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.

Seed Production and Germination of Eight Cultivars and the Wild Type of *Ruellia tweediana*: A Potentially Invasive Ornamental[1]

Sandra B. Wilson[2] and Laurie K. Mecca[3]
Department of Environmental Horticulture, Indian River Research and Education Center
2199 South Rock Road, University of Florida, Fort Pierce, FL 34945

Abstract

Seed production and the influence of light and temperature on germination were determined for eight cultivars and the wild type form of Mexican petunia (*Ruellia tweediana* Griseb). The wild type form of *R. tweediana* has been ranked by the Florida Exotic Pest Plant Council as a Category I invasive plant, meaning it has invaded and is disrupting native plant communities in Florida. The cultivar 'Purple Showers' did not set any seed. Peak flowering and seed production for other cultivars generally occurred in August with 'Morado Chi', 'Chi Chi', and the wild type plants producing approximately three times the amount of seed produced by 'Katie Pink', 'Katie Purple', 'Katie White', and 'Snow White'. For seed germination, significant cultivar × light interactions occurred for each temperature treatment. Some germination was observed at each temperature except for 'Katie Purple', 'Katie Variegated', and 'Katie White' at 33C (91.4F) without light. Regardless of cultivar or provision of light, 94–100% germination occurred at 30/20C (86/68F), with the exception of 'Katie Purple' (65%), 'Katie Variegated' (54%), and 'Katie White' (83%) without light. At 15, 24 or 33C (59, 75.2, and 91.4F), germination was generally greatest for 'Chi Chi' (with or without light) and 'Morado Chi' (with light). In parallel greenhouse studies, where seeds were germinated in pots containing a soilless medium, highest germination was achieved by 'Chi Chi', 'Katie Pink', Katie Variegated' and 'Morado Chi', while significantly lower germination was achieved by wild type plants (55%) by day 14. Storage studies demonstrated that germination of seed collected from the wild type and 'Chi Chi' plants began to decrease between 6 and 12 months when maintained at 24C (75.2F) but had equal ('Chi Chi') or higher (wild type) germination when maintained at 4C (39.2F) for 12 months.

Index words: light, temperature, exotic plants, invasive, ornamentals, Mexican petunia, sexual propagation.

Species used in this study: Mexican petunia (*Ruellia tweediana* Griseb. 'Chi Chi', 'Katie Pink', 'Katie Purple', 'Katie Variegated', 'Katie White', 'Morado Chi', 'Purple Showers', 'Snow White').

Significance to the Nursery Industry

The Tampa Bay Wholesale Growers, Florida Nurserymen and Growers Association, and the American Nursery and Landscape Association Board of Directors were among the first in the nation to adopt voluntary codes of conduct for the nursery industry with regards to invasive plants (6). The codes of conduct involve adoption of risk assessment methods that consider plant characteristics and prior observations or experience with the plant elsewhere in the world before it is released and distributed. Research on invasive plants is critical to provide scientific evidence of whether a plant is currently invasive or has potential to become invasive. This information can then be relayed to growers, who in turn can make informed decisions on whether or not a particular plant should be produced commercially.

Invasive species have biological characteristics in common that predispose them towards invasiveness. For example, the wild type Mexican petunia (*Ruellia tweediana*) has several invasive qualities, including (a) tolerance of variable conditions including light, temperature, and moisture, (b) aggressive growth, (c) preference to disturbed sites, and (d) ability to produce abundant seed over a long reproductive period. However, it is not appropriate to deem a species with high ornamental value as invasive without considering the invasiveness of its cultivars. Results of this research demonstrated that all Mexican petunia cultivars studied produced viable seed under open pollination, with the exception of 'Purple Showers'. The cultivars 'Chi Chi' and 'Morado Chi' produced as much seed as the wild type with higher germination rates.

Introduction

The State of Florida is the second largest producer of ornamental and landscape plants in the United States with an estimated 10 billion dollars in total industry sales during 2000 (12). While most intentionally introduced species remain in their cultivated settings, some invade natural areas (23). Invasive species have disrupted millions of acres of natural areas in the United States, costing Florida over 128 million dollars annually to control. Some of these plants were introduced originally as ornamentals and are highly prized by both producers and consumers for their rapid growth, adaptability, and ease of propagation. Of the 235 woody plant species that have escaped cultivation and naturalized in North America, 85% were introduced primarily for the landscape trade (17). Of the original 96 plant species listed as invasive by the Florida Exotic Pest Plant Council (FLEPPC), 45% were introduced as ornamentals (9). Today, severely invasive plants are regulated by statutory authority. In addition, many states have organized Exotic Pest Plant Councils that maintain a current list of plants that are considered to be invasive or have invasive potential.

While the FLEPPC list (7) contains some plants that are regulated also by state law, the list does not have statutory

[1]Received for publication 7, March 2003; in revised form June 26, 2003. Florida Agricultural Experiment Station Journal Series no. R-09372. This research was funded by the Florida Department of Environmental Protection and the UF-IFAS Invasive Plant Working Group.

[2]Corresponding author and Assistant Professor.

