HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

The use of any trade name in this article does not imply an endorsement of the equipment, product or process named, nor any criticism of any similar products that are not mentioned.

Evaluating North and South Florida Landscape Performance and Fruiting of Ten Cultivars and a Wild-type Selection of *Nandina domestica,* a Potentially Invasive Shrub[1]

Gary W. Knox[2] and Sandra B. Wilson[3]
Department of Environmental Horticulture
University of Florida – IFAS, NFREC, Quincy, FL 32351

Abstract

A wild-type selection of heavenly bamboo (*Nandina domestica*) and ten cultivars were evaluated for plant performance, growth, flowering, and fruiting in north and south Florida. Onset of flowering generally began by March and April in south Florida and 4 to 8 weeks later in north Florida. Fruit was first noted 8 to 16 weeks after most selections began flowering. Landscape performance and fruit production varied widely among taxa and locations. The dwarf selections 'Filamentosa' and 'Firepower' failed to flower or fruit in either location; while the medium-sized selection, 'Moon Bay', did not flower or fruit in south Florida, and the medium-sized selection, 'Gulf Stream', flowered but did not fruit in south Florida. Large-sized selections produced more fruit than did dwarf and medium-sized cultivars. Greater plant survival with generally heavier fruiting was observed in north Florida than in south Florida. In north and south Florida, 'Monum' and 'Compacta' produced more fruit than did the wild-type selection. Seed viability was fairly consistent among cultivars, ranging from 73 to 86%.

Index words: exotic plants, heavenly bamboo, invasive plants, variety trials.

Species used in this study: Heavenly bamboo (*Nandina domestica* Thunb.) cultivars 'Filamentosa', 'Harbour Dwarf', 'Jaytee', 'Firepower', 'Gulf Stream', 'Moon Bay', 'Compacta', 'Monum', 'Royal Princess', and 'Umpqua Chief'.

Significance to the Nursery Industry

In an effort to curb the use and distribution of invasive plant species, more than 38 botanical gardens, garden clubs, professional societies, and nursery associations have adopted voluntary codes of conduct associated with risk assessment, plant selection, importation, and production of ornamental plants. Research on landscape plants is critical to provide scientific evidence of whether a plant is currently invasive or has great potential to become invasive and to set priorities for developing or promoting sterile cultivars. We evaluated 10 cultivars and the species form of heavenly bamboo (*Nandina domestica*) grown in north and south Florida for 100 weeks. Plant performance and fruit production varied widely among cultivars and locations. Large-sized cultivars 'Compacta' and 'Monum' produced fruit in quantities comparable to the wild-type selection and could therefore have a greater likelihood of escaping into natural areas than would medium-sized or dwarf cultivars that produced few if any fruit. Above average visual-quality rankings, good survival, and poor or no fruit production observed for 'Gulf Stream', 'Jaytee', and 'Harbour Dwarf' support wider landscape use of these selections in the south Florida landscape. In north Florida, where wild-type heavenly bamboo has escaped and is considered invasive, 'Gulf Stream', 'Jaytee', and 'Harbour Dwarf' had good seasonal appearance, excellent survival, and limited fruit production, meriting landscape use if managed to prevent escape. Results of this study emphasize the importance of cultivar and geographic distinctions in determining the invasive status of a species.

Introduction

Florida is the second largest producer of landscape ornamental plants in the United States with an estimated $9.9 billion in total sales during 2000 (15). While most intentionally introduced species remain in their cultivated settings, some escape cultivation and invade natural areas. Although south Florida has been particularly affected by the invasion of nonindigenous species, the problem is statewide in scope. Today, approximately 15% of the 10 million acres of public conservation lands in Florida have been disrupted by invasive nonindigenous plants, costing the state more than $29 million annually for control and management practices (Don Schmitz, personal communication, 2005). In an effort to address the negative effects of nonnative species in natural areas, The University of Florida/Institute of Food and Agricultural Sciences (IFAS) has developed a status-assessment tool to guide IFAS recommendations of nonnative plants (11). To date, this tool has been used to evaluate 263 species. In addition to the 30 species that were already prohibited by State or Federal law in Florida, an additional 48 species were not recommended by IFAS for use in one or more regions of Florida because of their current invasive status (10). Of these 78 prohibited or not recommended species, at least 32% had been introduced for landscape use (16). There is often a delay between when a species is determined to be invasive and when it is no longer produced commercially. Caton (4) reported that almost 60% of the plants on the Florida Nursery Growers and Landscape Association (FNGLA) voluntary 'do not sell' list were available in 2004 from Florida nurseries.

