 level. Shoot height measurements taken six weeks after pruning and 16 weeks after pruning.

***Liriope muscari* 'Variegata'**

Root and shoot growth characteristics for *Liriope muscari* 'Variegata' showed significant differences only in root length and root dry weight. Root length and root dry weight with twenty percent pruning treatment was significantly higher than root length and root dry weight at eighty percent pruning treatment (Table 4.31). No other comparisons were signicant. This data supports Hayes et al., (1999) results that showed that when *Liriope* shoots are left intact at time of division, regardless of the root system, they produce more shoots and roots faster than when the shoots are cut bact to two inches.This research differs from Hayes research in that five pruning treatment percentages were used on bibs. This research compared percentages of bib pruning and

the only trend noted would be twenty percent pruning treatment is the best for some species for bib growth. Pruning is always indicated for control and prevention of insects and disease and for cosmetic purposes in the landscape.

From this data using Tukey Kramer, except for twenty percent pruning in some species, pruning does not benefit bib production. Pruning is still necessary in some cases to control insects and disease and for cosmetic purposes. This study supports Hayes et al. (1999) *Liriope* shoots not pruned at division produce more roots faster than when the shoots were pruned to a 5 cm height, regardless of the root volume. This research went further than past research in that five percentages of pruning treatments were compared for bib growth and showed that the amount of pruning of bibs at division and planting does not have any significance.

Table 4.30 Root and shoot growth characteristics of greenhouse produced *Liriope muscari* 'Variegata' as influenced by bib pruning percentages.

Pruning %	Root Length (cm)[z]	Root Dry Weight (g)	Shoot Dry Weight (g)	Shoot Height 6 weeks (cm)	Shoot Height 16 weeks (cm)
0%	5.80 c	1.93 abc	2.56 a	10.44 a	15.83 a
20%	11.30 a	3.09 a	2.72 a	9.85 a	19.00 a
40%	11.08 ab	2.68 ab	2.51 a	13.42 a	20.46 a
60%	8.20 abc	2.05 abc	1.66 a	9.05 a	13.20 a
80%	5.52 c	1.44 bc	.94 a	11.68 a	13.01 a

[z]Means averaged over ten replications and separated within columns by Tukey-Kramer at the p = 0.05 level. Shoot measurements taken six weeks after pruning and 16 weeks after pruning.

EFFECTS OF RATES AND METHODS OF FERTILIZATION IN NURSERY PRODUCTION

Ophiopogon intermedius root weight was significantly higher with no fertilization than the highest rate of fertilizer (Table 4.31). Height showed significance in treatments with LF (150 ppm N 3x/wk) + CRlr and LF (300 ppm N 3x/wk) + CRmr over no fertilizer. Ophiopogon

intermedius had significantly more N and P with LF (3X/wk 450 ppmN + CRhr, LF (3X/wk 300 pm N) + CRmr, LF (3X/wk 150 ppm N) + CRlr, and LF (1X/wk 450 ppm N) than the control.

Liriope gigantea 'Evergreen Giant' showed significant increases in all of the single and combination fertilizers compared to no fertilizer (Table 4.32). Plant quality showed significant increases using CRhr, LF (3X/wk 300 ppm N) + CRmr and LF (3X/wk 450 ppm N) + CRhr over no fertilizer. N was significantly higher in the two highest LF + CR combinations and the LF (1X/wk 450 ppm N) over no fertilizer.

Liriope spicata showed a significant increase in shoot weight for LF (3X/wk 300 ppm N) + CRmr over the CR and no fertilization (Table 4.33). Height and plant quality were posivively influenced by all combinations of LF + CR and LF (1X/wk 459 ppm N) over all CR and no fertilizer. Highest levels of N were found in LF (3X/wk 450 ppm N) + CRhr, LF (1X/wk 450 ppm N), and LF (3X/wk 300 ppm N) + CRmr over CR and no fertilizer. P was the highest in all combinations of LF and CRhr.

Liriope muscari 'Big Blue' height was increased for the LF (3X/wk 450 ppm N) + CRhr over all other treatments (Table 4.34).Plant Quality was significantly higher for all three LF + CR combinations over the control. There were significant increases in N and P with both LF and LF + CR fertilizer combinations over the control.