[3]Biological Scientist.

authority. As with many issues, the problem arises in that there are many different interpretations of whether a plant is invasive. Plants are placed on the FLEPPC list under 'Category I' if they are nonnative and known to have invaded Florida's natural areas, and are displacing native plants or otherwise disrupting the natural community structure and/or function. Unfortunately, once a plant is placed on the FLEPPC list, spread is often at advanced stages, making eradication more difficult, expensive, and destructive. Early prevention is undeniably the best method of protection.

Fourteen of the plants listed as Category I by FLEPPC are extensively cultivated for their ornamental value (25). One of these 14 plants, *R. tweediana*, is a herbaceous perennial (USDA Hardiness Zone 7–9) grown for its bright colored, trumpet-shaped flowers and adaptability to wet and dry sites in full sun or shade. It commonly is sold by the ornamental industry under the synonym *Ruellia brittoniana* Leonard. Named in 1879 by the German botanist, August Grisebach, this native Mexican species is characterized by linear-lanceolate leaves 8–22 cm (3.1–8.7 in) long with purple flowers borne solitary or in a few-flowered cymes from the leaf axils. The fruit is an elongated capsule up to 2.5 cm (0.9 in) long with brown circular seeds that are 2 mm (0.08 in) in diameter (22). Flower and seed stages alternate year-round in Florida. Seeds are viable almost immediately after dehiscing from the capsule (24).

Since its introduction sometime before 1940, *R. tweediana* has since naturalized in disturbed uplands and wetlands of 9 states, the Virgin Islands, and Puerto Rico (21). In Florida, it has formed naturalized populations in 26 counties throughout the state (27). In 2001, FLEPPC upgraded *Ruellia tweediana* from a Category II (potential problem) to Category I due to observed ecological invasion and disruption of native plant communities (7). The wild type form of *R. tweediana* is inferior to the cultivated forms and rarely offered for sale. There are eight known cultivars that have been selected commercially for pink, purple, or white flowers as well as tall and dwarf forms (5). The cultivars reportedly are weedy in cultivation with some seedlings having the typical growth form and flower color of the species (10).

Species and respective cultivars with highly invasive characteristics warrant caution and evaluation before thousands of dollars are spent marketing, optimizing production, and distributing plants that may require eradication in the future. Therefore, the overall objective of this study was to characterize potential invasiveness of wild type *R. tweediana* and its cultivars. Specific objectives were to a) determine the effect of light, temperature, and cultivar on germination rate, (b) relate viable germination to seed production, and c) determine the effect on storage time and temperature on germination.

Materials and Methods

Plant material. Original cultivars of *R. tweediana* were obtained from Boynton Botanicals (Palm Beach, FL) with the exception of 'Katie Variegated' (Plant Delights Nursery, Inc., Raleigh, NC). The wild type form was propagated from seed collected from a naturalized population (Tallahassee, FL). Plant size, flower color, synonymous cultivar names, and origin of each cultivar, if known, are listed in Table 1.

Plant growth. On August 14, 2001, six 4-week-old seedlings of each cultivar except 'Purple Showers' were transplanted to 3.8 liter (1 gal) pots containing a 3-B soilless medium (Fafard, Inc., Apopka, FL). Plants were maintained in

Table 1. Botanical description, origin and synonyms of wild type *Ruellia tweediana* and cultivars evaluated.

Cultivar/species	Synonyms	Botanical description and origin
'Chi Chi'	'Pink Showers'	0.9–1.2 m (3–4 ft), upright growth, 5 cm (2 in) diameter pink flowers, narrow leaves
'Katie Pink'	'Bonita Pink'™, 'Colobe Pink'PPAF, 'Compact Pink Ruffle'™, 'Pink Shorts Katie'™	15–30 cm (6–12 in) compact form, 5 cm (2 in) diameter pink flowers, narrow leaves; Discovered by Greg Grant who used 'Purple Katie' as the female parent to cross with the standard pink *R. tweediana* (15)
'Katie Purple'	'Compacta Katie', 'Dwarf Katie', 'Purple Katie'	15–30 cm (6–12 in) compact form, 5 cm (2 in) diameter purple flowers, narrow leaves; discovered in Texas by employees Herbert Durand and Nolan Guillot (13)
'Katie Variegated'	'Strawberries and Cream'	15–30 cm (6–12 in) compact form with variegated foliage, 5 cm (2 in) diameter purple flowers, narrow leaves; discovered by Scott Reaves of Tree Search Farms in Texas in 1994 in a grouping of 'Katie' (16)
'Katie White'	'Clean White Katie'™, 'Clean White Shorts'™, 'Compact White Ruffle'™	15–30 cm (6–12 in) compact form, 4.5 cm (1.8 in) diameter white flowers, narrow leaves
'Morado Chi'		0.9–1.2 m (3–4 ft), upright growth, 4.5 cm (1.8 in) diameter purple flowers, very narrow leaves
'Purple Showers' wild type species	'Purple Fountain'	0.9–1.2 m (3–4 ft), upright growth, 5.5 cm (2.2 in) diameter purple flowers, leaves wider than the
'Snow White'	'Snow Queen', 'White Snow'	0.9–1.2 m (3–4 ft), upright growth, 4.5 cm (1.8 in) diameter white flowers, rounded leaves; sold as *R. tweediana* but may be a distinct species
Wild type		0.6–0.9 m (2–3 ft), upright growth, 3.5 cm (1.4 in) diameter purple flowers, leaves more narrow than 'Purple Showers' and less narrow than 'Morado Chi'; designated as a Category I invasive plant by the Florida Exotic Pest Plant Council (7)