[1]Received for publication on November 18, 2005; in revised form April 19, 2006, Florida Agricultural Experiment Station journal series R-11033. Authors gratefully acknowledge funding from the Florida Department of Environmental Protection and the Florida Nursery, Growers, and Landscape Association. We extend gratitude to Laurie Mecca, John Zadakis, and Patricia Frey for providing technical assistance throughout the study.

[2]Professor. E-mail address: gwknox@ufl.edu.

[3]Associate Professor, Department of Environmental Horticulture, University of Florida–IFAS, Indian River Research and Education Center, Fort Pierce, FL 34945.

Voluntary efforts to help reduce the production, distribution, and use of invasive ornamentals can be strengthened through systematic research that addresses cultivars and their potential to spread. In Florida, significant controversy surrounds the current invasive status of a popular ornamental shrub, heavenly bamboo (*Nandina domestica* Thunb.). The wild-type of heavenly bamboo is adapted to conditions ranging from full sun to shade and moist to dry soils in USDA Hardiness Zones 6 to 10 (5, 8). The species is variably rhizomatous depending on the clone and is characterized by tripinnately compound leaves that are dark green turning blush to reddish-purple with the onset of low temperatures (12). Terminal panicles of white flowers appear in mid to late spring and are followed in summer and autumn by red fruit, each containing two or sometimes three seeds about 50 mg (0.0018 oz) in weight. Seeds contained within a fleshy red pericarp can augment predation, distribution, and establishment (19). The ornamental characteristics and adaptability of heavenly bamboo make it an extremely popular landscape plant. A Florida study documented the plant's importance, reporting that heavenly bamboo was grown by 14.9% of the responding nurseries with estimated statewide total sales of $3.3 million in 2003 (31).

Native to forest understories of central China and Japan and west to India, and introduced to the United States before 1804 (16), the species has escaped cultivation in nine states in the southeastern U.S. (27), including Florida (five counties) (33). The Florida Exotic Pest Plant Council (FLEPPC) lists heavenly bamboo as a Category I invasive species because it is ecologically damaging to natural areas (9). The IFAS Assessment documented self-sustaining and expanding populations of heavenly bamboo in natural plant communities of north and central Florida (10) where it is altering the light environment (5), and displacing native vegetation (16). Consequently, it is not recommended for planting in north Florida (area annually receiving 420 or more chill units) and central Florida (area receiving more than 110 but fewer then 420 chill units), and the IFAS Assessment recommends caution if planting in south Florida (receiving 110 or fewer chill units) (10).

Current designation of the invasive status of heavenly bamboo was based on the wild-type selection of the species, since landscape use of heavenly bamboo cultivars in the southeastern United States was not common until the 1980s (22). However, since the 1980s, production has shifted to selected cultivars that are widely utilized for foundation plantings, borders, and massed groupings. Over 40 cultivars of heavenly bamboo exist but no information is available in reference to their potential invasiveness. Based on cultivar evaluations of Mexican petunia (*Ruellia tweediana* Griseb.) (29) and butterfly bush (*Buddleja davidii* Franch.) (30), it is strongly suspected that seed production and viability could vary among heavenly bamboo cultivars and by geographic location. Such data for specific cultivars are of critical importance for the nursery and landscape industry when making informed decisions about which plants to grow and for implementing newly developed voluntary codes of conduct for invasive plants (6). The overall objective of this study was to evaluate plant performance, growth, flowering, fruit production, and seed viability of a heavenly bamboo wild-type selection and 10 cultivars planted in south Florida (Fort Pierce, USDA zone 9b) and north Florida (Quincy, USDA zone 8b).

Materials and Methods

Plant material and site conditions. The nursery-grown form of the species ('wild-type selection') and 10 cultivars of three size classes were chosen for this study based on popularity and availability (Table 1). Clonally propagated plants were obtained in finished #1 containers (Grandiflora division of San Felasco Nurseries, Gainesville, FL; Wight Nurseries/Monrovia Growers, Cairo, GA) or as plugs (Magnolia Gardens Nursery, Waller, TX) that were transferred to #1 containers at Quincy. Field plantings of nine uniform #1 plants of each taxon were established in south Florida (Fort Pierce) and north Florida (Quincy) on January 28, 2003. Plants were placed 1.2 m (4 ft) on center in beds covered with polyethylene mulch (Synthetic Industries Inc., Alto, GA). Plants were sub-irrigated by filling canals (south Florida) or drip irrigated (north Florida) as needed and fertilized 4 and 64 weeks after planting with 18 g (0.6 oz) of 12-month 15N–9P–12K Osmocote Plus (Scotts Co., Marysville, OH) in the area 30 to 45 cm (12 to 18 in) from the main stems. No significant pest outbreaks were observed at either location throughout the experiment.

