Research Reports

Flowering, Drought and Disease Tolerance, and Landscape Performance of Landscape Roses Grown under Low-input Conditions in North Central Texas

Derald Harp^{1,7}, Gaye Hammond², David C. Zlesak³,
Greg Church⁴, Mark Chamblee⁵, and Steve George⁶

ADDITIONAL INDEX WORDS. black spot, drought, powdery mildew, *Rosa* sp., shrub roses

SUMMARY. Landscaping today involves the struggle to balance aesthetically pleasing plants while minimizing the impact on the environment, reducing water usage, decreasing fertilizer use, and eliminating or significantly reducing pesticide usage. Roses (*Rosa* sp.), although seen as challenging plants, remain the most popular flowering shrub in the United States. The identification of new cultivars that combine beauty, pest and disease resistance, and drought tolerance are important to Texas landscapes. Sixty roses were assessed over a 3-year period to determine flowering, drought tolerance, disease resistance, and overall landscape performance in minimal-input gardens in north central Texas. Atypical weather during the study had a significant impact on performance. A 2-year drought (2010–11) was accompanied by the hottest summer on record (2011), which included a record number of days of at least 100 °F or higher. As a result, supplemental irrigation was provided three times both summers. Roses generally fared well under these conditions and survived the drought. Flowering was most abundant during the spring and fall, and it was least abundant in the summer. Powdery mildew [PM (*Sphaerotheca pannosa* var. *rosae*)] was a minor problem. Nine of 60 cultivars developed no visible symptoms of PM during the study. Most PM occurred in Spring 2010, with very little found after June; none was found in 2011. Black spot [BS (*Diplocarpon rosae*)] was serious for some cultivars, but most were BS-free; RADrazz (Knock Out®) and Lady Banks White had no observed BS during the study. BS occurred mostly in May, June, and November. Overall landscape performance ratings were high, with 23 cultivars having a mean landscape performance rating equal to or better than the Belinda's Dream standard. The best-performing cultivars were RADrazz (Knock Out), RADcon (Pink Knock Out®), RADyod (Blushing Knock Out®), WEKcibaco (Home Run®), and Alister Stella Gray. This study was able to identify many other highly performing roses in north central Texas.

Landscapers and homeowners struggle with numerous environmental and municipal challenges. Water is becoming a scarce resource, especially in Texas, with a potential water shortage of 4.8 million

acre-feet per year in 2020 and irrigation water needs of more than 3.5 million acre-feet per year (Texas Water Development Board, 2017). The use of pesticides is decreasing as customers seek insect and disease

control methods with minimal environmental impact (Zlesak, 2006). To address these challenges, the Texas A&M University AgriLife Extension Service (College Station, TX) developed the Earth-Kind® landscape management program (Harp et al., 2009; Zlesak et al., 2015) that focuses on three primary areas. First, Earth-Kind® recommends hardy landscape plants that survive with minimal amounts of water and fertilizer, are pest- and disease-resistant, and provide beauty with very low additional input. Second, Earth-Kind® landscape beds are prepared and maintained using organic composts and mulch to preserve soil moisture and provide consistent fertility sufficient to maintain plant growth. Third, Earth-Kind® gardens rely on limited irrigation delivered through drip irrigation. The combination of these strategies has resulted in high-quality roses, crepe myrtle (*Lagerstroemia* sp.), perennials, and annuals (Chretien and Harp, 2017; Church et al., 2012; Harp et al., 2009, 2017; Zlesak et al., 2015).

Even though roses remain the most popular woody ornamental shrub in the United States (Waliczek et al., 2015), their desired characteristics have changed over the years. Demand has increased for shrub roses that are of medium height (3 to 4 ft), disease-resistant, fragrant, floriferous, and reblooming (Grygorczyk, 2013; Waliczek et al., 2015). Consumers are less willing or able to spend time in their gardens treating plants for recurrent pest and disease problems (Harp et al., 2009; Waliczek et al., 2015; Zlesak et al., 2017). These traits are possessed by shrub or landscape roses (terms often used synonymously by marketers) that typically have lower maintenance requirements than other rose types, such as hybrid tea roses (Mackay et al., 2008; Mangandi et al., 2013). Hybrid tea roses need heavy pruning, frequent applications of fungicides and pesticides, heavy fertilization, and regular irrigation (Mackay et al., 2008). Recently, shrub and landscape roses have significantly increased in popularity and now account for the majority of U.S. landscape rose sales (Pemberton and Karlik, 2015).

The Texas A&M University Earth-Kind® Landscape Management Program has been conducting rose trials under low-input conditions since the 1990s. Cultivars with strong pest

and disease resistance that tolerate the high temperatures of a Texas summer are of great value to consumers and retailers in the southern Great Plains and the southern U.S. states bordering the Gulf Coast. They are particularly valuable because most nationally distributed rose cultivars have originated outside of this region. Trials are performed over multiple years and locations and use well-defined, low-input protocols (Harp et al., 2009; Mackay et al., 2008; Zlesak et al., 2015). Cultivars with consistently high performance across regional sites in Texas earn the Earth-Kind® designation for that particular region. To date, 23 rose cultivars have been awarded this designation in Texas (Texas A&M University, 2011).

Using basic plant care, consumers are very likely to be successful with these cultivars because they have been selected based on years of data supporting their regional adaptation. Earth-Kind® rose trialing efforts are ongoing, with new trials initiated as promising cultivars enter the marketplace. Earth-Kind® rose trials have expanded outside of Texas and the greater south central United States,

and horticulturists in other regions have been encouraged to partner with the Earth-Kind® program using the well-established Earth-Kind® trialing protocols developed in Texas and to modify them, as necessary, based on unique regional conditions (Harp et al., 2009; Zlesak et al., 2015).

The objective of this study was to evaluate a new collection of landscape rose cultivars for landscape performance, pest resistance, disease resistance, and drought tolerance that possessed desirable ornamental characteristics in north central Texas [U.S. Department of Agriculture (USDA) Plant Hardiness Zone 8a] using low-input Earth-Kind® rose trialing methodology.

Materials and methods

PLANT MATERIALS. We selected 60 rose cultivars for field evaluation based on recommendations by horticulturists, producers, public garden professionals, and American Rose Society members in the south central United States (Supplemental Table 1). Roses included cultivars from several established rose breeding programs in the United States and abroad, as well as domestic and international amateur hybridizers.

Newer and older rose cultivars showing promise in regional landscapes that were not previously involved in the Earth-Kind® rose trials were included. Cultivars were selected from breeding programs at universities [e.g., K. Zuzek and S. Hokanson at the University of Minnesota, Minneapolis (Zuzek et al., 2016)], commercial nurseries [e.g., P. Lim at Bailey Nurseries (Newport, MN), A. Meilland at Meilland International (Le Caneet-des-Maures, France), and R. Moore at Sequoia Nursery (Visalia, CA)] and independent breeders (e.g., R. Ponton, D. Zlesak, and W. Radler). Two cultivars (Belinda's Dream and Knock Out®) previously received the Earth-Kind® designation for Texas and were used as standards.

