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Growth, Flowering, and Survival of Black-eyed Susan from Different Regional Seed Sources

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SUMMARY. Growth, flowering, and survival of black-eyed susan (*Rudbeckia hirta* L.) from three seed sources—northern Florida (NFL), central Florida (CFL), and Texas (TEX)—were evaluated under low input conditions for one growing season at four sites in Florida. Two sites were in American Horticultural Society (AHS) Heat Zone 9 while the other two were in AHS Heat Zones 10 and 11. Growth, onset date of flowering, and number of flowers at peak flowering varied by site. With few exceptions, plants tended to reach peak flowering at about the same time. Flower diameter varied by seed source with TEX>NFL>CFL. While TEX plants were perceived as the showiest, NFL and CFL plants persisted longer under the low input conditions in Florida, and hence provided some evidence of adaptation to regional site conditions.

Black-eyed susan (*Rudbeckia hirta*) is a wildflower native to much of the United States (Rickett, 1967), including Florida (Wunderlin, 1998). It is thought that through a process of natural selection, populations of native wildflowers may perform better in one location (environment) than another. The selection process involves not only climate but also soils, insects, and microorganisms—the ecotype concept (Turesson, 1922).

Few published studies have focused on the ecotype issue with respect to native wildflowers. Although black-eyed susan is considered an obligate long-day (LD) plant (Garner and Allard, 1925), Beckwith (1991) observed that a Texas ecotype had a weak facultative LD flowering response, while a northern ecotype was an obligate LD plant. Celik (1996)

also noted a difference in flowering among black-eyed susan ecotypes. In a study conducted in northern Florida (Norcini et al., 1998), a northern Florida ecotype of black-eyed susan flowered until the end of the study (mid-October) whereas a Texas selection senesced and/or succumbed to disease by mid-August. There were no differences in the level of insect damage (which was minimal) and neither ecotype exhibited any signs of drought stress. A naturally-occurring selection from central Florida also outperformed two black-eyed susan cultivars ('Sonora' and 'Indian Summer') in a formal bedding plant evaluation conducted in central Florida (Howe, 1998).

Latitudinal effects on population adaptation are thought to occur in as little as 402 to 563 km (250 to 300 miles) (S. Meyer, personal communication). There are latitudinal ecotypes of black-eyed susan, as noted above, as well as of goldenrod (*Solidago sempervirens* L.) (Goodwin, 1944). However, other environmental conditions such as temperature, moisture, and mineral nutrition can affect species adaptation. Murfet (1977) points out several examples in which these factors affected flowering of forbs or grasses. In mountainous regions, populations of a species can be adapted to different elevations because of differences in climate (Meyer and Paulsen, 2000). Gordon and Rice (1998) as well as Kindell (1993) provided strong evidence of an environmental influence on growth and/or fecundity of wiregrass (*Aristida beyrichiana* Trin. & Rupr.) populations. Although evidence of genetic differences (based on isozyme analysis) was lacking, results of a reciprocal transplant study implied that genetic differences exist among wiregrass (Gordon and Rice, 1998).

The objective of this study was to evaluate, under low input conditions, the effects of site (four sites in Florida, representing AHS Heat Zones 9, 10, and 11) and seed source (northern Florida, central Florida, and Texas) on growth, flowering, and survival of black-eyed susan. Based on the ecotype concept, black-eyed susan should perform better under conditions from which the seed were derived than when seed were used from a different environment. Differences in growth, flowering, or survival due to site or seed source could affect recommendations for landscape use of black-eyed susan.

Materials and methods

PLANT MATERIAL. A northern Florida ecotype (NFL) of black-eyed susan originated from seed collected during 1997 from native populations located primarily in the Red Hills region of the Florida panhandle and extreme south Georgia (AHS Heat Zone 9; USDA Hardiness Zone 8b). All collection sites were upland. Populations from which seed were collected were growing under a high canopy of slash, loblolly, or longleaf pine (*Pinus elliotii* Engelm., *Pinus palustris* Mill., and *Pinus taeda* L., respectively) that may have been subjected to periodic prescribed burns. Leaves and stems of NFL are dark green with short, coarse hairs. The flowers are about 3.8 to 5 cm (1.5 to 2 inches) in diameter; ray flower color is yellow-orange (Royal Horticulture Society [RHS] 12A) (Royal Horticulture Society, 1991). Overall plant height in bloom is 0.46 to 0.61 m (1.5 to 2 ft) (Norcini et al., 1999).