In this study root weight and shoot weight were not influenced by any treatments over the control. Plant height, quality, N and P were the most influenced by all combinations of LF + CR and LF alone over any of the CR rates of fertilization. LF (1X/wk 450 ppm N) was statistically similar to and sometimes greater than LF (3X/wk 150 ppm N). This research found that fertilization with LF alone or in combination with CR increased height and quality. As expected, CR fertilization alone showed improved height and plant quality over no fertilizer.

Table 4.31 Growth characteristics of *Ophiopogon intermedius* using different fertilizer rates and regimes.

Treatment Rate	Root Wt[z] (g)	Shoot Wt. (g)	Height (cm)	Plant Quality 1-10	N %	P %
No Fertilizer (Control)	1.9a	3.0a	17.7bc	6.2a	0.9d	0.25d
Liquid Feed (LF) 1X/wk 450 ppm N	1.4ab	3.5a	22.7abc	5.2a	1.8ab	0.53ab
LF 3X/wk 150ppm N	1.4ab	2.6a	19.4abc	5.3a	1.3bcd	0.39bcd
Controlled Release Low Rate CRlr	1.6ab	2.3a	16.7c	6.2a	1.1d	0.32cd
Controlled Release Medium Rate CRmr	1.7ab	3.1a	19.8abc	4.1a	1.2cd	0.38bcd
Controlled Release High Rate CRhr	1.6ab	2.3a	20.2abc	5.6a	1.3bcd	0.31cd
LF 3x/wk 150 ppm N +CRlr	1.5ab	3.3a	24.8a	7.4a	1.8abc	0.54ab
LF 3x/wk 300 ppm N + CRmr	1.4ab	2.6a	25.4a	5.6a	1.8abc	0.47abc
LF 3x/wk 450 ppm N + CR hr	0.9b	2.5a	23.8ab	5.7a	2.2a	0.65a

[z]Means within columns followed by the same letter are significantly different according to Duncan's Multiple Range Test ($p \leq 0.05$)
CR=Osmocote® 14-14-14 LR=3lbs N/yd^3; MR=6lbs N/yd^3; HR=12lbs N/yd^3
LF=Peters®150 ppmN; 300 ppm N; 450 ppm N Plant Quality (1-dead; 5.0=commercially acceptable; 10=dark green healthy plants)

Table 4.32 Growth characteristics of *Liriope gigantea* using different fertilizer rates and regimes.

Treatment Rate	Root[z]Weight (g)	Shoot Weight (g)	Height Plant (cm)	Quality 1-10	N %	P %
No Fertilizer (Control)	2.8ab	8.2ab	21.6b	6.0b	1.2cd	0.62a
Liquid Feed (LF) 1X/wk 450 ppm N	2.1b	8.9ab	31.0a	6.3ab	1.9ab	0.59a
LF 3X/wk 150 ppm N	2.6ab	6.7ab	30.8a	6.9ab	1.7abc	0.61a
Controlled Release Low Rate CRlr	3.2ab	8.6ab	31.1a	7.4ab	1.0d	0.29a
Controlled Release Medium Rate CRmr	2.9ab	7.6ab	28.4a	7.0ab	1.0d	0.27a
Controlled Release High Rate CRhr	2.8ab	5.8b	32.2a	7.4a	1.1d	0.34a
LF 3X/wk 150 ppm N + CRlr	3.4a	10.0a	30.5a	6.9ab	1.4bcd	0.42a
LF 3X/wk 300 ppm N + CRmr	3.2ab	9.1ab	33.2a	7.6a	1.9a	0.54a
LF 3X/wk 450 ppm N + CRhr	2.7ab	8.3ab	30.0a	7.5a	2.0a	0.64a

[z]Means within columns followed by the same letter are significantly different according to Duncan's Multiple Range Test ($p \leq 0.05$)
CR=Osmocote® 14-14-14 LR=3lbs N/yd^3.

Table 4.33 Growth characteristics of *Liriope spicata* using different fertilizer rates and regimes.