the greenhouse for the duration of the experiment (33/22C max/min) (91/72F). All plants were top-dressed at a standard rate of 15 g (0.53 oz)/pot of 15N–3.9P–10K Osmocote Plus® (The Scotts Co., Marysville, OH) and drip irrigated every other day. Flowering was monitored daily and recorded as the number of days from transplanting to the first day of a fully open flower. Plants were harvested 14 weeks after transplanting. Shoots were severed at the soil surface, plant heights were recorded as stem length to the shoot apex, and all shoots were oven dried at 72C (162F) for 72 hr. Relative stem length and dry weight were calculated by subtracting initial stem length and dry weight at transplanting (week 4) from final stem length and dry weight (week 18).

Seed production. On March 10, 2002, five uniform seedlings of each cultivar except 'Katie Variegated' and 'Purple Showers' were transplanted in 3.8 liter (1 gal) pots containing a 3-B soilless medium (Fafard, Inc., Apopka, FL), and positioned randomly on outside benches. After 12 weeks, plants were transferred to 11.4 liter (3 gal) pots containing the same medium and top-dressed at a standard rate of 45 g (1.59 oz)/pot of 15N–3.9P–10K Osmocote Plus® and watered as needed. Seed capsules were removed daily before capsules opened from May to December. The number of capsules was recorded per plant per day. Seeds were allowed to dehisce and then weighed each month.

Germination. Seeds with visible indication of pathogen or insect damage were discarded. Individual treatments for all incubator germination experiments consisted of five replications of 25 seeds in 9 cm (3.5 in) plastic petri dishes containing two sheets of Reeve angel® filter paper (Whatman Inc., Clifton, NJ) moistened with 10 mL (0.34 oz) nanopure water. All dishes were sealed with parafilm to prevent desiccation and placed in temperature and light controlled chambers equipped with cool-white fluorescent lamps (Model 818, Precision Scientific, Winchester, VA). Petri dishes were placed in light (12 hr photoperiod) or darkness (no photoperiod) at 15, 24, 33, or 30/20C (59, 75, 91, or 86/68F). The 12 hour photoperiod was maintained in each chamber with a photosynthetic photon flux of 22–30 □mol·m^{-2}·s^{-1} at shelf level. The diurnal treatment with light was administered by providing 12 hours light at 30C (86F) followed by 12 hours dark at 20C (68F). Dark treatments were administered by wrapping petri dishes in two layers of heavy duty aluminum foil. These dishes remained unopened until the final day of the experiment. Germination of seed exposed to light was monitored daily for a period of 14 days. A seed was considered germinated when radicle emergence was ≥ 2 mm (0.08 in). At the end of the germination period, final germination percentage (FGP), T50 (days to 50% of FGP), and the radicle length (mean value excluding seeds that did not germinate) were determined per petri dish.

Seed germination in the incubators was concurrent with seed germination in the greenhouse. Five replicates of 25 seeds of each species were placed in 8.9 cm (3.5 in) pots filled with a soilless germination medium (Fafard, Inc., Apopka, FL). Diurnal greenhouse temperatures were recorded with a Universal K thermograph (Ryan® Instruments, Redmond, WA). Average maximum and minimum temperatures in the greenhouse were 38/25C (100/77F), respectively. A seed was considered germinated when a cotyledon was visible above the surface of the growth medium.

A separate germination study was conducted concurrently in the greenhouse to determine seed germination after extended periods of storage. Seed capsules were collected from wild type species (tall, purple) (Lake Jessup Conservation Area, Sanford, FL) and from the cultivated form, 'Chi Chi' (tall, pink) (Indian River Research and Education Center, Fort Pierce, FL). Dehisced seeds were placed in polyethylene bags and stored at 4 or 24C (39 or 75F). Sub-samples consisting of 125 seeds were removed and germinated in a soilless medium (25 seeds per pot) as described above at 0, 6, 12 and 18 months.

Experimental design and statistical analysis. For the primary germination study, a split block experimental design was used with temperatures as the main blocks, and cultivar and light treatments as the split-plots. Each treatment consisted of 25 seeds per petri dish and was replicated five times. Data were subjected to analysis of variance (ANOVA). Since all variables had a significant cultivar × light interaction, LSD (P 0.05) for interactions was calculated. For all other experiments, five or six plants per cultivar were evaluated for plant growth or seed production and data were subjected to ANOVA procedures and means separated by Duncan's multiple range test at P ≤ 0.05.

Results and Discussion

*Growth rate and juvenile period***.** Of the tall forms evaluated, 'Snow White' had the greatest plant height (stem length) followed by wild type, 'Chi Chi' and 'Morado Chi' (Table 2). Relative shoot dry weight of 'Snow White' was 22% and 38% greater than that of 'Chi Chi' and 'Morado Chi', respectively. 'Morado Chi' plants generally were smaller, slower growing, and had 50% less flower initiation than the other tall forms by week 14. Of the dwarf forms evaluated, 'Katie Pink' had the greatest plant height (Table 2). 'Katie Purple' and 'Katie White' had similar plant heights but 'Katie Purple' had 7.3% more shoot dry weight than 'Katie White'. 'Katie Variegated' plants were smaller and slower growing as compared to the other dwarf forms, and had no flower development by week 14. A short period between seed germination and the onset of flowering has been associated with

Table 2. Relative stem length, relative shoot dry weight, and days to flower for dwarf and tall forms of *R. tweediana* grown for 14 weeks.