A central Florida seed source (CFL) was a selection that originated from two plants purchased from Viola Wildflower of Sarasota, Fla. It is a variant of black-eyed susan that has yellow ray flowers (RHS 6A) and was named 'Viola's Lemonade' by the grower. This selection originated from a chance seedling collected by the grower in a mesic area of eastern Sarasota County in central Florida (AHS Heat Zone 10; USDA Hardiness Zone 9a). In addition to a different flower color, CFL appears to be slightly smaller overall, including flower size, compared to the NFL. Leaf and growth characteristics are similar.

The third seed source was a selec-

tion of a Texas ecotype (TEX) that was produced by Wildseed Farms, Fredericksburg, Texas (AHS Heat Zone 9; USDA Hardiness Zone 8a). This selection is much larger than either NFL or CFL, with flowers, foliage, and overall size appearing to be 150% to 200% greater than that of NFL (Norcini et al., 1998). Its foliage has lighter green leaves with longer, soft hairs compared to NFL and CFL. Ray flowers are two shades of yellow-orange—RHS 17B on the basal part of the petal and RHS 14A on the outer portion.

SITES. Plantings were established at four sites that represented AHS Heat Zones 9, 10, and 11 (average number of days $>30^{\circ}\text{C}$ [86°F] is 120 to 150, 150 to 180, and 180 to 210, respectively). The sites were at four University of Florida/Institute of Food and Agricultural Sciences Research and Education Centers (RECs)—West Florida REC, Jay (31.0°N , 87.2°W ; AHS Heat Zone 9; USDA Hardiness Zone 8b), North Florida REC, Monticello (30.5°N , 83.9°W ; AHS Heat Zone 9; USDA Hardiness Zone 8b), Gulf Coast REC, Bradenton (27.4°N , 82.5°W ; AHS Heat Zone 10; USDA Hardiness Zone 9b), and Ft. Lauderdale REC (26.1°N , 80.2°W ; AHS Heat Zone 11; USDA Hardiness Zone 10a). The sites at Jay and Monticello were less than 56 km (35 miles) apart in latitude (based on a conversion factor of 111 km [69 miles] per degree latitude) but were over 483 km (300 miles) north of Ft. Lauderdale and over 322 km (200 miles) north of Bradenton. Soil at all sites was sandy and of low fertility (Table 1), and contained several nematode genera (Table 2).

CULTURE. During the first week of

Jan. 1998, seeds were sown in Metro-Mix 220 (Scotts Co., Marysville, Ohio) in cell packs. Seedlings were fertilized once per week after the first true leaves appeared with N at $50\text{ mg}\cdot\text{L}^{-1}$ (ppm) ($15\text{N}-13.2\text{P}-12.4\text{K}$; Peters 15-30-15, Scotts Co., Marysville, Ohio), and once with trace elements (DynaGreen at $530\text{ mg}\cdot\text{L}^{-1}$ (ppm); A.H. Hummert, St. Louis, Mo.).

Seedlings were transplanted during the first week of March 1998 to a $3.1 \times 3.7\text{-m}$ ($10 \times 12\text{-ft}$) plot, with plants spaced 0.61 m (2 ft) on center. All sites were previously in turfgrass, had not been recently cultivated, and were in full sun. Turfgrass was killed with a nonselective herbicide (glyphosate) 2 to 4 weeks before planting. At Bradenton, Ft. Lauderdale, and Jay all turfgrass was removed, and then plots were rototilled and raked before planting. However at Monticello, dead turfgrass remained in the rows and between plants, with a 20.3 to 22.9 cm (8 to 9 inches) ring of turfgrass-free soil maintained on all sides of each plant. The entire $3.1 \times 3.7\text{-m}$ plot at all sites was mulched with 5 to 7.6 cm (2 to 4 inches) of pine straw or shredded cypress bark (Ft. Lauderdale only). Weeds that emerged were manually removed.