Treatment Rate	Root Wt[z] (g)	Shoot Wt (g)	Height (cm)	Plant Quality 1-10	N %	P %
No Fertilizer (Control)	1.1ab	0.6e	15.3c	5.4d	0.86f	0.16d
Liquid Feed (LF) 1X/wk 450 ppm N	1.3ab	1.4ab	18.5ab	6.7bcd	3.5b	0.87ab
LF 3X/wk 150 ppm N	1.5ab	1.2abc	19.0ab	7.9ab	2.9cd	0.81ab
Controlled Released Low Rate CRlr	1.2ab	0.7de	16.0bc	6.1cd	0.87f	0.25cd
Controlled Released Medium Rate CRmr	1.5ab	0.8cde	18.9ab	6.7bcd	1.3e	0.38c
Controlled Released High Rate CRhr	0.9b	0.8cde	17.2bc	6.1cd	2.6d	0.75ab
LF 3X/wk 150 ppm N + CRlr	1.5ab	1.0bcde	21.0a	7.4abc	2.7d	0.68b
LF 3X/wk 300 ppm N + CRmr	1.7a	1.7a	20.8a	8.3a	3.2c	0.83ab
LF 3X/wk 450 ppm N + CRhr	1.1ab	1.1bcd	20.7a	7.0abc	3.9a	0.92a

[z]Means within columns followed by the same letter are significantly different according to Duncan's Multiple Range Test ($p \leq 0.05$).Plant Quality (1=dead; 5.0=commercially acceptable; 10=dark green healthy plants).
CR=Osmocotes® 14-14-14 LR=3lbs N/yd^3; MR=6.bs N/yd^3; HR=12lbs N/yd^3
LF=Peters® 20-20-20; 150 ppm N; 300 ppm N; 450 ppm N

Table 4.34 Growth characteristics of *Liriope muscari* 'Big Blue' using different fertilizer rates and regimes.

Treatment Rate	Root Wt (g)[z]	Shoot Wt (g)	Height (cm)	Plant Quality 1-10	N %	P %
No Fertilizer (Control)	1.3a	1.2a	19.1b	6.9bc	1.1d	0.28d
Liquid Feed (LF) 1X/wk 450 ppm N	1.1a	1.2a	18.0b	7.5ab	2.5b	0.78abc
LF 3X/wk 150 ppm N	1.2a	1.4a	20.2b	7.5abc	2.3bc	0.76abc
Controlled Releasedd Low Rate CRlr	1.2a	1.2a	18.6b	6.7c	1.5cd	0.41cd
Controlled Released Medium Rate CRmr	1.2a	1.2a	17.2b	6.9bc	1.5cd	0.78abc
Controlled Released High Rate CRhr	1.2a	1.4a	20.3b	7.2abc	1.4cd	0.48bcd
LF 3X/wk 150 ppm N + CRlr	0.9a	1.2a	20.5b	7.8a	2.8ab	1.10a
LF 3X/wk 300 ppm N + CRmr	0.9a	1.5a	19.8b	7.8a	2.5b	0.79abc
LF 3X/wk 450 ppm N + CRhr	0.9a	1.5a	23.5b	7.9a	3.6a	0.9ab

[z]Means within columns followed by the same letter are significantly different according to Duncan's Multiple Range Test ($p \leq 0.05$).Plant Quality (1=dead; 5.0=commercially acceptable; 10=dark green healthy plants).
CR=Osmotoes® 14-14-14 LR=3lbs N/yd^3; MR=6.bs N/yd^3; HR=12lbs N/yd^3
LF=Peters® 20-20-20; 150 ppm N; 300 ppm N; 450 ppm N

CHAPTER 5
SUMMARY AND CONCLUSIONS

Experiments were conducted to morphologically establish the correct identification of 19 cultivars of *Liriope* and *Ophiopogon* and collect, mount, and label the 19 cultivars in the Louisiana State University Herbarium for permanent record. Effects of sun and shade on landscape performance, effect of rates and methods of fertilization, and effects of pruning percentages on bib production were also studied.

This research has identified distinctive characteristics to morphologically distinguish the genera *Liriope* from *Ophiopogon* for those who categorize these as two genera. The findings also identify characteristics to distinguish the unique species within the genera. Once the species is correctly identified cultivars can be categorized within the correct species. Some of the cultural factors determined for specific cultivars will aid horticulturists and green industry professionals in producing, labeling, and marketing a consistent product for consumers.