Cultivar	Relative plant height (cm)	Relative shoot dry weight (g)	Days to flower
Dwarf cultivars			
Katie Pink	8.9a[z]	17.3a	49.5
Katie Purple	7.1b	17.3a	51.3
Katie Variegated	1.7c	1.2c	—[y]
Katie White	7.3b	14.1b	47.8
Tall cultivars			
Chi Chi	71.1c	31.7bc	83.3a
Morado Chi	43.8d	27.7c	—[x]
Snow White	105.6a	38.7a	51.3b
Wild type	90.1b	36.0ab	80.2a

[z]Means separation (n = 6) within columns for dwarf or tall cultivars by Duncan's multiple range test at P ≤ 0.05.

[y]No flowering was observed by week 14.

[x]Only 50% of the plants flowered by week 14.

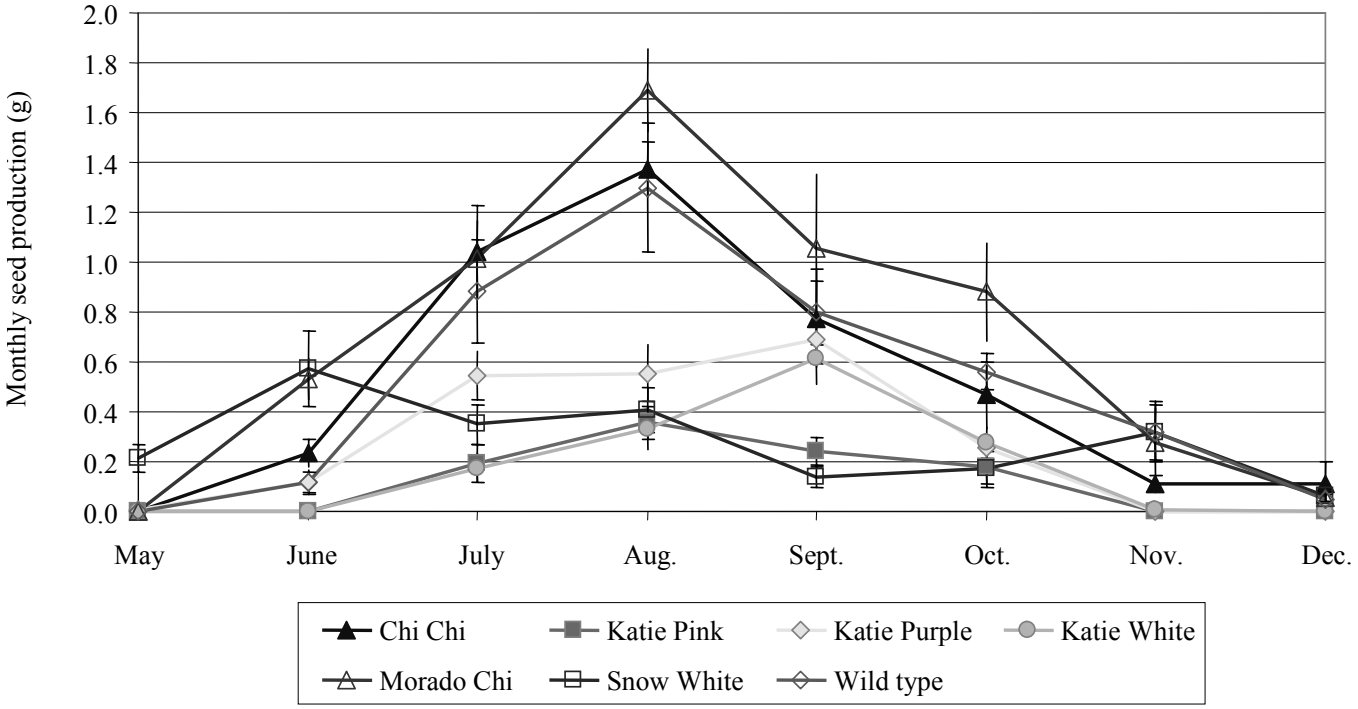

Fig. 1. Monthly seed production of the wild type *Ruellia tweediana* and six cultivars. Data were collected daily from five plants per cultivar of identical age and are presented as means ± standard error (n = 5).

many invasive species (17). Although fast growing, 'Chi Chi' and wild type plants flowered approximately 4.5 weeks later than 'Katie Pink', 'Katie Purple' and 'Katie White'. Regardless, 3 months is considered a short generation time that may result in a fast population growth rate. Growth rate also has been used to predict the weedy status in annuals (14).