Plants were irrigated for 2 to 4 weeks after transplanting to aid in establishment. From mid-April through mid-June, most of Florida experienced a drought that was exacerbated by unseasonably warm weather in May and June [mean ($\pm\text{SE}$) departures from normal maximum temperature averaged over sites: May = $+2.7 \pm 1.2^{\circ}\text{C}$ ($+5.1 \pm 2.3^{\circ}\text{F}$), June = $+3.6 \pm 1.0^{\circ}\text{C}$ ($+6.5 \pm 1.8^{\circ}\text{F}$)], so periodic supplemental irriga-

Table 1. Soil characteristics (before transplanting) at the University of Florida/Institute of Food and Agricultural Sciences Research Centers located at Bradenton, Fort Lauderdale, Jay, and Monticello, Florida.

Site	pH	Soluble salts ($\text{mS}\cdot\text{cm}^{-1}$)	$\text{NO}_3\text{-N}$ ($\text{mg}\cdot\text{kg}^{-1}$) ^z	$\text{NH}_4\text{-N}$ ($\text{mg}\cdot\text{kg}^{-1}$)	P ($\text{mg}\cdot\text{kg}^{-1}$)	K ($\text{mg}\cdot\text{kg}^{-1}$)
Bradenton Soil type: Eau Gallie fine sand (2%–8% OM, 0%–2% slope) (Alfic haplaquod)	5.01	0.08	1.00	2.70	3.70	3.7
Ft. Lauderdale Soil type: Margate fine sand (1.6% OM, nearly level)	6.74	0.30	9.00	5.00	27.00	3.7
Jay Soil type: Orangeburg sandy loam (2.1% OM, 1% slope) (typic paleudult)	5.85	0.12	1.00	3.30	20.50	41.7
Monticello Soil type: Fuquay fine sand (0.5%–2% OM, 0%–5% slope) or Dothan loamy fine sand (<5% OM, 2%–5% slope)	5.66	0.10	5.50	2.00	13.00	7.4

^z1.00 $\text{mg}\cdot\text{kg}^{-1}$ = 1.00 ppm.

Table 2. Nematodes and root insects present in the Florida evaluation sites before transplanting.

Nematodes and root insects	Bradenton	Ft. Lauderdale	Jay	Monticello
Lance (<i>Hoplolaimus</i> Daday)	0 ^z	0	0	7
Lesion (<i>Pratylenchus</i> Filipjev)	0	0	0	104
Ring (<i>Criconeimoides</i> Taylor)	0	0	110	459
Root-knot (<i>Meloidogyne</i> Goeldi)	24	58	0	0
Sheathoid (<i>Hemicycliophora</i> de Mann)	37	0	0	0
Spiral (<i>Scutellonema</i> Andrassy)	212	0	540	0
Sting (<i>Belonolaimus</i> Steiner)	3	0	0	0
Stubby root (<i>Trichodorus</i> Cobb)	0	10	0	0
Stunt (<i>Tylenchorhynchus</i> Cobb)	3	66	0	0
Ground pearls ^y (Margarodidae)	0	0	NA ^x	56

^zNo./100 cm³ (100 cm³ = 6.1 inches³) as conducted by University of Florida/Institute of Food and Agricultural Sciences.

^yGround pearls are scale insects that live in the soil and suck juices from roots; they are generalist feeders (J. Rich, personal communication). Injury is most noticeable during periods of plant stress (Short, 1994).

^xNA = Ground pearl analysis was not available for Jay.

tion was necessary at one or more sites. No supplemental fertilizer was applied. Pesticides were not used except for fire ant control, and for a major aphid infestation at Ft. Lauderdale (no apparent preference for TEX, CFL, or NFL was observed) when imidacloprid {Marathon 1G; Olympic Hort. Products, Mainland, Pa. [1.3 g (0.5 oz)] at base of plant and watered in} was applied to all plants.