Roses were propagated from stem cuttings and not grafted ("own root")

to avoid graft incompatibilities and unpredictable rootstock and scion interactions (Richer et al., 2005). Roses, at planting, were 2-year-old plants obtained from Chamblee's Rose Nursery (Tyler, TX) and the Antique Rose Emporium (Independence, TX).

PLANTING SITE, PLANT INSTALLATION, AND MAINTENANCE. We conducted the study on 2.5 acres at the Gussie Field Waterworth Park in Farmers Branch, TX (USDA Plant Hardiness Zone 8, American Horticultural Society Heat Zone 8) from Jan. 2008 through Oct. 2012. The soil in ≈60% of the study area was Houston Black clay (fine, smectitic, thermic, udic Haplusterts; pH 7.9), and the remaining 40% was Lewisville silty clay (fine-silty, mixed, active, thermic udic Calciustolls; pH 8.2).

Ten-foot-wide beds were created by spraying existing vegetation with glyphosate and tilling the dead plant material into the soil to a depth of 12 inches. Fifteen-foot-wide mowed grassy walkways were maintained between rows. Roses were planted in a single row down the middle of the beds with within-row spacing of 8 ft. The experimental area was divided into four blocks, with one plant of each cultivar randomized per block. Buffer plants (either 'Belinda's Dream' or 'Duchesse de Brabant') were installed at the ends of each row to reduce the risk of performance bias because they could experience higher levels of air circulation that could increase stress and reduce disease pressure.

A drip irrigation system with emitters spaced 18 inches apart and lines running parallel to each other 18 inches apart was added to each bed and covered with 4 inches of shredded tree trimmings. Roses were planted between the parallel drip lines. Mulch from shredded tree trimmings was maintained at 4 inches throughout the duration of the study.

Plants were irrigated to maintain soil moisture during year 1 to ensure

Received for publication 25 Oct. 2018. Accepted for publication 5 Feb. 2019.

Published online 2 April 2019.

We thank the Houston Rose Society and the City of Farmers Branch, TX, for their funding and generous support of this project. We also thank Pam Smith and the Farmers Branch landscape maintenance staff, the staff of Chamblee's Rose Nursery, and the many generous volunteers (e.g., members of the Houston Rose Society, residents of Farmers Branch, and nearby rose society members) who helped make this research possible.

Mention of a trademark, proprietary product, or vendor does not constitute an endorsement, guarantee or warranty of the product by the authors, Texas A&M University–Commerce, Texas A&M University, Texas A&M AgriLife Extension, University of Wisconsin–River Falls, the Houston Rose Society, or the City of Farmers Branch, and does not imply its approval to the exclusion of other products or vendors that also may be suitable.

¹Texas A&M University–Commerce, P.O. Box 3011, Commerce, TX 75429

²Houston Rose Society, 5020 Montrose Boulevard, 9th Floor, Houston, TX 77006

³University of Wisconsin–River Falls, 410 South 3rd Street, River Falls, WI 54022

⁴Arboricultural Services, Inc., 16 Steel Road, Wylie, TX 75098

⁵Chamblee's Rose Nursery, 10926 U.S. Highway 69 N, Tyler, TX 75706

⁶Texas A&M Research and Extension Center, 17360 Coit Road, Dallas, TX 75252

⁷Corresponding author. E-mail: Derald.Harp@tamuc.edu.

This is an open access article distributed under the CC BY-NC-ND license (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).

<https://doi.org/10.21273/HORTTECH04215-18>

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
1233.4819	acre-ft	m ³	0.0008
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

Fig. 1. Average monthly maximum and minimum temperatures and total monthly precipitation during the growing season (April to October) for Farmers Branch, TX, from 2009 to 2011; $(^{\circ}\text{F} - 32) \div 1.8 = ^{\circ}\text{C}$, 1 inch = 25.4 mm.

establishment. During year 2, irrigation was applied on an as-needed basis to maintain plant quality. During years 3 and 4, irrigation was only applied to maintain plant survival. During the study, north central Texas experienced an exceptional drought event, with below normal rainfall, above normal pan evaporation, and a severe heat wave with temperatures above 100°F during 25 d in 2010 and 71 d in 2011. Monthly precipitation for the 2010 growing season was less than 2.5 inches for 5 months of the 7-month growing season, and it was less than 1 inch during 3 months of the 7-month growing season in 2011 (Fig. 1). We irrigated plants once in June, once in July, and once in August during both 2010 and 2011.

Plants were maintained using Earth-Kind[®] protocols (Harp et al., 2009; Zlesak et al., 2015). Decomposing mulch provided plant nutrition throughout the study, with no supplemental fertilizers applied. No

pesticides, fungicides, or other treatments were used during the study; spent blossoms were not removed, and plants were not pruned to observe the natural plant form.

PLANT QUALITY ASSESSMENT. Beginning in 2009, a scientist from either Texas A&M University AgriLife Extension Service or Texas A&M University–Commerce (Commerce, TX) assessed the roses monthly from April to October to determine overall landscape performance, drought stress, blossom number, and percentage of plant covered with blossoms.

Overall landscape performance encompassed vigor, foliage quality and color, blossom quantity and quality, fragrance, disease and insect tolerance/resistance, soil tolerance, growth habit, and overall aesthetics. We rated landscape performance using a scale of 0–10 with three indices (Mackay et al., 2008). The three indices were flower quantity and quality, foliage quantity and quality,

and plant habit and vigor. The following scores were used: 10 = no deductions for all three indices; 9 = slight deduction for one index; 8 = slight deduction for two indices; 7 = slight deduction for three indices or moderate deduction for one index; 6 = moderate deduction for one index and slight deduction for one index; 5 = moderate deductions for one index and slight deductions for two indices; 4 = moderate deductions for two indices; 3 = severe deductions for one index and moderate deduction for one index; 2 = severe deductions for two indices; 1 = severe deductions for three indices; and 0 = a dead plant.

A specialist with the Texas A&M University AgriLife Extension Service assessed the roses for disease five times in 2009 (May, June, August, September, and November), four times in 2010 (April, June, July, and September), and three times in 2011 (May, August, and September). Plants were rated on a scale of 0 to 5: 0 = no

observable disease; 1 = up to 20% of the plant infected; 2 = between 21% and 40% of the plant infected; 3 = between 41% and 60% of the plant infected; 4 = between 61% and 80% of the plant infected; and 5 = more than 80% of the plant infected. Plants were rated separately for black spot, powdery mildew, and cercospora leaf spot [CLS (*Cercospora rosicola*)]. At the time of the study, rose rosette disease had not become common in the study area, and although roses did develop the disease later, we noted no symptoms of rose rosette disease during the study.