Seed production. With the exception of 'Purple Showers', all cultivars produced seed. In May, only 'Snow White' produced any seed. The tall forms generally produced seed from June to December, while the dwarf forms generally produced seed from July to October (Fig. 1). Perrins et al. (14) reported that the length of the flowering period was greater in

Table 3. Final germination, radical length, and number of days to 50% of final germination (T50) of seed collected from the wild type *Ruellia tweediana* and seven cultivars. Seeds were germinated with (12 hr photoperiod) and without light in petri dishes placed in incubators set at 15, 24, 30/20 or 33C (59, 75.2, 86/68 or 91.4F).

		Final germination (%)				Radical length (cm)				T50 (d)[z]			
Cultivar	**Light**	**15**	**24**	**30/20**	**33**	**15**	**24**	**30/20**	**33**	**15**	**24**	**30/20**	**33**
Chi Chi	Yes	98	88	100	100	2.0	4.8	3.9	2.7	6.2	3.0	3.0	2.2
Chi Chi	No	92	82	100	90	1.5	2.7	2.4	1.3				
Katie Pink	Yes	66	71	98	87	1.3	4.2	3.8	2.1	8.6	3.8	3.0	3.0
Katie Pink	No	53	12	97	36	1.2	1.6	2.1	1.6				
Katie Purple	Yes	42	20	100	30	0.9	3.5	3.1	2.4	8.8	4.5	3.4	5.0
Katie Purple	No	14	2	65	0	1.0	1.0	2.0	0.0				
Katie Vari.	Yes	67	5	98	21	0.8	2.0	4.0	2.1	11.0	6.3	4.6	6.8
Katie Vari.	No	10	4	54	0	0.8	0.8	2.2	0.0				
Katie White	Yes	61	29	100	40	1.2	4.1	4.2	2.6	9.2	4.4	3.6	5.4
Katie White	No	39	3	83	0	1.1	1.3	2.2	0.0				
Morado Chi	Yes	92	54	99	90	2.2	4.9	4.1	2.8	7.6	3.2	3.0	3.0
Morado Chi	No	75	34	96	10	1.7	2.3	2.3	1.8				
Snow White	Yes	40	6	96	9	0.8	1.9	4.0	3.6	11.6	6.7	3.0	3.2
Snow White	No	83	18	94	2	1.5	1.9	2.4	0.9				
Wild type	Yes	58	43	99	46	1.5	6.0	4.2	2.4	8.0	4.0	3.4	3.8
Wild type	No	59	23	94	7	1.6	2.9	3.0	1.6				
LSD (0.05) (C × L)		22	12	9	13	0.3	1.4	0.4	0.8				
LSD (C)										1.4	0.6	0.5	1.7
Cultivar (C)		**	**	**	**	**	**	**	**	**	**	**	**
Light (L)		**	**	**	**	NS	**	**	**				
Cultivar × light (C × L)		**	**	**	**	**	*	*	**				

[z]T50 is reported only for seeds that germinated in light.