PARAMETERS. Total plant height (measured from the soil surface to the top of the plant) and two widths (width at widest point, and width perpendicular to widest point) were recorded at transplanting, and approximately every 30 d; all measurements included the contribution of inflorescences. A plant growth index (GI) was calculated as

follows: $GI = (\text{height} + \text{average width}) / 2$, where average width was the average of width at the widest point and width perpendicular to the widest point. For each plant, date of first fully opened flower, number of fully opened flowers (once per week initiated at first flowering), and diameter of three individual fully opened flowers were recorded. Percent survival was also monitored monthly.

EXPERIMENTAL DESIGN AND ANALYSIS. The experimental design was a 4 (site) by 3 (seed source) factorial arranged in a completely random design, with 10 single plant replications per seed source per site. Due to a technical problem at Ft. Lauderdale, there were 3, 3, and 11 single plant replications for NFL, CFL, and TEX, respectively. Data

(except survival data) were subjected to analysis of variance using the General Linear Model (GLM) procedures of SAS. Main effects means (Site, Seed source) were separated using Tukey's studentized range (HSD; $\alpha = 0.05$). Significant differences between two specific seed sources within or between sites were determined by the LSMEANS/PDIFF option within the GLM procedure of SAS.

Results and discussion

GROWTH. Increases in width and GI were significantly affected by site (Table 3). Plants tended to grow more in the northern half of Florida (Monticello and Jay) than in the southern half of Florida (Bradenton and Ft. Lauderdale). TEX plants were perceived as larger

Table 3. Effect of site and seed source on growth and flowering characteristics of black-eyed susan.

Main effects	Maximum increase in growth (maximum minus initial)			Date of first flower (days after transplant)		Flower size	
	Ht ^z (cm)	Avg width ^z (cm)	GI ^{z,y} (cm)	Number	Minimum/ maximum values	Diam (cm)	Minimum/ maximum values
Site ^x							
Bradenton, Fla.	39.1 a	17.3 c	27.9 c	93.2 a	72–107	5.5 a	3.3–9.2
Ft. Lauderdale, Fla. ^w	34.5 a	36.8 b	33.1 bc	87.7 ab	73–120	6.8 a	4.2–9.7
Jay, Fla.	47.1 a	28.6 b	38.2 b	80.5 b	60–95	5.2 a	3.2–13.0
Monticello, Fla.	47.3 a	50.7 a	48.1 a	80.8 b	64–111	4.9 a	2.5–9.8
Seed source ^x							
Northern Florida	45.0 a	27.9 a	35.4 a	81.4 a	60–101	5.2 b	3.2–8.5
Central Florida	37.9 a	32.1 a	34.6 a	83.6 a	67–120	3.6 c	2.5–4.8
Texas	45.2 a	37.7 a	40.9 a	89.8 a	60–107	7.1 a	4.4–13.0
Significance							
Site	NS	***	*	*	NA	NS	NA
Seed source	NS	NS	NS	NS	NA	***	NA

^zMeasurements were based on total plant size (vegetative + inflorescence); 1.0 cm = 0.39 inches.

^yGI = growth index = (height + average width)/2.

^xThe interaction of site by seed source was not significant at $P \leq 0.05$. Main effect means for site are averaged over seed source, and seed source means are averaged over site.

^wMean values for Fort Lauderdale, Fla. for northern Florida, central Florida, and Texas seed sources were based on 3, 3, and 11 plants, respectively.

ns, *, ***Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

Table 4. Effect of site and seed source on peak flowering characteristics of black-eyed susan.