MORPHOLOGICAL DIFFERENCES AND HERBARIUM MOUNTS

Of the 19 cultivars studied for proper identification, four were found to be incorrectly named as to species. Genera are identified according to flower characteristics. *Liriope* has erect flowers and a hypogynous ovary; *Ophiopogon* has nodding flowers and a semi-epigynous ovary. Species are identified by a combination of flower, leaf, and root system characteristics. *Liriope muscari* has a tufted root system in combination with the erect flowers and hypogynous ovary. *Liriope gigantea* has a rhizomatous root system in combination with erect flowers and distinctive leaves that are described as leathery. *Liriope spicata* has a rhizamoutous root system and erect flowers on scapes shorter than the leaves which are grass-like. *Liriope exiliflora* has a rhizomatous root system, and erect flowers with flower fascicles widely separated on the rachis and taller than the dark green foliage. *Ophiopogon intermedius* has a hemi-epigynous ovary,

nodding flowers on pedicels that are 3-6 mm long, rachis of flowers shorter than the variegated leaves, and a rhizamatous root system. *Ophiopogon japonicus* has a hemi-epigynous ovary, and nodding white flowers that grow close to the crown and are inconspicuous within the thin black foliage. *Ophiopogon planiscapus* has nodding flowers with hemi-epigynous ovaries. Flowers are close to the top of the single scape that is as tall as or taller than the black leaves. *Ophiopogon jaburan* has nodding flowers on pedicels that are 6-8 mm long. The ovary is hemi-epigynous. The flowers scapes are taller than the foliage.

At the beginning of the experiment *Ophiopogon jaburan* was the scientific name given to the plant that was later found to be *Ophiopogon intermedius* according to flower characteristics and type of root system. Measurements of the flowers of *O. intermedius* match the *O. intermedius* measurements of P.Fantz, personal communication September, 2006. The pictures and descriptions of *O. jaburan* support what Bailey described in 1929. *Liriope muscari* 'Evergreen Giant' and *Liriope muscari* 'Merton Jacobs' Supergreen™ were both found to be *Liriope gigantea*. This is the first study done that morphologically makes distinctions between *Liriope muscari* and *Liriope gigantea. Liriope gigantea* is a species described by Hume (1961) as one found growing abundantly in Florida. Other areas of the south have not recognized it as a separate species but have called it *Liriope muscari*. *Lirope muscari* 'Samantha' was found not to be a *muscari* but compared favorably to *Liriope exiliflora* which has not been identified in Louisiana to my knowledge. *Liriope gigantea* and *Liriope exiliflora* are both known in Florida and have been described in the literature by Hume (1961), Skinner (1971), and Fantz (1993). The species name *Liriope muscari* is often misused in the industry to name plants that are *Liriope exiliflora* and *Liriope gigantea* as well as *Ophiopogon intermedius*. Of the 19 herbarium mounts, two had to be annotated in December 2006 and January 2007 when more information was

obtained, relating to measurements and pictures of flowers of *O. intermedius* described by Paul Fantz, personal communication, (2006). Due to morphological characteristics identified during this research, *Liriope* cf. *exiliflora 'Samantha'* replaced *Liriope muscari 'Samantha'* and *Ophiopogon intermedius* replaced *Ophiopogon jaburan* for the plant known in the south as Aztec grass. These are the first vouchers of *Liriope* and *Ophiopogon* in the Herbarium at LSU. The vouchers are on the Louisiana State University Herbarium website under the family Liliaceae.

EFFECTS OF SUN AND SHADE ON GROWING CONDITIONS ON LANDSCAPE PERFORMANCE

Liriope muscari 'Monroe White', *Ophiopogon japonicus* commonly called monkey grass, and *Ophiopogon intermedus* commonly called Aztec grass, were found to perform significantly better in the shade than they perform in the sun. There were no significant differences in performance within other cultivars between sun and shade. There were no significant differences in any of the cultivars plant canopy widths in the sun compared to shade. There did not seem to be any pattern with regard to genera. *Liriope muscari* 'Big Blue' and *Liriope muscari* 'Densiflora' performed equally in the sun and shade. 'Big Blue' was consistently a good performer in sun and shade whereas 'Densiflora' was consistently lower performing than many other cultivars in the shade, however performed equal in the sun to it's own shade performance. Three cultivars, *L. muscari* 'Monroe White', *O. japonicus*, and *O. intermedius* showed statistical significance in their shade performance over their sun performance and 16 showed no significant difference in their performance in the shade verses the sun.