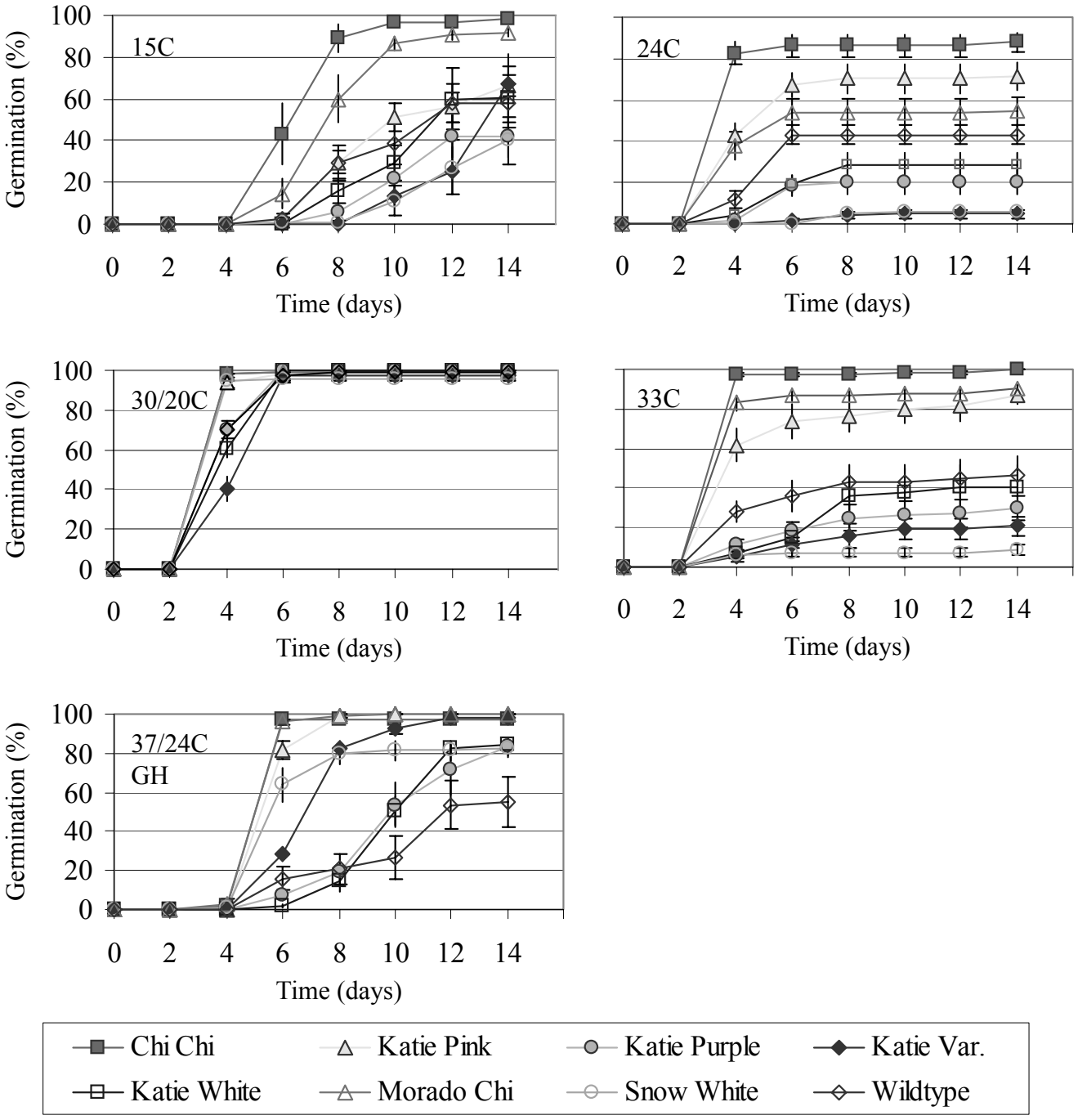

Fig. 2. Daily germination of seed of wild type *Ruellia tweediana* and seven cultivars in incubators with light (12 hr photoperiod) at 15, 24, 30/20 or 33C (59, 75.2, 86/68 or 91.4F) for 14 days. For parallel greenhouse (GH) studies (37/24C max/min) (99/75F), seeds were placed 1 cm below the soil surface. Data represent the mean of five replications of 25 seeds per petri dish or pot ± standard error.

weedy species as compared to nonweedy species. Long flowering periods may allow greater accessibility to pollinators and a greater chance of seed set (17). During July thru October, 'Morado Chi', 'Chi Chi', and wild type plants consistently produced more seed than other cultivars (Fig. 1). In August, 'Morado Chi', 'Chi Chi', and the wild type plants produced approximately three times the seed weight than that produced by 'Katie Pink', 'Katie Purple', 'Katie White', and 'Snow White'.

Hiebert and Stubbendieck (11) developed a method for ranking exotic plants for management and control in which the number of seeds per plant is categorized as 'few' (0–10), 'moderate' (11–1,000), or 'many-seeded' (>1,000). Under these guidelines, most of the containerized *R. tweediana* cultivars used in our study (with the exception of 'Purple Showers') would be categorized as moderate seed producers. In addition to quantifying seed production, it is also important to consider seed dispersal mechanisms. Characteristic of spe-

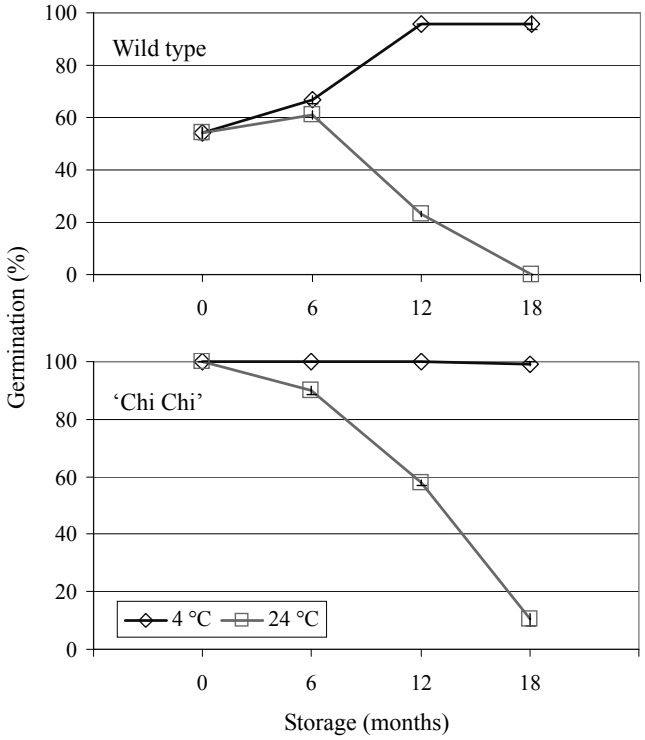

Fig. 3. Percent germination of *Ruellia tweediana* seeds collected from wild type species (tall, purple) (Lake Jessup Conservation Area, Sanford, FL) (top) and from cultivated 'Chi Chi' (tall pink) (Indian River Research & Education Center, Fort Pierce, FL) (bottom). Seeds were stored for 0, 6, 12, or 18 months in sealed polyethylene bags at 4 or 24C (39.2 or 75.2F) and germinated in a soilless medium. Data represent the mean of five replications of 25 seeds per pot ± standard error.

cies in the Acanthaceae subfamily Acanthoideae, plants of *R. tweediana* disperse their seeds by an explosive action to distances of up to 2.5 to 3.0 m (8.2 to 9.8 ft) (26).