Site	Seed source	Peak flower (days after transplant)		Number flowers at peak	
		Number ^z	Minimum/ maximum values	Number ^z	Minimum/ maximum values
Bradenton, Fla.	Northern Florida	116.1 a	114–128	10.3 a	6–16
	Central Florida	114.9 a	107–128	8.6 a	1–12
	Texas	116.1 a	107–135	9.8 a	3–19
Ft. Lauderdale, Fla. ^y	Northern Florida	124.0 b	108–156	27.0 a	8–46
	Central Florida	156.0 a	156	33.3 a	4–56
	Texas	113.1 b	108–115	43.4 a	7–84
Jay, Fla.	Northern Florida	113.6 a	89–160	19.8 b	9–35
	Central Florida	112.1 a	110–124	19.0 b	10–32
	Texas	105.1 a	89–117	48.0 a	32–71
Monticello, Fla.	Northern Florida	99.7 b	88–104	23.2 a	7–55
	Central Florida	113.8 a	102–171	28.3 a	17–47
	Texas	96.9 b	92–104	34.3 a	14–56
Significance	Site	NS	NA	*	NA
	Seed source	NS	NA	NS	NA
	Site × seed source	***	NA	*	NA

^zMeans with different letters, within a site and column, are significantly different ($P \leq 0.05$).

^yMean values for Fort Lauderdale, Fla., for northern Florida, central Florida, and Texas seed sources were based on 3, 3, and 11 plants, respectively.

NS, *, ***Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

than NFL or CFL because TEX had 1) visibly larger leaves (data not shown) than either NFL or CFL, 2) the largest flowers (FLOWERING, see below), and 3) flowers that were held only slightly above the vegetative growth in contrast to NFL and CFL flowers which were held visibly higher above the mass of vegetative growth.

FLOWERING. Site affected date of first flowering in a manner analogous to the effect of site on growth. Plants in the northern half of Florida (Jay and

Monticello) generally started flowering about 1 to 2 weeks earlier than those in the southern half of Florida (Bradenton and Ft. Lauderdale) (Table 3). TEX plants tended to start flowering later than either NFL or CFL, although seed source was not a significant main effect at the 5% level for date of first flower ($P = 0.092$). However, peak flowering of TEX was about 2 and 6 weeks earlier than CFL at Monticello and Ft. Lauderdale, respectively (Table 4). Peak flowering dates of TEX and NFL at

Monticello or Ft. Lauderdale were not significantly different (within a site). There were no seed source differences in peak flowering date at Bradenton or Jay, nor were there any trends in range of dates at which plants from different seed sources attained peak flowering.

The number of flowers at peak flowering was affected by site. Significantly ($P = 0.05$) more flowers were produced on plants at Ft. Lauderdale, Jay, and Monticello compared to Bradenton but there were no significant

Table 5. Summer and fall 1998 survival of black-eyed susan from different seed sources.

Seed source	Percent of plants surviving to the beginning of					
	June	July	August	September	October	November
Bradenton, Fla. (AHS Heat Zone 10)						
Northern Florida	100	100	100	80	80	70
Central Florida	100	100	100	100	90	90
Texas	100	100	80	30	0	0
Ft. Lauderdale, Fla. ^z (AHS Heat Zone 11)						
Northern Florida	100	100	100	66	33	33
Central Florida	100	100	100	100	66	66
Texas	100	100	64	9	9	0
Jay, Fla. (AHS Heat Zone 9)						
Northern Florida	100	100	100	0	0	0
Central Florida	100	100	100	0	0	0
Texas	100	100	100	0	0	0
Monticello, Fla. (AHS Heat Zone 9)						
Northern Florida	100	100	100	80	60	20
Central Florida	90	90	90	90	90	90
Texas	80	80	80	20	0	0

^zPercentages for Fort Lauderdale, Fla. for northern Florida, central Florida, and Texas seed sources were based on 3, 3, and 11 plants, respectively.

differences in number of flowers at peak among Ft. Lauderdale, Monticello, or Jay. There was also a significant site by seed source interaction. However, within a site, the only significant differences among seed sources were at Jay where TEX plants had substantially more flowers than either CFL or NFL (Table 4). There were no trends in range of number of flowers at peak flowering.