Liriope gigantea 'Merton Jacobs' Supergreen™ performed significantly better in the sun than the two low performers *Ophiopogon japonicus* 'Silver Mist' and *Liriope muscari* 'Monroe White'. These two cultivars tend to burn or bleach out in the sun. *Liriope muscari* 'Big Blue'

performed significantly better than *Liriope muscari* 'Monroe White' which reinforces common knowledge that 'Monroe White' is a shade plant only. *Ophiopogon japonicus* performed significantly better than *Lirope muscari* 'Densiflora' or *Liriope gigantea* 'Evergreen Giant'. *Liriope gigantea* 'Merton Jacobs' Supergreen Giant™ commonly called supergreen, was the highest rated and 'Monroe White' the lowest rated. Though there were few significant differences, the ratings and the research observations did indicate which cultivars performed satisfactorily in diverse landscapes, which is specific information that has been requested by the green industry professionals.

EFFECTS OF FIVE PRUNING PERCENTAGES ON BIB PRODUCTION

Pruning does not benefit bib production except for twenty percent pruning in some species. Admittedly, pruning is necessary in the landscape to control insects and disease and for cosmetic purposes. This study supports Hayes et al. (1999) that *Liriope* shoots not pruned at division produce more roots faster than when the shoots were pruned to a 5 cm height, regardless of the root volume. Growers producing liriope liners should be able to root and sell a crop quicker if shoots are not pruned at division. There are no prior studies to my knowledge that compare different pruning percentages. This study did not find any differences in quality of bib production with differences in percentages of bib pruning indicating that pruning is not necessary for bib production, only for use in the landscape.

EFFECTS OF RATES AND METHODS OF FERTILIZATION IN NURSERY PRODUCTION

In this study, *Liriope* spp. and *Ophiopogon* spp. root weight and shoot weight were not influenced by any treatments over the control. Plant height, quality, N and P were the most influenced variables for all combinations of LF + CR and LF alone over any of the CR rates of fertilization. LF (1X/wk 450 ppm N) was statistically similar to and sometimes greater than LF

(3X/wk 150 ppm N). It would appear that fertilization with LF alone or in combination with CR increased height and quality. As expected, CR fertilization alone showed improved height and plant quality over no fertilizer. This represents the first study to statistically show how different regimes of fertilization effect the growth of *Liriope* and *Ophiopogon* bibs in greenhouse production.

Future Research

Molecular work on these species and cultivars will be a giant step in confirming the morphological descriptions. In the near future molecular studies would be beneficial for the cultivar 'Big Blue' which has an uncertain origin. There are an unknown number of different plants in the industry that are called *Liriope muscari* 'Big Blue', also, the cultivar 'Densiflora' needs further morphological and molecular studies to determine its species. Molecular and morphological studies need to be conducted on *Liriope exiliflora* grown in Florida and the cultivar we call 'Samantha' as they compare favorably and 'Samantha' has been erroneously called *Liriope muscari*. We need to look more closely at the species we call *Liriope muscari* to determine how many different species are included under this species. It would benefit the landscape industry and the nursery profession to perform sun/shade trials on new cultivars that are being introduced so determination can be made on how those cultivars perform in different climates and under different cultural conditions.

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APPENDIX A: CARBON 13 ANALYSIS

Job number 06-071

Date received: 3/14/2006
Date returned: 3/23/2006

Name: Catherine Broussard

Institution: Louisiana State University
Department of Horticulture
137 Julian C. Miller Hall
LSU
Baton Rouge, Louisianna 70803

Sample description: plant samples

Isotope analyzed: carbon
standard used: pdb

SIRFER #	sample id	genus	wt(mg)	13C/12C	wt%C
06-937	1	Liriope	1.664	-25.0	43.0
06-938	2	Ophiopogon	1.884	-26.2	45.4
06-939	3	Cynodon	2.430	-14.1	41.3
06-940	4	Lolium	2.089	-30.7	41.2
			stdev	0.01	0.26

APPENDIX B: NOTES FROM KEW GARDENS

Folder: Eastern Asia

Liriope muscari, Bailey, var communis, Nakai Flora of Japan Aug 4, 1951 slide 1

Ophiopogon spicatus Gawl Herbarium Savatier Japan 1909 slide 2

Type folder-slide 3 Ophiopogon spicatus Gawl Japonica Nagasaki 1863 and 2 varieties