Field conditions for south Florida were as follows: Ankona sand with 2.2% organic matter, pH 5.7, average monthly rainfall 4.0 cm (1.6 in), and mean monthly minimum and maximum temperatures 11.9C (53F) and 32.1C (90F), respectively. Field conditions for north Florida were as follows: eroded Ruston loamy fine sand with 1.8% organic matter, pH 5.2, average monthly rainfall 4.5 cm (1.8 in), and mean monthly minimum and maximum temperatures 6.4C (44F) and 30.8C (87F), respectively. Chilling units received for 2002–2003 and 2003–2004 were 234 and 123 for south Florida and 697 and 741 for north Florida.

Visual quality and plant growth. Visual quality (plant color and form) was independently assessed monthly by three individuals for each cultivar at each location. The assessments considered the combined visual quality of the three plants that were grouped together in each plot. Assessments were performed on a scale from 1 to 5 where 1 = poor quality, not acceptable, severe leaf necrosis or yellowing, 2 = fair quality, marginally acceptable, 3 = average quality, adequate and somewhat desirable form and color, 4 = good quality, very acceptable, nice color and good form, and 5 = excellent quality and landscape value. Plant height and two perpendicular widths were recorded and the crown diameter of each plant was measured at the soil surface after 100 weeks (December 15, 2004).

Flowering, fruit production, and seed viability. Observations of flower initiation and fruit set were recorded monthly in north and south Florida, but presented as the cumulative average number of surviving plants that flowered in each location each year. After 86 weeks (September 2004), all fruits were removed at each location (regardless of maturity) and counted. Mature and immature fruits were separated for subsequent seed testing. Seeds were manually isolated from pericarp tissue using a seed trough (Hoffman Manufacturing, Inc., Albany, OR). Viability tests were performed for the four taxa that generated enough mature seed for analysis ('Compacta', 'Monum', 'Umpqua Chief', and the wild-type selection). In accordance with AOSA protocols (1), seed-viability tests were replicated twice on 100 seeds per taxon. Seeds were provided to Mid-West Seed Service, Inc. (Brookings, SD) where

Table 1. Taxon name, size category, and description (8, 25) of eleven heavenly bamboo (*Nandina domestica)* taxa evaluated during the study.

Taxon	Size category[z]	Description
'Filamentosa'	Dwarf	Finely dissected leaves give this plant a lacy, fern-like appearance; New foliage is reddish becoming bright green in summer and turning orange, bronze or purplish red in fall; Slow growing; Sometimes called *Nandina domestica* var. *filamentosa* 'Threadleaf', *N.* 'San Gabriel' and *N.* 'Kirajuse'.
'Harbour Dwarf'	Dwarf	Branches from the ground and forms a dense mound of blue-green summer foliage with red-tinged winter coloration; Spreads rhizomatously.
'Jaytee' (Plant Patent No. 14668; Harbour Belle™)	Dwarf	New, more robust form of 'Harbour Dwarf'; Fine compound leaves with burgundy fall color.
'Firepower'	Medium	Dwarf similar to 'Atropurpurea Nana' but without contorted leaves; Foliage turns brilliant red in fall and winter.
'Gulf Stream' (Plant Patent No. 5656)	Medium	Variable red-green winter coloration; Extremely dense growth; Does not sucker like 'Harbour Dwarf'.
'Moon Bay' (Plant Patent No. 5659)	Medium	Dwarf with a mounded habit; Shiny, light green summer leaves with red hues in winter.
'Compacta'	Large	Green foliage in summer turning brilliant red in fall and winter.
'Monum' (Plant Patent No. 12069; Plum Passion®)	Large	New growth is deep purplish red; Foliage is deep green in summer and reddish-purple in winter. Considered a medium-sized selection by nursery personnel (18).
'Royal Princess'	Large	Large, upright shrub; Spreads rhizomatously; Narrow leaves, turning reddish-purple in winter.
'Umpqua Chief'	Large	New foliage emerges copper or purple-red and turns blue-green.
Wild-type selection	Large	Broadleaf evergreen shrub; Bluish-green leaves turning to reddish purple in winter.