Drought stress was determined by visual scoring. Leaf wilting, stem tip wilting, marginal leaf browning and necrosis, and yellowing and chlorosis of foliage served as indicators of plant drought stress (Harp et al., 2015; Pinior et al., 2005). We assigned plant scores based on a visual estimate of the percentage of the plant with drought symptoms. Although we collected no affirming physiological data, the emphasis was the identification of asymptomatic cultivars rather than conferring a quantifiable assessment of drought stress in an individual plant or cultivar.

The experimental design was a randomized complete block, with each cultivar represented once in each of the four blocks. Arcsine square root transformations were made for bloom coverage percentages and drought scores, and the data were back-transformed for publication purposes. We conducted a normality test using the UNIVARIATE procedure in SAS (version 9.4; SAS Institute, Cary, NC) before analysis of all data sets. Although skewness and kurtosis were within acceptable ranges (−2.0 to 2.0), the data sets did not satisfy the requirements of the Kolmogorov-Smirnov ($P < 0.001$) normality tests; therefore, data were analyzed using the GLIMMIX procedure in SAS (version 9.4) following the techniques described by Stroup (2014) using Newton–Raphson Optimization. Months were controlled as a repeated variable and data were analyzed using a covariance structure selected by using Akaike’s information criterion (AIC) score; Fisher’s least significant difference was used to contrast cultivars ($\alpha = 0.05$).

Results and discussion

WEATHER. Temperatures in Farmers Branch in 2009 and 2010

were normal, but north central Texas experienced an extreme heat wave in 2011, with temperatures above 100 °F for 71 d, including 40 d consecutively. The average high temperature was above 100 °F in both July and Aug. 2011, imparting major stress on the plants (Fig. 1). An exceptional drought in north central Texas exacerbated the heat during the study period, with record low rainfall between Oct. 2010 and Sept. 2011. During the growing season, only 19 inches of precipitation fell in 2010, and only 18.1 inches fell in 2011, but almost half of each year’s total occurred during just 1 month, in Sept. 2010 and May 2011 (Fig. 1). In addition, pan evaporation rates in 2011 increased to more than 5 inches per week, placing the study plants in severe moisture stress. The severe heat and drought required the use of supplemental irrigation during both 2010 and 2011, with supplemental irrigation applied once per month in June, July, and August of both years.

OVERALL LANDSCAPE PERFORMANCE. Across all cultivars, plants scored highest in April, followed by May, September, and October (Supplemental Table 2). Plants scored lowest in June through August, reflecting declining plant performance during the heat and drought of summer. This pattern was not reflected in 2009, because plants received regular irrigation throughout the growing season to ensure plant establishment. However, plants fared much more poorly during Summer 2010 and Summer 2011, both of which were periods of exceptional drought in north central Texas.

Several cultivars performed well throughout the study. Knock Out®, Pink Knock Out®, Blushing Knock Out®, Double Knock Out®, ‘Alister Stella Gray’, and Home Run® received the highest landscape performance ratings across the entire study (Table 1). Landscape performance ratings for these cultivars followed the overall pattern of higher ratings in the spring and fall and lower ratings in the summer (Supplemental Fig. 1). However, these roses were typified by not only extremely strong performance during the spring but also good relative performance during the heat and stress of summer. For example, ‘Alister Stella Gray’ received very high landscape performance ratings throughout the study (Supplemental Fig. 1, Supplemental Table 3).

BLOOM NUMBER. When considering the overall bloom number, the roses continued the spring/fall bimodal pattern found during bloom coverage (Supplemental Table 4). Maximum bloom number occurred in April, with an average of 84.5 blooms per plant, and more than 90% of roses were in bloom. In May and October, the average bloom numbers decreased to 43.6 and 43.2, respectively. The greatest bloom decreases occurred in August, when plants averaged only 15.9 blooms per plant, and more than 37% of roses had no blooms. The greatest reduction in bloom development occurred during the severe heat and drought of July 2011, with an average of only 5.3 flowers per plant, and 52.8% of plants had no flowers.

‘Red Cascade’ and ‘Lena’ were the most floriferous. ‘Red Cascade’ averaged 152.8 blooms per plant (Table 1, Supplemental Table 5) and had many months with more than 500 blooms per plant, including one plant in Apr. 2011 with more than 1200 blooms. ‘Lena’ produced a similar number of blooms (143.8) and had many months with more than 400 blooms per plant, with a peak of 864 in Apr. 2010. ‘Ole’ and ‘Oso Happy® Candy Oh!’ averaged 122.0 and 115.5 blooms, respectively, and were the only other roses to average more than 100 blooms per plant (Supplemental Table 5). All of these roses have small flowers (<1.5 inches) and flower in dense, terminal clusters.

As the flower size increased, the average number of blooms decreased; this trend was consistent with that of previous studies (Zlesak et al., 2017). Although still in the top 10, in terms of bloom number, the larger flowered (>2 inches) cultivars Alister Stella Gray (97.6), Knock Out® (70.5), Rouletti (66.4), and Blushing Knock Out® (66.2) had an average of fewer than 100 blooms per plant.

The climbing cultivar, Peggy Martin, is a prolific bloomer, but only during spring. In Apr. 2011, the four plants averaged 932 blooms, with one outperforming all other roses with its 1380 blooms. Unfortunately, these same plants had only 90 blooms in May 2011 and 9 blooms for the remainder of the growing season. ‘Peggy Martin’ should be considered a very heavy bloomer, but only in spring. Although consumers overwhelmingly prefer to purchase roses that bloom throughout the summer (Zlesak, 2006), cultivars

Table 1. Landscape performance, bloom number, bloom coverage, drought rating, black spot, and powdery mildew ratings for roses evaluated during 3 years under minimal-input conditions in north central Texas. Rose cultivars are listed in order of landscape performance from best to worst.