Seed germination. Significant cultivar × light interactions occurred at each germination temperature (Table 3). At 15C (59F), highest germination occurred with 'Chi Chi' in light or darkness (92%–98%) and with 'Morado Chi' in light (92%). Both 'Chi Chi' and 'Morado Chi' also germinated several days sooner than the other cultivars (Fig. 2) with low T50 values and longer radicles at harvest (Table 3). Light generally did not significantly affect germination, with the exception of 'Katie Purple' and 'Katie Variegated' where light increased germination, and of 'Snow White' where twice as much germination occurred in darkness (Table 3). At 24C (75.2F), highest germination occurred with 'Chi Chi' in light or darkness (82%–88%) and 'Katie Pink' in light (71%). Seeds exposed to light had 1.6 to 11.8 times greater germination than that of seeds in darkness for all cultivars except for 'Chi Chi' and 'Katie Variegated' (where no difference was observed) and 'Snow White' (where more than three times as much germination occurred in darkness). For 'Chi Chi', 50% of FPG was achieved in light by day 3 (Table 3, Fig. 2). Radicle length at harvest was similar to that of 'Morado Chi' and the wild type species when germinated in light. At 30/20C (86/68F), very high or complete germination (94–100%) occurred for each cultivar, with or without light, except for 'Katie Purple', 'Katie Variegated' and 'Katie White' where germination was lower in darkness (54–83%). At 30/20C (86/68F), the T50 was similar for most cultivars (3.0–3.6 days) with the exception of 'Katie Variegated' which required 4.6 days to reach 50% germination (Table 3, Fig. 2). Radicle length at harvest was similar for all cultivars in light with the exception of 'Katie Purple' which had shorter average radicle lengths (Table 3). At 33C (91.4F), seeds of 'Katie Purple', 'Katie Variegated' and 'Katie White' did not germinate in the dark. Exposure to light improved germination for all cultivars with 'Chi Chi' achieving the highest germination (100%). Plants of 'Chi Chi' reached 50% of total germination after 2.2 days and 100% by day 4 (Table 3, Fig. 2). Although 'Snow White' had low germination at 33C (91.4F), the radicles of seedlings that germinated were longer as compared to other cultivars, revealing high vigor of some seeds but poor viability of most in warm temperatures.

Under greenhouse conditions in a soilless medium, highest germination was achieved by 'Chi Chi', 'Katie Pink', 'Katie Variegated' and 'Morado Chi', while significantly lower germination was achieved by wild type plants (55%) by day 14. Germination rate is a useful measure of the speed of germination since germination patterns can be very different while final germination percentages can be nearly identical (Table 3, Fig. 2). Results indicate that cultivars of *R. tweediana* have the capacity to germinate over a wide range of temperatures. This suggests the likelihood of emergence of these seedlings throughout the year in Florida. Several weed species have been shown to germinate over a wide range of temperatures (2, 19). In the present study, exposure to light had no effect on germination percentages for five out of eight cultivars tested at 15 or 30/20C (59 or 86/68F). This is significant, since seeds that do not require light for germination are capable of germinating when shaded by liter or a leaf canopy or following burial in soil. However, at 33C (91.4F), exposure to light increased germination of all cultivars. Nondormant seeds of many species germinate equally well in light and darkness or have higher germination percentages in light than in darkness (3). The light requirement for germination of other species has been found to vary with temperature (4). Baker (1) suggested that germination requirements of an ideal weed could be fulfilled in a variety of environments. The data in the present study suggest that seeds of *R. tweediana* are capable of germinating under various light and temperature conditions, and would be able to colonize in a variety of naturalized locations. In Florida, it has been found commonly in riparian sites but has been reported on drier sites as well (27). While the most 'weedy' species of Viper's bugloss (*Echium* spp.) in Australia germinated far more quickly than two less weedy species (8), Rejmánek and Richardson (18) found no differences between percent germination of invasive and noninvasive pine species. Clearly, seed germination is only one important factor to consider when fully characterizing the invasive potential of a plant species.

Seed germination following storage. Unstored *R. tweediana* seeds germinated 54% (wild type) and 100% ('Chi Chi') (Fig. 3). When stored at 4C (39.2F), germination of wild type seeds increased following storage time of 6 to 18 months, while seeds of 'Chi Chi' maintained 100% germination. Germination of wild type seeds increased slightly to 61% after 6 months of storage at 24C (75.2F), but then decreased to 23% and 0% after 12 and 18 months, respectively.

Germination of 'Chi Chi' seeds decreased continually as storage time at 24C (75.2F) increased. These data are informative as to whether the seeds could be persistent in a seed bank. Balyan and Bhan (2) reported higher germination when seeds were stored in the soil than under laboratory conditions, seemingly due to the effect of soil moisture softening the hard seed coat. Thompson and Grime (20) distinguish a transient seed bank from a persistent seed bank as one in which none of the seeds produced at a given time remain viable in the habitat for more than 1 year. Greater longevity may allow seeds to remain in the soil bank for long periods of time, germinating as conditions become favorable (4). Eradication of plants that produce seeds with hard seed coats or with prolonged viability generally becomes more problematic once infestation occurs.