[z]Large = mature height of 1.5 m (5 ft) or more; Medium = mature height of 0.75–1.5 m (2.5–5.0 ft); Dwarf = mature height of 0.75 m (2.5 ft) or less (25).

they were stained for 6 to 8 hr at 35C (95F) in 1% tetrazolium (2, 3, 5-triphenyl chloride) solution with positive staining patterns confirming seed viability.

Experimental design and statistical analysis. In both north and south Florida, a randomized complete block experimental design was used with 11 taxa replicated three times. Each replication consisted of three-plant samples. Data from individual plant samples (three) from each plot were combined. Plots with fewer than three plant samples (due to plant loss) were averaged and used as the means for that experimental unit. Percentage data were transformed by a sqrt arcsine (13) prior to conducting an analysis of variance (ANOVA). Untransformed means were separated by LSD, p = 0.05 level. An ANOVA was performed on each collected variable using the SAS statistical software program (SAS Institute, Inc., 1989) and taxa means for the size categories were separated by LSD, p = 0.05 level.

Results and Discussion

Visual quality, plant growth, and survival. In 2003, visual-quality ratings (averaged among all months) were very good to excellent for 'Jaytee', 'Compacta', and 'Monum' in south Florida and good to very good for 'Royal Princess' and 'Umpqua Chief' in north Florida (Table 2). In 2004, average visual-quality ratings were slightly lower than those reported for 2003 except for 'Gulf Stream' (Table 2). Visual quality of 'Filamentosa' dramatically decreased throughout the study at both locations. Although 'Firepower' maintained a nice form throughout the study, lower rankings were attributed to mottled foliage color as brilliant red initial attributes were lost and never regained. These visual quality assessments are of particular interest from an ornamental perspective, because heavenly bamboo is not as commonly used in south Florida landscapes as it is in north Florida landscapes (S.B. Wilson and G.W. Knox, personal observations), yet the majority of the taxa evaluated performed well in either location.

Table 2. Average visual-quality rating (based on plant color and form) of eleven heavenly bamboo taxa grown in north and south Florida for 100 weeks. Level of performance is rated 1 (poor quality) to 5 (excellent).

	2003		2004	
Taxon	South FL	North FL	South FL	North FL
'Filamentosa'	2.28	3.07	1.73	1.88
'Harbour Dwarf'	3.88	2.72	3.56	2.20
'Jaytee'	4.01	2.61	3.38	2.12
'Firepower'	3.55	2.71	3.14	2.51
'Gulf Stream'	3.56	2.47	4.20	2.61
'Moon Bay'	3.23	2.43	3.03	1.98
'Compacta'	4.33	3.10	4.17	3.35
'Monum'	4.09	3.15	3.74	3.22
'Royal Princess'	3.28	3.50	3.11	2.68
'Umpqua Chief'	3.95	3.42	3.41	2.34
Wild-type selection	3.97	2.94	3.30	2.83
LSD (0.05)	0.42	0.39	0.62	0.51

Table 3. Maximum visual-quality rating (based on plant color and form) and respective peak month(s) of eleven heavenly bamboo taxa grown in north and south Florida. Level of performance is rated 1 (poor quality) to 5 (excellent).

	2003				2004			
Taxon	South FL	Peak month(s)	North FL	Peak month(s)	South FL	Peak month(s)	North FL	Peak month(s)
'Filamentosa'	4.67	July	3.89	July	2.33	July	2.67	November
'Harbour Dwarf'	4.78	June, July	3.78	November	5.00	July	2.56	January, November
'Jaytee'	4.89	January, June	3.22	February	4.22	April to July	2.89	June
'Firepower'	4.67	January	4.11	January	3.67	May to July	3.22	November
'Gulf Stream'	4.89	July	3.67	February	4.67	April to July	3.67	November
'Moon Bay'	4.33	January	3.33	January	4.50	May	2.56	June
'Compacta'	5.00	July	4.11	December	5.00	May	3.89	November, December
'Monum'	5.00	June	3.78	October	5.00	May	3.89	June
'Royal Princess'	4.56	July	4.22	June	3.78	July	3.44	October
'Umpqua Chief'	4.89	June	4.00	June to August	4.56	July	3.11	November
Wild-type selection	5.00	July	4.00	April	4.33	May	3.56	November
LSD (0.05)	0.35		0.48		0.50		0.64	