Cultivar ^z	Landscape performance (0–10) ^y	Blooms (no.) ^x	Bloom coverage (%) ^x	Drought (%) ^x	Black spot (0–5) ^w	Powdery mildew (0–5) ^w
Knock Out® (RADrazz)	7.9 a ^v	70.5 c-e	18.1 a-c	7.1 a-i	0.0 s	0.06 j-n
Pink Knock Out® (RADcon)	7.9 ab	59.3 d-f	16.7 a-e	6.0 a-i	0.65 d-j	0.21 e-m
Blushing Knock Out® (RADyod)	7.8 a-c	66.2 c-f	12.7 b-k	8.9 a-i	0.02 rs	0.15 g-n
Alister Stella Gray	7.6 a-d	97.6 b-d	14.4 a-i	3.4 a-d	0.38 j-q	0.33 d-g
Double Knock Out® (RADtko)	7.6 a-d	49.7 ef	14.8 a-g	8.0 a-i	0.48 h-m	0.27 e-k
Sunrise Sunset™ (BAIset)	7.5 a-f	50.2 ef	16.8 a-d	10.3 a-i	0.17 n-s	0.0 n
Home Run® (WEKcisbako)	7.5 a-e	31.7 f	13.2 b-j	7.1 a-i	0.50 g-n	0.17 f-n
Super Hero (BAIsuhe)	7.3 a-h	34.2 f	11.0 b-o	9.2 a-i	0.10 p-s	0.0 n
Lena (BAIlena)	7.3 a-g	143.8 ab	25.8 a	16.9 i	0.60 e-l	0.06 j-n
Easy Does It™ (HARpageant)	7.3 a-f	18.0 f	14.5 a-i	7.3 a-i	0.65 d-j	0.08 i-n
Pink Double Knock Out® (RADtkopink)	7.2 a-h	50.3 ef	12.0 b-m	7.1 a-i	0.04 q-s	0.21 e-n
Crepuscle	7.1 a-i	30.5 f	7.9 d-r	7.0 a-i	0.29 k-s	0.27 e-j
Katy Girl (PONGirl)	7.1 a-i	23.7 f	12.8 b-j	4.3 a-g	0.15 o-s	0.04 l-n
Ole (BAIole)	7.0 a-k	122.0 ab	14.1 b-j	12.5 c-i	0.42 i-p	0.0 n
Chuckles	7.0 a-j	56.5 ef	13.3 b-j	5.9 a-i	0.48 h-n	0.52 b-d
My Girl™ (BAIgirl)	7.0 a-j	20.6 f	9.3 c-q	11.0 a-i	0.10 p-s	0.0 n
Coral Knock Out® (RADral)	6.9 a-l	45.0 ef	14.5 a-h	12.8 c-i	0.17 n-s	0.02 mn
Red Cascade (MOORcap)	6.9 a-l	152.8 a ^v	11.5 b-m	3.9 a-f	0.48 h-n	0.06 j-n
Madame Berkeley	6.9 a-k	18.2 f	9.6 b-q	3.4 a-c	0.65 d-j	0.06 k-n
McClinton Tea	6.8 a-l	46.3 ef	7.3 f-s	6.4 a-i	0.54 g-m	0.60 ab
Oso Happy® Candy Oh! (ZLEMartinCipar)	6.8 a-l	115.5 ab	10.3 b-p	9.9 a-i	0.13 p-s	0.06 j-n
Karen Poulsen	6.7 a-m	32.2 f	12.6 b-l	12.4 c-i	0.50 g-n	0.02 mn
Jean Bach Sisley	6.6 c-n	19.2 f	6.8 g-s	5.5 a-i	0.96 ab	0.23 e-l
Penelope	6.6 c-n	36.9 f	7.9 d-r	6.0 a-i	1.04 ab	0.29 e-h
Sunny Knock Out® (RADsunny)	6.6 b-m	28.5 f	10.2 b-p	14.7 e-i	0.17 n-s	0.06 j-n
Belinda's Dream	6.5 d-n	10.3 f	6.1 j-s	6.5 a-i	0.23 m-s	0.08 h-n
Rainbow Knock Out® (RADcor)	6.5 d-n	60.8 d-f	19.3 ab	3.8 a-e	0.19 n-s	0.75 a
Rouletii	6.5 d-n	66.4 c-f	12.2 b-l	3.6 a-d	0.71 d-j	0.11 h-n
Deanna	6.5 c-n	16.7 f	7.4 f-r	6.3 a-i	0.72 d-i	0.31 d-h
Brite Eyes™ (RADbrite)	6.4 d-o	8.6 f	9.3 c-q	7.9 a-i	0.04 q-s	0.27 e-i
Peggy Martin	6.4 d-o	55.5 ef	4.5 n-s	8.0 a-i	0.46 h-o	0.38 d-f
Sven (BAIsven)	6.4 d-o	61.9 d-f	14.7 a-g	15.4 f-i	0.46 h-o	0.0 n
White Pet	6.4 d-o	103.3 a-c	15.6 a-f	12.8 c-i	0.63 d-k	0.04 l-n
Cinco de Mayo™ (WEKcobeju)	6.3 e-p	22.5 f	12.5 b-l	4.8 a-i	0.79 b-h	0.0 n
Cameron Bohls (PONbohls)	6.2 g-q	48.6 ef	9.8 b-q	12.3 c-i	0.63 d-k	0.23 e-m
Cinderella	6.2 g-q	63.0 c-f	13.7 b-j	6.2 a-i	0.56 f-l	0.0 n
Lady Banks White	6.2 g-q	27.2 f	2.5 st	2.9 ab	0.0 s	0.10 h-n
Oso Easy® Peachy Cream™ (HORcoherent)	6.2 f-q	13.3 f	7.2 f-s	9.7 a-i	0.13 p-s	0.06 j-n
Centennial™ (BAIcent)	6.2 d-p	11.2 f	6.8 g-s	10.4 a-i	0.10 p-s	0.0 n
All the Rage™ (RAIrage)	6.1 h-r	17.5 f	9.5 b-q	11.4 b-i	0.06 q-s	0.02 l-n
Seminole Wind (KORTersen)	6.1 h-r	18.9 f	7.7 e-r	9.1 a-i	0.83 b-g	0.06 j-n
Carefree Marvel™ (MEIrameca)	6.1 g-p	33.3 f	6.2 i-s	14.2 d-i	0.13 p-s	0.19 f-n
Macy's Pride™ (BAIcream)	6.0 i-s	10.2 f	6.3 h-s	6.4 a-i	0.54 g-m	0.04 l-n
Sweet Fragrance™ (BAInce)	6.0 i-s	15.5 f	7.0 f-s	9.5 a-i	0.60 e-l	0.08 i-n
Lady Banks Yellow	5.9 i-s	4.5 f	1.8 t	2.9 a	0.35 j-r	0.17 f-n
Soney	5.9 i-s	12.6 f	5.1 l-s	10.5 a-i	0.92 a	0.19 f-n
Chireno	5.8 k-s	14.0 f	3.8 p-s	5.5 a-i	0.50 g-n	0.13 g-n
Surrey (KORlanum)	5.8 j-s	30.1 f	11.3 b-n	5.9 a-i	0.79 b-h	0.0 n
Aloha	5.7 l-s	9.4 f	3.9 p-s	6.9 a-i	0.64 d-j	0.04 l-n

(Continued on next page)

Table 1. (Continued) Landscape performance, bloom number, bloom coverage, drought rating, black spot, and powdery mildew ratings for roses evaluated during 3 years under minimal-input conditions in north central Texas. Rose cultivars are listed in order of landscape performance from best to worst.