Flower diameter was only affected by seed source (Table 3). TEX flowers [mean = 7.1 cm (2.8 inches) diameter] were 37% wider than NFL flowers [5.2 cm (2.0 inches) diameter] and twice as wide as CFL flowers [3.6 cm (1.4 inches) diameter]. The TEX and NFL results concur with the observations of Norcini et al. (1998), while the average size of CFL concurs with the observations of Howe (1998). CFL plants had the most consistent flower diameters (data not shown).

SURVIVAL. It was clear that NFL and CFL survived longer than TEX (Table 5) except at Jay. None of the TEX plants at any site survived to November, and most of these plants were dead by the beginning of September. This concurs with the findings of Norcini et al. (1998) who observed that most TEX plants in northern Florida were dead by mid-August. Furthermore, Norcini (unpublished observations) has noted during the past few years that at least the top growth of TEX plants consistently dies in late summer when plants are grown under low input conditions.

At Monticello, CFL survived better than NFL but there didn't seem to be any differences between survival of CFL or NFL within other sites. Plants at Ft. Lauderdale were flooded for 3 days (ankle-deep) in mid-September due to excessive rain. Because of the flooding, one of three NFL survived and only three of 11 TEX survived. However, two of three CFL survived flooding, and while flooded, new flowers even opened on CFL.

Conclusions

There are many factors that could have caused the plants to perform differently at the different sites. Soil phosphorus level was very low at Bradenton [3.7 mg·kg⁻¹ (ppm)] compared to the other sites [13 to 27 mg·kg⁻¹ (ppm) at the other sites]. Researchers at Bradenton even observed purple foliage, a sign of phosphorus deficiency.

Nematodes may have affected

growth, flowering, and survival at Bradenton and Jay. Even though black-eyed susan is unaffected by root-knot nematodes (Thetford and Kinloch, 1999), it could be affected by other nematode species. Spiral nematode populations were very high at these sites compared to other locations, especially at Jay, which had over two and a half times the number of spiral nematodes compared to Bradenton (Table 2). This high spiral nematode level at Jay may have been the reason for the relatively early death of CFL, NFL, and TEX compared to the other three sites. It does not seem likely that root lesion nematodes caused a problem as McKeown et al. (1999) showed that black-eyed susan was not infected by lesion nematodes [*Pratylenchus penetrans* (Cobb) Filipjev & Shuurmans Stekhoven] after being exposed to it for 6 years in a prairie nursery; however, tolerance of black-eyed susan to lesion nematodes (*Pratylenchus* sp. Filipjev) occurring in Florida has not been evaluated.

One factor that was not measured but could have had an effect on vigor and longevity was disease. A preliminary pathological assessment indicated that TEX at Monticello succumbed to *Fusarium* Synd. & Han. (J. Marois, personal communication). Work has begun to determine the relative susceptibility of CFL, NFL, and TEX to *Fusarium*.

Photoperiod and temperature can have interactive effects on flowering of *Rudbeckia* (Kochankov and Chailakhyan, 1986; Murneek, 1940). The trend of plants from all three seed sources to start flowering later at Bradenton and Ft. Lauderdale than at Jay and Monticello (Table 3) may have been due to temperature (AHS Heat Zones 10 and 11 vs. 9). Since all three seed sources originated in the south, plants may have had only a weak facultative LD response similar to what Beckwith (1991) noted about a Texas ecotype of black-eyed susan. Hence, temperature may have had a greater effect on flowering (Kochankov and Chailakhyan, 1986).

In conclusion, site had the greatest influence on growth and flowering of NFL, CFL, and TEX. Those making recommendations or considering use of black-eye susan under low input conditions like those in this study need to be aware of the variability that could occur at different sites despite apparent similarities in environmental conditions and/or

cultural practices. TEX plants were the showiest in flower but plants from the two Florida seed sources were better able to survive the low fertility sites under Florida conditions. This provides some evidence of adaptation to regional site conditions, and hence, seed source should be considered when season-long persistence of black-eyed susan is an issue.

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