Peak performance varied widely by time, taxon, and location (Table 3). In south Florida, peak ratings were high among taxa ranging from 4.3 ('Moon Bay') to 5.0 ('Compacta', 'Monum', and wild-type selection) in 2003, and from 2.3 ('Filamentosa') to 5.0 ('Harbour Dwarf', 'Compacta', and 'Monum') in 2004. Peak months were recorded in south Florida from January to July in 2003 or from April to July in 2004, depending on the taxon (Table 3). In north Florida, peak ratings were slightly lower, ranging from 3.2 ('Jaytee') to 4.2 ('Royal Princess') in 2003, and from 2.6 ('Harbor Dwarf' and 'Moon Bay') to 3.9 ('Compacta' and 'Monum') in 2004. Peak months in north Florida were recorded from January to July in 2003 and from January to November in 2004 (Table 3). Plants in north Florida may have been slower to establish due to their exposure (while still containerized) to six of the coldest days of the year [lowest daily minimum air temperatures averaging –6.2C (21F)] immediately before the winter planting date. It should be noted that some decline in plant performance was visually observed during the fall of 2004 following hurricanes Frances (September 5) and Jeanne (September 26), but that plants fully recovered. Also, although not significantly different as an independently measured trait, plant mortality undoubtedly contributed to decline in visual quality for some cultivars (Table 4), especially 'Filamentosa', 'Jaytee', 'Gulf Stream', 'Moon Bay', 'Royal Princess', and 'Umpqua Chief' in south Florida and for 'Filamentosa' and 'Moon Bay' in north Florida.

Among the three dwarf taxa in both locations, plant growth (crown diameter, height, and width) was similar, with the exception that 'Harbour Dwarf' in south Florida had a 2.1 times greater crown diameter than did 'Filamentosa' (Table 4). Among the medium-sized taxa in each location, 'Gulf Stream' was taller and wider than were 'Firepower' and 'Moon Bay'. Among the large-sized taxa in each location, 'Compacta', 'Monum', and the wild-type selection had greater crown diameters than did 'Royal Princess' or 'Umpqua Chief'. 'Monum' and 'Compacta' were about as tall as the wild-type selection but were significantly wider in

Table 4. Average crown diameter, plant height, perpendicular plant width, and survival of eleven heavenly bamboo taxa grown in north and south Florida for 100 weeks.

		Crown diameter (mm)		Plant height (cm)		Plant width (cm)[z]		Survival (%)	
Size group	Taxon	South FL	North FL	South FL	North FL	South FL	North FL	South FL	North FL
Dwarf	'Filamentosa'	15.9	11.4	20.4	23.1	15.0	28.4	67	56
	'Harbour Dwarf'	33.7	13.3	20.1	20.7	22.6	32.3	100	100
	'Jaytee'	21.5	11.9	18.1	21.6	24.4	34.2	78	100
	LSD (0.05)	16.1	NS	NS	NS	NS	NS	NS	NS
Medium	'Firepower'	50.5	14.8	39.3	25.9	30.2	28.4	100	100
	'Gulf Stream'	41.4	21.9	45.8	35.7	37.1	35.9	89	100
	'Moon Bay'	39.4	22.8	31.9	29.0	19.0	19.0	56	89
	LSD (0.05)	NS	7.5	10.1	6.0	10.4	14.1	NS	NS
Large	'Compacta'	77.3	52.3	70.5	61.6	48.9	68.8	100	100
	'Monum'	79.3	44.7	84.3	93.0	50.2	68.7	100	100
	'Royal Princess'	44.0	17.9	49.1	42.5	45.8	41.8	89	100
	'Umpqua Chief'	48.7	18.7	60.3	53.9	34.2	48.1	67	100
	Wild-type selection	87.9	62.0	76.4	67.9	39.6	62.8	100	100
	LSD (0.05)	23.7	18.6	11.6	34.1	8.7	22.1	NS	NS

[z]Reported as the average of two perpendicular plant widths.

Table 5. Flowering, total fruit number, and seed viability of eleven heavenly bamboo taxa grown in north and south Florida for 100 weeks.