Cultivar ^z	Landscape performance (0–10) ^y	Blooms (no.) ^x	Bloom coverage (%) ^x	Drought (%) ^x	Black spot (0–5) ^w	Powdery mildew (0–5) ^w
Parade	5.7 l-s	14.7 f	6.6 g-s	6.4 a-i	0.71 d-j	0.04 l-n
Splendor (PONdora)	5.5 m-t	18.6 f	8.3 d-q	11.7 c-i	0.63 d-k	0.04 l-n
Dublin Bay (MACdub)	5.4 n-t	20.1 f	10.1 b-p	13.2 c-i	0.60 e-l	0.19 f-n
Ilse Krohn Superior	5.4 n-t	3.3 f	2.9 r-s	16.2 g-i	0.27 l-s	0.33 d-g
Molineux (AUSmol)	5.4 n-t	15.0 f	8.4 d-q	10.9 a-i	0.98 a-c	0.13 g-n
Julia Child™ (WEKvossutono)	5.3 o-t	17.0 f	13.0 b-j	4.7 a-h	1.04 ab	0.08 i-n
Mrs. Oakley Fisher	5.3 n-t	1.4 f	4.3 o-s	6.5 a-i	0.63 d-k	0.10 h-n
Lady Hillingdon	5.1 q-t	8.9 f	9.0 c-q	11.3 b-i	0.65 d-j	0.10 h-n
Antoine Rivoire	5.1 p-t	6.8 f	4.8 m-s	10.3 a-i	0.63 d-k	0.58 a-c
Autumn Sunset	4.8 st	5.7 f	3.7 q-s	15.1 e-i	0.90 a-f	0.04 l-n
Meredith Bohls (PONmer)	4.3 t	22.3 f	5.1 k-s	16.6 hi	1.19 a	0.13 g-n

^zCultivar name or trademark followed by cultivar name in parentheses.

^yLandscape performance was scored using a criterion-referenced scale from 0 (dead plant) to 10 (strong performance) with three indices (flower quantity and quality, foliage quantity and quality, and plant habit and vigor) as described by Mackay et al. (2008). Ratings were recorded once monthly during the growing season. Least square means are displayed.

^xDrought ratings were determined by estimating the percentage of the plant demonstrating drought symptoms, which included wilting, leaf margin browning and necrosis, chlorosis, and branch dieback without observed disease. Data were transformed using arcsine square root transformations and back-transformed for presentation purposes.

^wBlack spot and powdery mildew incidence was rated separately using a scale of 0 to 5: 0 = no observable disease, 1 = up to 20% of the plant infected, 2 = between 21% and 40% of the plant infected, 3 = between 41% and 60% of the plant infected, 4 = between 61% and 80% of the plant infected, and 5 = >80% of the plant infected.

^vData followed by different letters within the columns indicate they were significantly different at $P < 0.05$ according to Fisher's least significant difference.

like Peggy Martin serve a valuable niche when a strong burst of color and landscape focal point are required during a few weeks in spring.

BLOOM COVERAGE. Across all cultivars and years, maximum bloom coverage occurred during the early and late months of the growing season, with maximum flowering in April, May, and October (Supplemental Table 6). Heat and drought stress decreased blooms during the summer, with the lowest bloom coverage in July and August. We recorded a high bloom coverage percentage in July 2010 following an irrigation application used to alleviate drought stress.

Consistent with findings by Mackay et al. (2008), the 10 best roses in terms of bloom coverage were shrub and polyantha roses. These roses included six shrub roses, including three from the Knock Out® series (Table 1, Supplemental Table 7). The poorest performers in terms of bloom coverage were the once-blooming Lady Banks White and Lady Banks Yellow roses, along with other climbing cultivars Autumn Sunset, Peggy Martin, and Aloha. Although some of these spring-blooming cultivars produced spectacular floral displays in April, the deductions received for failure to flower during subsequent months greatly influenced the once blooming cultivars' overall bloom coverage rating during each year of evaluation. Among the tea and hybrid tea cultivars, Mrs.

Oakley Fisher, Antoine Rivoire, and Soncy had the lowest bloom coverages during the study period.

DROUGHT. The cultivars selected appeared to tolerate drought stress reasonably well, with 24 of 60 cultivars with drought stress ratings statistically similar to that of Lady Banks Yellow, with an average score of 2.6% and only one score higher than 10% (Table 1, Supplemental Table 8). Even the cultivars most susceptible to drought had an average score less than 20%.

However, within individual months, several cultivars suffered. 'Ilse Krohn Superior' had an average score of 17.9%, but post-August scores frequently exceeded 60%, with individual specimens of the cultivar with 80% or more of the plant having severe drought stress symptoms. Similar patterns existed in the cultivars Lena, Meredith Bohls, Carefree Marvel™, and several others.

Drought stress symptoms first appeared, on average, in June, and were more common in September and October (Supplemental Table 9). Because irrigation was only applied to ensure survival, plants did not recover during the milder fall weather. Damage during the summer likely exceeded the recuperative ability of the plant, and significant improvement did not occur until the following spring. This was consistent with the results of a related study in which data collection was ended following a severe heat wave (daily high temperatures consistently above 100 °F) and

drought (pan evaporation >70 mm/week) that led to premature dormancy of test plants (Zlesak et al., 2017).

DISEASES. As anticipated, BS and PM were the two most common diseases found. No evidence of CLS was found during the study. PM and BS were prevalent during the spring and fall. Black spot was most prevalent in May (0.69), June (0.79), and November (1.94) (scores were determined based on a scale of 0 to 5). Increases in disease ratings are typical because BS infection begins in the spring and early summer and progresses, becoming worse throughout the year without any treatment, similar to the results described by Mueller et al. (2008). Infection rates decreased in August (0.02) and September (0.12) because the extreme heat and drought prevented the formation of water droplets needed to spread the water-borne conidia (Smith et al., 1988); however, this may be more common in Texas (Black et al., 1994).

As seen with BS, PM was found most common in May (0.43), June (0.29), and April (0.16) (scores were determined based on a scale of 0 to 5). The disease virtually disappeared during the summer, with scores of 0.07, 0.05, and 0.02 in July, August, and September, respectively. It should be noted that most of the disease scores occurred during the first year of the study, with no PM noted during Summer 2011.

This study used roses with known BS tolerance. Of the best performing

roses, the cultivars Knock Out® and Lady Banks White had no record of BS, and the mean BS score of 20 of the 60 cultivars could not be separated statistically (Table 1), with scores ranging from 0.0 on a 5-point scale for Knock Out® to an average score of 0.29 for Crepuscule.

In terms of PM incidence, nine cultivars showed no infection during the study period, and 49 of the 60 cultivars had scores consistent with the best performers. Because PM infection occurs during periods of mild temperatures and high relative humidity, the absence of disease likely resulted from a combination of both genetic resistance and generally dry, hot weather during the study period.