Results from the present studies suggest that several *R. tweediana* cultivars exhibit invasive behavior similar or more pronounced than that of the wild type form. In addition, it was noted that under open pollination, 12–22% of seedlings from dwarf plants were of the wild type or standard pink form. Thus, producers and consumers should use caution when utilizing this species in the Florida landscape and may opt to explore suitable non-invasive alternatives.

Literature Cited

1. Baker, H.G. 1974. The evolution of weeds. Annu. Rev. Ecol. Systematics 5:1–24.

2. Balyan, R.S. and V.M. Bhan. 1986. Germination of horse purslane (*Trianthema portulacastrum*) in relation to temperature, storage conditions, and seeding depths. Weed Sci. 34:513–515.

3. Baskin, J.M. and C.C. Baskin. 1998. Greenhouse and laboratory studies on the ecological life cycle of *Daleafoliosa* (Fabaceae), a federal-endangered species. Nat. Areas J. 18:54.

4. Baskin, C.C. and J.M. Baskin. 2001. Seeds. Academic Press, San Diego, CA.

5. Betrock's Plant Finder. 2003. Betrock Information Systems, Hollywood, FL. Retrieved February 14, 2003. <http://www.plantfinder.com>.

6. Draft Voluntary Code of Conduct. 2001. St. Louis Invasive Plants Species Workshop: Linking Ecology and Horticulture to Prevent Plant Invasions. Retrieved May 14, 2003. <http://www.mobot.org/invasives>.

7. Florida Exotic Pest Plant Council (FLEPPC). 2001. List of Florida's Most Invasive Species. Florida Exotic Pest Plant Council. Florida EPPC Newsletter 11(1):3–4.

8. Forcella, F, J.T. Woods, and S.P. Dillon. 1986. Characteristics distinguishing invasive weeds within *Echium* (bugloss). Weed Res. 26:351–364.

9. Gordon, R.D. and K.P. Thomas. 1997. Florida's invasion by nonindigenous plants: History, screening, and regulation. p. 21–37 *In*: D. Simberloff, D.C. Schmitz, and T.C. Brown (Editors). Strangers in Paradise. Island Press, Washington, DC.

10. Hammer, R.L. 2002. Mexican Bluebell (*Ruellia tweediana* Griseb.): A pretty invasive weed. Wildland Weeds 5:6–8.

11. Hiebert, R.D. and J. Stubbendieck. 1993. Handbook for ranking exotic plants for management and control. Natural resources report NPS/NRMWRO/NRR-93/08, July. U.S. Dept. of the Interior, National Park Service, Natural Resources Publication Office, Denver, CO.

12. Hodges, A.W. and J.J. Haydu. 2002. Economic Impacts of the Floriculture Environmental Horticulture Industry, 2000. Economic Info. Rpt. EI 02-3. Univ. of Florida, Gainesville.

13. Lowrey, L.R. 1991. *Ruellia brittoniana* var. *katie*. Amer. Nurseryman 173(3):138.

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

15. Pickens, M. 1999. Lynn Lowrey, Plantsman. Retrieved May 23, 2001. <http://aggie-horticulture.tamu.edu/plantanswers/heroes/lowrey2.html>.

16. Plant Delights Nursery, Inc. 2003. Juniper Level Botanic Gardens, Raleigh, NC. Retrieved May 23, 2001 <http://www.plantdelights.com/>.

17. 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 (Editors). Assessment and Management of Plant Invasions. Springer-Verlag, New York.

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

19. Susko, D.J., J.P. Mueller, and J.F. Spears. 1999. Influence of environmental factors on germination and emergence of *Pueraria lobata*. Weed Science 47:585–588.

20. Thompson, K. and J.P. Grime. 1979. Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. J. Ecol. 67:893–921.

21. United States Department of Agriculture National Resources Conservation Service. USDA, NRCS. 2002. The PLANTS Database, Version 3.5. National Plant Data Center, Baton Rouge, LA. Retrieved January 15, 2002. <http://plants.usda.gov>.

22. Wagner, W.L., D.R. Herbst, S.H. Sohmer, and Y. Wilson-Ramsey. 1990. Manual of the Flowering Plants of Hawaii. University of Hawaii Press, Bishop Museum Press, Honolulu, HI.

23. Williamson, M. 1996. Biological Invasions. Chapman & Hall, London.

24. Wilson, S.B., P.C. Wilson, and M.E. Tignor. 2001. Assessment of germination, nutrient uptake and photosynthetic efficiency for evaluating the potential invasiveness of *Ruellia brittoniana*. Proc. Fla. State Hort. Soc. 114:247–249.

25. Wirth, F.F., K.J. Davis, and S.B. Wilson. 2003. Market economics of 14 potentially invasive ornamental plant species in Florida. Economic Info. Rpt. EIR 03-1, Food and Resource Economics Dept. Univ. of Florida, Institute of Food and Agricultural Sciences, Gainesville.

26. Witztum, A. and K. Schulgasser. 1995. The mechanics of seed expulsion in Acanthaceae. J. Theor. Biol. 176:531–542.

27. Wunderlin, R.P. and B.F. Hansen. 2003. Atlas of Florida Vascular Plants [S.M. Landry and K.N. Campbell (application development), Florida Center for Community Design and Research.] Institute for Systematic Botany, Univ. of South Florida, Tampa. January 10, 2003. <http://www.plantatlas.usf.edu/>.