		Flowering plants (%)				Total fruit no. (n = 9)[z]		Seed viability (%)
		2003		2004		2004	2004	2004
Size group	Taxon	South FL	North FL	South FL	North FL	South FL	North FL	North FL
Dwarf	'Filamentosa'	0	0	0	0	0	0	–[y]
	'Jaytee'	13	0	71	67	2	3	–[y]
	'Harbour Dwarf'	56	100	22[x]	100	0	42	–[y]
Medium	'Firepower'	0	0	0	0	0	0	–[y]
	'Gulf Stream'	0	11	25[x]	22	0	28	–[y]
	'Moon Bay'	0	11	0	13[x]	0	0	–[y]
Large	'Compacta'	33	67	78	89	607	1728	86
	'Monum'	100	100	100	100	1503	1542	73
	'Royal Princess'	0	0	25	33	117	73	–[y]
	'Umpqua Chief'	0	0	33	100	100	353	80
	Wild–type selection	22	44	89	89	148	1503	85

[z]Data collected in 2004 on September 23 (south Florida) and September 3 (north Florida). Because maturity times vary within a single panicle, this value includes both mature and partially mature fruits, all potentially producing 2 seeds.

[y]Seed production absent or insufficient for tetrazolium study.

[x]Flowers did not result in fruit.

south Florida. 'Royal Princess' and 'Umpqua Chief' in north Florida also were considerably smaller than were the other large-sized taxa. Plant vigor, as characterized by height and biomass measured over a set duration, is one of a suite of parameters monitored to assess the ability of a plant to invade (20, 28). It is interesting to note that heavenly bamboo is only listed as invasive in north or central Florida (9), yet plants in north Florida generally did not grow as much as did the plants in south Florida. Conceivably, reduced growth in north Florida could be due to slow establishment (due to January planting date) or altered source-sink demands associated with heavy fruiting.

It should also be noted that heavenly bamboo is reported as a shade-tolerant species occasionally escaping in wet, disturbed hammocks of Florida (32). The ability to capture and efficiently use light can greatly contribute to a plant's competitive ability (3). While establishment, growth, and reproduction are expected to vary under shade and full sun environments, Cherry (5) reported that wild-type heavenly bamboo exhibited high physiological acclimation ability at varying light levels. This suggests that heavenly bamboo has the potential to acclimate well to high light conditions found in north or south Florida.

Flowering, fruit production, and seed viability. In 2003, 'Filamentosa', 'Firepower', 'Royal Princess', and 'Umpqua Chief' did not flower at either location (Table 5). However, 'Harbour Dwarf', 'Compacta', 'Monum', and the wild-type selection flowered in both south and north Florida. Thirteen percent of 'Jaytee' flowered in south Florida, and 11% of 'Gulf Stream' and 'Moon Bay' flowered in north Florida. The onset of flowering generally began 8 and 12 weeks after planting in south and north Florida, respectively. In south Florida, 'Monum' and the wild-type selection flowered 4 weeks earlier than did the other cultivars, and in north Florida, 'Moon Bay' flowered 4 weeks later than did the other cultivars (data not presented). Flowering continued for 8–16 weeks and was often simultaneous with fruiting. This information may be useful since Perrins et al. (21) reported that the length of the flowering period was longer in weedy species as compared to related non-weedy species. Also, long flowering periods may allow a greater accessibility to pollinators and a greater chance of seed set (23). In 2004, only 'Filamentosa' and 'Firepower' failed to flower in both locations (Table 5). All other taxa flowered in both locations except for 'Moon Bay', which flowered in north Florida only.

By 2004, all flowering taxa fruited with the exception of 'Moon Bay' (did not fruit in either location), and 'Harbour Dwarf' and 'Gulf Stream' (did not fruit in south Florida) (Table 5). Large-sized selections produced more fruit than did dwarf and medium-sized cultivars (Table 5). The few fruit found on dwarf and medium selections not only limits their potential for dispersal, but fruit on dwarf selections may also be less likely to be consumed by birds. McPherson (17) reported that birds display decided preferences for foraging in taller plants and from abundant rather than rare food sources.

It should be noted that reported fruit yield is conservative in that fruit occasionally fell before maturing, and panicles missing fruit were observed, particularly on dwarf cultivars. Fruit abortion and loss can be caused by pollination problems, maternal resource limitations, climatic conditions, and pest or physical damage (2, 26), but evaluating the causes of fruit loss was not within the scope of this study.