Conclusion

Several roses demonstrated strong performance throughout the study, even with atypical weather conditions during the last 2 years; therefore, we recommend these for landscape use in north central Texas and regions with similar conditions. The top 10 cultivars overall based on landscape performance rating were Knock Out®, Pink Knock Out®, Blushing Knock Out®, Alister Stella Gray, Double Knock Out®, Sunrise Sunset™, Home Run®, Lena, Super Hero™, and Easy Does It™. As the study progressed and the drought intensified, only 'Alister Stella Gray' ranked in the top 10 for drought tolerance. In fact, only 5 of these 10 roses scored in the top 50% for drought tolerance ('Alister Stella Gray', Home Run®, Knock Out®, Pink Knock Out®, and Easy Does It™). Interestingly, as the study continued, the performance of 'Lena' decreased considerably, and it was in last place for drought tolerance. This study reinforced the negative impact of black spot disease on rose performance and the importance of identifying and using resistant cultivars under low-input conditions. Data from this study can help consumers and landscapers identify roses with strong ornamental performance (e.g., overall performance, drought tolerance, strong performance early in the season, etc.), breeders identify parents that possess traits of interest (e.g., Julia Child™ is a parent of 'Cinco de Mayo™', and both were in the top 10 roses for drought tolerance), and researchers identify opportunities for continued study (e.g., root architecture differences related to drought tolerance).

Literature cited

- American Rose Society. 2007. Modern roses XXII. Pediment Publ., Battleground, WA.
- American Rose Society. 2014. Consulting rosarian manual. Amer. Rose Soc., Shreveport, LA.
- Black, W.A., D.H. Byrne, and H.B. Pemberton. 1994. Field study of black spot resistance in rose. *HortScience* 29:525 (abstr.).
- Chretien, K. and D.A. Harp. 2017. Performance of Black Diamond® crepe myrtles (*Lagerstroemia indica* L.) in northeast Texas. *HortScience* 52:S38 (abstr.).
- Church, G., D.C. Zlesak, D.A. Harp, K. Schofield, J. Sloan, G. Hammond, P. Smith, and S. George. 2012. Response of selected roses to low-input cultural practices, high disease pressure, and severe heat and drought conditions. *HortScience* 47:S230–S231 (abstr.).
- Grygorczyk, A., S. Mhlanga, and I. Leescave. 2013. Hardy rose breeding: Consumer preferences for roses. 11 Dec. 2016. <http://vinelandresearch.com/sites/default/files/hardy_rose_breeding_consumer_preferences_for_roses.pdf>.
- Harp, D.A., K. Kay, D.C. Zlesak, and S. George. 2015. The effect of rose root size on drought stress tolerance and landscape plant performance. *Tex. J. Agr. Nat. Resour.* 28:82–88.
- Harp, D.A., D.C. Zlesak, G. Hammond, S. George, and W. Mackay. 2009. Earth-Kind® rose trials - Identifying the world's strongest, most beautiful landscape roses. *Flor. Orn. Biotechnol.* 3:166–175.
- Harp, D.A., T. Williams, A. Sandifeer, and S. George. 2017. Long-term performance of cool-season annuals fertilized with slow-release fertilizer or compost. *HortScience* 52:S50 (abstr.).
- Mackay, W.A., S.W. George, C. McKenney, J.J. Sloan, R.I. Cabrera, J.A. Reinert, P. Colbaugh, L. Lockett, and W. Crow. 2008. Performance of garden roses in north central Texas under minimal input conditions. *HortTechnology* 18:417–422.
- Mangandi, J., S.P. Brown, and N. Peres. 2013. Evaluation of low-maintenance landscape roses in central Florida. *HortTechnology* 23:252–257.
- Mueller, D.S., M.L. Gleason, N.P. Howell, and E.M. Moran. 2008. Evaluation of Griffith Buck roses for resistance to black spot. *HortTechnology* 18:588–591.
- Pemberton, H.B. and J.F. Karlik. 2015. A recent history of changing trends in garden rose plant sales, types, and production methods. *Acta Hort.* 1064:223–234.
- Pinior, A., G. Grunewaldt-Stöcker, H. vol Alten, and R.J. Strasser. 2005. Mycorrhizal impact on drought stress tolerance of rose plants probed by chlorophyll *a* fluorescence, proline content and visual scoring. *Mycorrhiza* 15:596–605.
- Richer, C., J.A. Rioux, M.P. Lamy, and R. Drapeau. 2005. Impact of propagation method on the growth of 10 rose shrubs of the Explorer™ Series under natural and extreme winter conditions. *Can. J. Plant Sci.* 86:799–807.
- Smith, I.M., J. Dunez, D.H. Phillips, R.A. Lelliott, and S.A. Archer. 1988. European handbook of plant diseases. Blackwell Scientific, Oxford, UK.
- Stroup, W.W. 2014. Rethinking the analysis of non-normal data in plant and soil science. *Agron. J.* 106:1–17.
- Texas A and M University. 2011. Monsieur Tillier and Mrs. Dudley Cross - Earth-Kind® 2011 roses. 14 Jan. 2018. <<https://aggie-horticulture.tamu.edu/newsletters/hortupdate/2011/apr/ek-roses-2011.html>>.
- Texas Water Development Board. 2017. Water supply needs, p. 76–85. In: 2017 State water plan. Texas Water Dev. Board, Austin, TX.
- Waliczek, T.M., D.J. Holeman, and D.H. Byrne. 2015. Growers' and consumers' knowledge, attitudes and opinions regarding roses available for purchase. *Acta Hort.* 1064:235–239.
- Zlesak, D.C. 2006. *Rosa x hybrida* L., p. 695–738. In: N.O. Anderson (ed.). Flower breeding and genetics: Issues, challenges, and opportunities for the 21st century. Springer, Dordrecht, The Netherlands.
- Zlesak, D.C., D.A. Harp, K. Zuzek, J.J. Sloan, A. Owings, and S.W. George. 2015. Earth-Kind® rose trialing: An international model for the identification of regionally adapted landscape roses. *Acta Hort.* 1064:123–129.
- Zlesak, D.C., R. Nelson, D. Harp, B. Villarreal, N. Howell, J. Griffin, G. Hammond, and S. George. 2017. Performance of landscape roses grown with minimal input in the north-central, central, and south-central United States. *HortTechnology* 27:718–730.
- Zuzek, K., D.C. Zlesak, V.M. Whitaker, S. McNamara, and S.C. Hokanson. 2016. Northern Accents® 'Lena', 'Ole', 'Sigrid', and 'Sven': Four cold-hardy polyantha rose cultivars from the University of Minnesota woody landscape plant breeding program. *HortScience* 51:296–299.