Ophiopogon spicatus slide 4

Liriope graminifolia 1867 var densiflora slide 4

Liriope platyphylla slide 5 on signs in garden it says syn muscari

Oct 18, 1964

Convallariacea Liriope spicata Lour 4 Oct 1962 slide 6

Liriope platyphylla slide 7

Liriope platyphylla slide 8 (I notice it is bushier)

Liriope platyphylla Wand et Tang syn L. muscari var commenis Nakai Aug 1972 slide 9

Liriope graminifolia var densiflora (Wright) slide 10

Liriope graminifolia var latifolia. A note on the far right corner is the oldest label and it says

Ophiopogon spicatus Ker April 1866 slide 11

Flora from China

Liriope graminifolia Bak Oct 3, 1947 slide 12

Liriope gracilis Nakai Sept 26, 1947 slide 13

Plants of India

Slide 14 1917 card says *Ophiopogon intermedius* Don

But the newer note has *Liriope graminifolia* (L) Baker

Slide 16 to show how they changed labels *Liriiope spica* written over *Allum sp*

Slide 17 to show some only have the genus

Slide 18 only Genus- *Liriope* Flora of Indo China, Semi woody, note the wide leaves

Flora of Philippeans

Slide 19 very tall Liriope as it is bent over

Liriope graminifolia (L.) Baker no root material July 1930

This is a type slide 20 labeled *Ophiopogon muscari* very old you can tell from the writing so note there is a change in name *Ophiopogon-Liriope*

Slide 21/22 is interesting because of the note so I actually took 2 slides

Slide 23 another note which I have hand written the back page *Liriope muscari* (Decne.) Baily var variegate Bailey

The note said "band of purple next to the fleshy part. Young inflorescence appearing which has 3-4 mm x.emm bracts green speckled purple emerging between the tightly packed whitish buds. Leaves to 35 cm, recessed to 1 cm broad furrowed, slightly concave and with a trickenen midrib.

Slide 24 *Liriope muscari* Decne

Folder: Eastern Asia

Convallariaceae

Ophiopogon

O. bockianus

O. bockianus var angusti folia

O. bodimeri

O. cavaleria

O. clavalus

Slide 25 Type *O. bockianus* var angustifolius red trim folder

Slide 26 *Ophiopogon bockianius* Diet

What does Determinavit mean?

Ophiopogon clavalus wright tpe folder with a write up slide 27

Slide 28 *Ophiopogon bodinier* the type folder

Slide 29 *Ophiopogon wallichianium*

Slide 30 and 31 are *Ophiopogon japonicus*

Next folder

Ophiopogon bodinier and *O. japonicus* resemble in this folder slides 31 and 32 are comparisons

Next folder

O. crassifoliatus

O. dracaenoides

O. faurier

O. formosanum

Slide 23 crassifolicitus woody stem

Slide 34 *O. dracaenoindes* (Baker)

And next slide 35 is *O. formosaum*

Folder says 4 China and Japan

Hong Kong

Liriope carnea slide 36 and beginning of the next role slide 1

Next slide is a type folder

L. kansuensis thin leaves, spikes are long and florets on terminal

Slide 2 *Liriope minor* type 1862

Slide 3 showing the changes which I say are the confusing taxonomy. Very old specimen 1867 stamp

*Liriope minor*___makino

A slide taken in Japan when I was a week old or 6 days. Slide 4 is my birthday slide

Slide 5 *Liriope spicata* Lour July 11, 1951 very tall plant

Slide 6, from China 1845 on blue herbarium paper. *Ophiopogon gracelis*

Slide *7 Liriope graminifolia* (L.) Baker Agu 15, 1970 note the variegation in the leaves