Most taxa produced more fruit in north Florida than in south Florida, and in both locations, 'Monum' and 'Compacta' produced more fruit than did the wild-type selection (Table 5). This is of particular interest, since the IFAS assessment concluded that the wild-type form of heavenly bamboo is invasive and not eligible for use in north or central Florida, but that it may be recommended in south Florida if managed to prevent escape (10).

Dwarf and medium-sized cultivars within the experimental plots did not generate enough fruit (despite two seeds per fruit) within the collection timeframe of the study to conduct viability or germination tests. While these cultivars may require establishment for more than 100 weeks to reach full reproductive potential, the limited fruit production by dwarf

selections in this study corresponds with other observations (12).

Seed viability was fairly consistent among large-sized cultivars, ranging from 73 ('Monum') to 86% ('Compacta') (Table 5). This was comparable to the seed viability of the wild-type selection (85%). A short period between the onset of flowering and subsequent seed production and germination has been associated with many invasive species (24). In contrast, the rudimentary embryo characteristic of heavenly bamboo seeds requires considerable time to develop prior to germination, and some embryo abortion is likely (7). Also, regardless of the planting date, germination tends to be delayed until fall (14). Seed collected from a 'Harbour Dwarf' landscape planting and from a natural area where wild-type plants had escaped cultivation had germination rates of 58 and 56%, respectively, after 36 weeks (S.B. Wilson, unpublished data).

In summary, performance, flowering, and fruiting varied among heavenly bamboo cultivars and planting locations. Greater plant survival with heavier fruiting was observed in north Florida than in south Florida. The large-sized cultivars 'Compacta' and 'Monum' produced fruit with viable seed in quantities comparable to the wild-type selection and could therefore have a greater likelihood of escaping into natural areas, as compared to medium-sized or dwarf size cultivars that produced few if any fruit. Above average visual-quality rankings, good survival, and little or no fruit production for 'Gulf Stream', 'Jaytee', and 'Harbour Dwarf' warrant wider landscape use of these selections in the south Florida landscape. In north Florida, where the wild-type heavenly bamboo has escaped and is considered invasive, 'Gulf Stream', 'Jaytee', and 'Harbour Dwarf' had good seasonal appearance, excellent survival, and limited fruit production, meriting landscape use if managed to prevent escape. 'Filamentosa', 'Firepower', and 'Moon Bay' did not fruit but were not as attractive as the other taxa.

Literature Cited

1. Association of Official Seed Analysts (AOSA). 2000. Tetrazolium testing handbook. AOSA, Inc., Las Cruces, NM 29:1–18.

2. Banelos, M.J. and J. Obeso. 2005. How is fruit production regulated in the dioecious fleshy-fruited shrub *Rhamnus alpinus*? Basic Appl. Ecol. 6:249–259.

3. Baruch, Z. and G. Goldstein. 1999. Leaf construction cost, nutrient concentration, and net CO_2 assimilation of native and invasive species in Hawaii. Oecologia 121:183–192.

4. Caton, B.P. 2005. Availability in Florida nurseries of invasive plants on a voluntary 'do not sell' list. United States Department of Agriculture, Animal and Plant Health Inspection Service, Final Report, July, p. 1–9.

5. Cherry, H.M. 2002. Ecophysiology and control of *Nandina domestica* Thunb. MS Thesis. University of Florida, Gainesville, FL.

6. Chicago Botanic Gardens. 2002. Linking ecology and horticulture to prevent plant invasions II. <http://www.centerforplantconservation.org>. Accessed July 8, 2005.

7. Dehgan, B. 1984. Germination of *Nandina domestica* seed as influenced by GA_3 and stratification. Proc. Fla. State Hort. Soc. 97:311–313.

8. Dirr, M. 2002. Dirr's Trees and Shrubs for Warm Climates: An Illustrated Encyclopedia. Timber Press, Inc., Portland, OR.

9. Florida Exotic Pest Plant Council (FLEPPC). 2005. List of Florida's invasive species. <http://www.fleppc.org/Plantlist/05list.htm>. Accessed May 15, 2005.

10. Fox, A.M., D.R. Gordon, J.A. Dusky, L. Tyson, and R.K. Stocker. 2005. IFAS assessment of the status of non-native plants in Florida's natural areas. <http://plants.ifas.ufl.edu/assessment.html>. Accessed July 8, 2005.

11. Fox, A.M., D.R. Gordon, and R.K. Stocker. 2003. Challenges of reaching consensus on assessing which non-native plants are invasive in natural areas. HortScience 38:11–13.