Supplemental Fig. 1. Mean monthly landscape performance ($\pm$ SE) during the growing season over Branch, TX. Landscape performance was determined using a criterion-referenced scale from 0 (dead plant) to 10 (strong performance) with three indices (flower quantity and quality, foliage quantity and quality, and plant habit and vigor) as described by Mackay et al. (2008).

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Fig. 1. Continued.

Supplemental Table 1. Rose cultivars evaluated for landscape performance in north central Texas. Roses were chosen according to recommendations from rosarians and horticulturists from across the United States.

Cultivar ^z	Commercial class ^y	Flower color ^y	Yr of introduction	Breeder ^x	Introducer ^x
Alister Stella Gray	Noisette	Light Yellow	1854	A.H. Gray	
All the Rage™ (RAIrage)	Shrub	Apricot	2008	Ping Lim	Bailey Nurseries (Newport, MN)
Aloha	Climber	Pink	1949	Boerner	Jackson & Perkins (Hodges, SC)
Antoine Rivoire	Hybrid Tea	Med. Pink	1895	Pernet-Ducher	
Autumn Sunset	Shrub	Apricot Blend	1988	Malcolm Lowe	Lowe's Own-Root Roses (Nashua, NH)
Belinda's Dream	Shrub	Med. Pink	1988	Robert Basye	
Blushing Knock Out® (RADyod)	Shrub	Pale Pink	2004	William Radler	Star Roses and Plants (West Grove, PA)
Brite Eyes™ (RADbrite)	LFCI	Pink blend	2006	William Radler	Star Roses and Plants
Cameron Bohls (PONbohls)	Shrub	Dark Red	2000	Ray Ponton	Chamblee's Rose Nursery (Tyler, TX)
Carefree Marvel™ (MEIrameca)	Shrub	Deep Pink	2000	Alain Meilland	Star Roses and Plants
Centennial™ (BAIcent)	Shrub	Pale Yellow	1996	Ping Lim	Bailey Nurseries
Chireno	Shrub	Deep Pink	2002	Ray Ponton	Chamblee's Rose Nursery
Chuckles	Floribunda	Deep Pink	1958	Roy E. Shepherd	Bosley Nursery (Mentor, OH)
Cinco de Mayo™ (WEKcobeju)	Floribunda	Russet	2006	Tom Carruth	Weeks Roses (Wasco, TX)
Cinderella	Shrub	Lt. Pink	1992	Kordes	Wayside Gardens (Hodges, SC)
Coral Knock Out® (RADral)	Shrub	Orange	2007	William Radler	Meilland-Star Roses (Cutler, CA)
Crepuscule	Noisette	Apricot	1904	Francis Dubreuil	
Deanna	Shrub	Pink blend	2005	Ray Ponton	Antique Rose Emporium (Brenham, TX)
Double Knock Out® (RADtko)	Shrub	Deep Red	2004	William Radler	Star Roses and Plants
Dublin Bay (MACdub)	LFCI	Med. Red	1969	Samuel McGredy IV	McGredy Roses International (Auckland, New Zealand)
Easy Does It™ (HARpageant)	Floribunda	Orange	2006	Harkness New Roses, Ltd.	Bailey Nurseries
Home Run® (WEKcibako)	Shrub	Red	2001	Tom Carruth	Weeks Roses
Ilse Krohn Superior	Shrub	White	1964	Reimer Kordes	W. Kordes Sohne (Schleswig-Holstein, Germany)
Jean Bach Sisley	China	Pink	1898	Francis Dubreuil	
Julia Child™ (WEKvossutono)	Floribunda	Yellow	2004	Tom Carruth	Weeks Roses
Karen Poulsen	Floribunda	Red	1932	Svend Poulsen	Jackson & Perkins
Katy Girl (PONGirl)	Shrub	Lt. Pink	2000	Ray Ponton	Antique Rose Emporium
Knock Out® (RADrazz)	Shrub	Red	1988	William Radler	Star Roses and Plants
Lady Banks White	Climber	White	1807	William Kerr	
Lady Banks Yellow	Climber	Yellow	1824		Royal Horticultural Society (London, England)
Lady Hillingdon	Tea	Apricot	1910	Lowe & Shawyer	
Lena (BAIlena)	Shrub	Pink blend	2007	Kathy Zuzek	Bailey Nurseries
Macy's Pride™ (BAIcream)	Shrub	White	1992	Ping Lim and Jerry Twomey	Bailey Nurseries
Mme. Berkeley	Tea	Salmon	1898	Pierre Bernaix	
McClinton Tea	Tea	Med. Pink	1901	Unknown	Antique Rose Emporium

(Continued on next page)

Supplemental Table 1. (Continued) Rose cultivars evaluated for landscape performance in north central Texas. Roses were chosen according to recommendations from rosarians and horticulturists from across the United States.

Cultivar ^z	Commercial class ^y	Flower color ^y	Yr of introduction	Breeder ^x	Introducer ^x
Meredith Bohls (PONmer)	Shrub	Med. Pink	2003	Ray Ponton	Chamblee's Rose Nursery
Molineux™ (AUSmol)	Shrub	Yellow	1994	David Austin	David Austin Roses, Ltd. (Wolverhampton, England)
Mrs. Oakley Fisher	Hybrid Tea	Yellow	1921	Benjamin R. Cant	Hazlewood Bros. (Epping, Australia)
My Girl™ (BAIgirl)	Shrub	Deep Pink	2008	Ping Lim	Bailey Nurseries
Ole (BAIole)	Shrub	Lt. pink	2007	Kathy Zuzek	Bailey Nurseries
Oso Easy® Peachy Cream™ (HORcoherent)	Shrub	Apricot	1994	Colin Horner	Proven Winners (Sycamore, IL)
Oso Happy® Candy Oh! (ZLEMartinCipar)	Shrub	Dark Red	2008	David Zlesak	Spring Meadow Nursery (Grand Haven, MI)
Parade	LFCl	Deep Pink	1953	Gene Boerner	Jackson & Perkins
Peggy Martin	Climber	Pink	2007	Unknown	Chamblee's Rose Nursery
Penelope	Hybrid Musk	Lt. Pink	1924	Joseph Pemberton	Hazlewood Bros.
Pink Double Knock Out® (RADtkopink)	Shrub	Med. Pink	2005	William Radler	Star Roses and Plants
Pink Knock Out® (RADcon)	Shrub	Med. Pink	2001	Found by Israel Montesino	Star Roses and Plants
Rainbow Knock Out® (RADcor)	Shrub	Orange-Pink	2005	William Radler	Star Roses and Plants
Red Cascade (MOORcap)	Miniature	Dark Red	1976	Ralph Moore	Sequoia Nursery (Visalia, CA)
Rouletii	Miniature	Red blend	1815	Unknown	
Seminole Wind (KORTersen)	LFCl	Deep Pink	1960	Wilhelm Kordes	Chamblee's Rose Nursery
Soncy	Tea	Lt. Yellow		Found in Bermuda	
Splendora (PONdora)	Shrub	Deep Pink	2005	Ray Ponton	Chamblee's Rose Nursery
Sunny Knock Out® (RADsunny)	Shrub	Yellow	2006	William Radler	Star Roses and Plants
Sunrise Sunset™ (BAIset)	Shrub	Pink	2004	Ping Lim	Bailey Nurseries
Super Hero™ (BAIsuhe)	Floribunda	Med. Red	1996	Ping Lim	Bailey Nurseries
Surrey (KORlanum)	Shrub	Lt. Pink	1985	Reimer Kordes	W. Kordes Sohne
Sven (BAIsven)	Shrub	Mauve	2007	Kathy Zuzek	Bailey Nurseries
Sweet Fragrance™ (BAInce)	Grandiflora	Apricot	1991	Ping Lim	Bailey Nurseries
White Pet	Polyantha	White	1879	Peter Henderson	Bennett's Greenhouses (Lafayette, IN)