Slide 8 note the change in name *Liriope spicata* was *Mondo wallichianum*

Slide 9 *Liriope spicata* note the rhizomes

Slide 10 *L. spicata* also 1909 looked at inflorescence

Slide 11 *L. graminifolia* 1930

12 *L. graminifolia* Baker note the large nodes rooting system

13th slide *Liriope spicata* var. Longipus in a type folder

New folder

China and Japan

L. muscari L. platyphylla Convallariaceae

Slide 14 *Liriope muscari*, Bailey var communis Nakais

Slide 15 type folder *Ophiopogon spliatus* 2 different var

Slide 16 *Liriope platyphylla* 1964 which I believe is syn muscari

Folder: India

Slide 17 *Ophiopogon draceanoides* 1989 (Baker) Hook f. woody stems

Slide 18 The type folder *O. draeanoides* Baker

Slide 19 *O. clardei* note the woody stems

Slide 20 is the type folder of the above species *O. clarkei*

Slide 21 from a type folder O. intermedius on one card and japonica on another

Slide 22 *O. wallichiaius* has a drawing of the floral parts with explantation which I found helpful. Says flower perygnous

Slide 23 could be *O. intermedius* or *O. wallichiaius* says blue berries specimen from 1872-name revised in 1990 possibly. The work or name Flugger is also associated with this type so *O. intermedius = O. wallichiaius*

Slide 24 A type folder I found interesting because it has *Flugger japonica* Rich var F. intermedius

Slide 25 *O. wallichianius* white flower 1929

The more folders I look through the more I think there could be method to this madness. The best I can tell is that *Liriope* and *Ophiopogon* genus have in the past been used interchangeably. Muscari is a synonym. We must use a key and before we can begin to talk about cv we must be

sure we have the genera explained and correctly identified. *Muscari* is a scientific term. A 'real' specific epitet.

Folder: East Asia

Convallariaceae

Ophiopogon

This first picture is called *Mondo japonicus* and *Ophiopogon japonicus* long thin leaves

Seems *O. japonicus* has long thin leaves

Next folder has a lot of type specimens

Slide 26 *Ophiopogon lofowuse* or lofoullse or something I can't read.

Slide 27 *Liriope minor* (Maximum) M

Slide 28 *O. peliosauthorides* a type specimen in folder

Then I found numerous specimens of it on herbarium paper and drew what the leaf looked like in my notebook.

There was a herbarium paper with *O. wallichiana* Hook J and at the botton of the page on R corner card says Deterninavit

Ophiopogon planiscapus took a slide 29 of *Ophiopogon planiscapus* all the specimens of it say plants of Japan

Slide 30 days *Mondo japonicum=Ophiopogon japonicus* Determinavit

Slide 31 *Ophiopogon sparsiflorus* Way May 9, 1989

Slide 32 *O. stenophyllus* (Merr.)

APPENDIX C: PICTURES OF 19 CULTIVARS OF RESEARCH PLANTS

Ophiopogon intermedius

Liriope muscari
'Big Blue'

Liriope muscari
'Christmas Tree'

Liriope muscari
'Densifolia'

Liriope gigantea
'Evergreen Giant'

Liriope muscari
'John Burch'

Ophiopogon japonicus

Ophiopogon planiscapus

Ophiopogon japonicus
'Nana'

Ophiopogon japonicus
'Silver Mist'

Liriope muscari
'Monroe White'

Liriope muscari
'Royal Purple'

Liriope exiliflora
'Samantha'

Liriope spicata

Liriope spicata
'Silver Dragon'

Liriope muscari
'Silvery Midget'

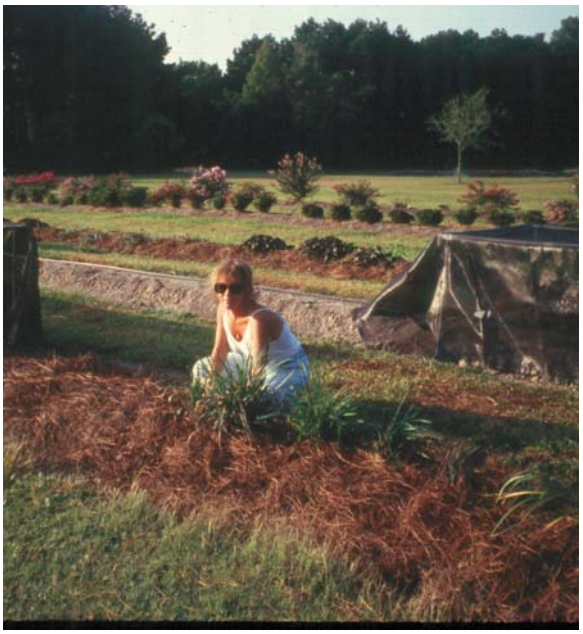
Liriope gigantea
'Merton Jacobs' Supergreen Giant™