12. Gilman, E.F. 1999. *Nandina domestica*. Fact Sheet FPS-421 October. Department of Environmental Horticulture, University of Florida.

13. Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research. John Wiley & Sons, Inc., New York, NY.

14. Hartmann, H.T., D.E. Kester, F.T. Davies, Jr., and R.L. Geneve. 2002. Plant Propagation Principles and Practices. 7th ed. Prentice Hall, Upper Saddle River, NJ.

15. Hodges, A.W. and J.J. Haydu. 2002. Economic impacts of the Florida environmental horticulture industry, 2000. Economic Information Report EI 02-3. University of Florida.

16. Langeland, K.A. and K. Craddock Burks. 1998. Identification and biology of non-native plants in Florida's natural areas. University of Florida IFAS Distribution, Gainesville, FL.

17. McPherson, J.M. 1987. A field study of winter fruit preferences of cedar waxwings. The Condor 89:293–306.

18. Monrovia Nursery Company. 2005. Plum Passion® heavenly bamboo. <http://www.monrovia.com>. Accessed June 16, 2005.

19. Myers, J.H. and D.R. Bazely. 2003. Ecology and Control of Introduced Plants. Cambridge University Press, Cambridge, UK.

20. Pattison, R.R., G. Goldstein, and A. Ares. 1998. Growth, biomass allocation and photosynthesis of invasive and native Hawaiian rainforest species. Oecologia 117:449–459.

21. Perrins, J., M. Williamson, and A. Fitter. 1992. Do annual weeds have predictable characters? Acta Ecologica 13:517–533.

22. Raulston, J.C. 1984. *Nandina domestica* cultivars in the NCSU Arboretum. Friends of the Arboretum Newsletter 11 (December 1984). <http://www.ncsu.edu/jcraulstonarboretum/publications/newsletters/ncsu_arboretum_newsletters/News11_84-12.html>. Accessed June 16, 2005.

23. Reichard, S.H. 1997. Prevention of invasive plant introductions on national and local levels. p. 215–243. *In*: J.O. Luken and J.W. Thieret (eds.). Assessment and Management of Plant Invasions. Springer-Verlag, New York, NY.

24. Rejmánek, M. and D.M. Richardson. 1996. What attributes make some plant species more invasive? Ecology 77:1655–1661.

25. Roethling, J.L., C.T. Glenn, and F.T. Lasseigne. 2003. Long-term evaluation of *Nandina domestica* cultivars at the JC Raulston Arboretum. Proc. SNA Research Conf. 48:373–378.

26. Shiell, K.J., R.G. St-Pierre, and A.M. Zatylny. 2002. Timing, magnitude and causes of flower and immature fruit loss in pin cherry and choke cherry. Can. J. Plant Sci. 82:157–164.

27. United States Department of Agriculture National Resources Conservation Service (USDA, NRCS). 2004. The PLANTS Database, Version 3.5 National Plant Data Center, Baton Rouge, LA. < http://npdc.usda.gov/>. Accessed May 15, 2005.

28. Willis, A.J. and B. Blossey. 1999. Benign environments do not explain the increased vigor of non-indigenous plants: A cross-continental transplant experiment. Biocontrol Sci. Technol. 9:567–577.

29. Wilson, S.B. and L.A. Mecca. 2003. Seed production and germination of eight cultivars and the wild-type of *Ruellia tweediana*: A potentially invasive ornamental. J. Environ. Hort. 21:137–143.

30. Wilson, S.B., M. Thetford, L.K. Mecca, J.S. Raymer, and J.A. Gersony. 2004. Evaluation of 14 butterfly bush taxa grown in western and southern Florida: II. Seed production and germination. HortTechnol. 14:1–6.

31. Wirth, F.F., K.J. Davis, and S.B. Wilson. 2004. Florida nursery sales and economic impacts of 14 potentially invasive ornamental plant species. J. Environ. Hort. 22:12–16.

32. Wunderlin, R.P. and B.F. Hansen. 2003. Guide to the Vascular Plants of Florida. 2nd ed. University Press of Florida, Gainesville, FL.

33. Wunderlin, R.P. and B.F. Hansen. 2004. Atlas of Florida vascular plants. [S.M. Landry and K.N. Campbell (application development), Florida Center for Community Design and Research]. Institute of Systematic Botany, Univ. of South Florida, Tampa. <http://www.plantatlas.usf.edu/>. Accessed May 15, 2005.