Liriope muscari
'Variegata'

Liriope muscari
'Wideleaf Webster'

Ophiopogon jaburan

APPENDIX D: PICTURES OF RESEARCH PLOTS (SUN/SHADE)



APPENDIX E: CHLOROPHYLL ANALYSIS TABLE

Cultivar	Shade	Sun	Significance
Ophiopogon intermedius	47.79 ± 3.80	32.26 ± 3.80	*
Ophiopogon japonicus 'Silver Mist'	15.87 ± 3.18	21.07 ± 3.18	ns
Liriope muscari 'Monroe White'	56.20 ± 5.28	47.73 ± 5.28	ns
Liriope muscari 'Royal Purple'	59.70 ± 2.71	45.32 ± 2.71	**
Liriope exiliflora 'Samantha'	55.14 ± 2.41	48.28 ± 2.41	ns
Liriope spicata 'Silver Dragon'	23.09 ± 3.94	23.94 ± 3.94	ns
Liriope muscari 'Silvery Midget'	58.25 ± 3.51	52.83 ± 3.51	ns
Liriope spicata	54.79 ± 1.80	43.74 ± 1.80	**
Liriope gigantea 'Merton Jacobs' Supergreen™	61.37 ± 4.52	58.87 ± 4.52	ns
Liriope muscari 'Variegata'	54.35 ± 3.79	34.93 ± 3.79	**
Liriope muscari 'Wideleaf Webster'	55.13 ± 2.75	40.09 ± 2.75	**
Liriope muscari 'Big Blue'	59.21 ± 1.48	45.96 ± 1.48	**
Liriope muscari 'Densiflora'	53.83 ± 3.18	41.37 ± 3.18	*
Liriope gigantea 'Evergreen Giant'	60.04 ± 5.58	45.78 ± 5.58	ns
Liriope muscari 'John Burch'	55.79 ± 2.89	43.60 ± 2.89	*
Ophiopogon japonicus	54.64 ± 4.52	41.57 ± 4.52	ns
Ophiopogon japonicus 'Nana'	58.69 ± 2.66	49.97 ± 2.66	*
Liriope muscari 'Christmas Tree'	61.92 ± 1.68	43.71 ± 1.68	*

APPENDIX F: TERMS DEFINED

Acaulescent - Without a stem, or the stem is so short that the leaves are apparently all basal, as in dandelions.

Bib – "A shoot or plantlet consisting of one crown with leaves and attached roots and/or stolons" according to a compilation of definitions from nursery operators.

Caespitose - Growing in dense clumps or tufts.

Conserved name – A conserved name or nomen conservandum (plural nomina conservanda) is a scientific name that enjoys special nomenclatural protection.

Fascicles - A tight bundle or cluster

Inflorescence – The flowering part of a plant; a flower cluster; the arrangement of the flowers on the flowering axis.

Pedicel – The stalk of a single flower in an inflorescence.

Peduncle – the stalk of a solitary flower or of an inflorescence.

Perianth – The calyx and corollan of a flower, collectively, especially when they are similar in appearance.

Putative clones - Commonly regarded as such

Rachis – the main axis of a structure, such as a compound leaf or an inflorescence.

Rhizomatous – With rhizomes, horizontal underground stems.

Scapes - A leafless peduncle arising from ground level (usually from a basal rosette) in acaulescent plant.

Synonyms - One or two or more scientific names applied to a single taxon.

Taxon - A taxonomic category, as a species or genus.

Tissue culture - Growing parts of plants aseptically on an artificial medium under controlled environmental condition

VITA

Mary Catherine Broussard, daughter of Vernon Joseph and Mirza Berthelot Broussard, was born in Baton Rouge, Louisiana. on the 23rd of June, 1952.

After graduating from Redemptorist High School in May 1970 she enrolled at Louisiana State University where she graduated in 1976 with a bachelor of science in Agriculture. Catherine enrolled in the School of Social Welfare in the same year and received her master's degree in Social Welfare in 1978.

Catherine enrolled in the Department of Horticulture at Louisiana State Universtiy in 1998 and is currently a candidate for a Doctor of Philosophy in that department.