^zCultivar name or trademark followed by cultivar name in parentheses.

^yReported by the American Rose Society (2014).

^xReported by the American Rose Society (2007).

Supplemental Table 2. Monthly average landscape performance of roses grown in north central Texas.

Month	Landscape performance (0–10) ^z	Landscape performance [mean ± SE (0–10)]		
	Across all years	2009	2010	2011
April	7.6 a ^y	n/a ^x	7.6 ± 0.1	7.2 ± 0.1
May	6.8 b	6.8 ± 0.1	6.5 ± 0.1	7.1 ± 0.1
June	5.8 d	5.8 ± 0.1	6.2 ± 0.1	5.5 ± 0.1
July	5.9 d	6.3 ± 0.1	6.3 ± 0.1	5.1 ± 0.1
August	5.8 d	7.0 ± 0.1	5.3 ± 0.1	5.2 ± 0.1
September	6.3 c	6.7 ± 0.1	6.5 ± 0.1	5.8 ± 0.1
October	6.3 c	6.4 ± 0.1	6.1 ± 0.1	6.3 ± 0.1

^zLandscape performance rating was determined using a criterion-referenced scale from 0 (dead plant) to 10 (strong performance) with three indices (flower quantity and quality, foliage quantity and quality, and plant habit and vigor) as described by Mackay et al. (2008). Ratings were recorded once monthly during the growing season. Scores provided are averages across all roses for that particular month.

^yMeans within the column followed by the same lowercase letter are not significantly different at $P < 0.05$ by Fisher's least significant difference.

^xData not available because data were not collected in Apr. 2009.

Supplemental Table 3. Average overall and yearly ratings for landscape performance of roses evaluated during 3 years under minimal-input conditions in north central Texas ranked in order of performance from best to worst.

Cultivar ^z	Landscape performance (0–10) ^y Across all years	Landscape performance [mean ± SE (0–10)]		
		2009	2010	2011
Knock Out® (RADrazz)	7.9 a ^x	8.5 ± 0.2	7.9 ± 0.2	6.9 ± 0.3
Pink Knock Out® (RADcon)	7.8 ab	8.4 ± 0.2	7.1 ± 0.2	6.6 ± 0.2
Blushing Knock Out® (RADyod)	7.7 a-c	8.1 ± 0.2	7.9 ± 0.2	6.7 ± 0.2
Double Knock Out® (RADtko)	7.5 a-d	7.6 ± 0.3	6.4 ± 0.3	5.90 ± 0.2
Alister Stella Gray	7.5 a-d	8.3 ± 0.2	7.9 ± 0.2	6.8 ± 0.3
Home Run® (WEKciskako)	7.5 a-e	8.2 ± 0.2	7.9 ± 0.2	6.5 ± 0.3
Sunrise Sunset™ (BAIset)	7.4 a-f	7.4 ± 0.3	7.6 ± 0.3	7.4 ± 0.2
Lena (BAIlena)	7.3 a-g	7.9 ± 0.2	7.2 ± 0.2	6.7 ± 0.2
Easy Does It™ (HARpageant)	7.3 a-g	7.6 ± 0.2	7.0 ± 0.2	6.5 ± 0.2
Super Hero™ (BAIsuhe)	7.2 a-h	7.3 ± 0.2	7.1 ± 0.2	6.6 ± 0.3
Pink Double Knock Out® (RADtkopink)	7.2 a-h	6.9 ± 0.2	6.8 ± 0.2	6.9 ± 0.2
Crepuscle	7.1 a-i	7.6 ± 0.2	7.1 ± 0.3	6.5 ± 0.2
Katy Girl (PONgirl)	7.1 a-i	6.9 ± 0.3	6.9 ± 0.3	6.9 ± 0.2
My Girl™ (BAIgirl)	7.0 a-j	8.5 ± 0.2	6.7 ± 0.3	5.5 ± 0.5
Chuckles	7.0 a-j	7.8 ± 0.2	6.93 ± 0.2	6.11 ± 0.3
Ole (BAIole)	7.0 a-k	7.9 ± 0.2	7.3 ± 0.2	5.7 ± 0.3
Madame Berkeley	6.9 a-k	6.9 ± 0.4	6.9 ± 0.3	6.4 ± 0.4
Red Cascade (MOORcap)	6.8 a-l	7.0 ± 0.3	6.7 ± 0.3	6.8 ± 0.3
Coral Knock Out® (RADral)	6.8 a-l	7.3 ± 0.1	7.0 ± 0.2	5.9 ± 0.2
Oso Happy® Candy Oh! (ZLEMartinCiper)	6.7 a-l	7.2 ± 0.2	6.9 ± 0.2	5.6 ± 0.3
McClinton Tea	6.7 a-l	6.3 ± 0.3	6.7 ± 0.2	6.7 ± 0.2
Karen Poulsen	6.7 a-m	6.2 ± 0.2	7.1 ± 0.3	5.9 ± 0.2
Sunny Knock Out® (RADsunny)	6.6 b-m	6.4 ± 0.4	6.5 ± 0.2	6.1 ± 0.02
Penelope	6.5 c-n	7.0 ± 0.2	6.5 ± 0.2	5.6 ± 0.2
Jean Bach Sisley	6.5 c-n	6.9 ± 0.2	6.1 ± 0.2	6.4 ± 0.2
Deanna	6.5 c-n	7.3 ± 0.2	6.2 ± 0.2	5.3 ± 0.3
Rouletii	6.5 d-n	7.0 ± 0.3	6.3 ± 0.3	5.9 ± 0.2
Belinda's Dream	6.5 d-n	7.0 ± 0.3	6.4 ± 0.3	5.7 ± 0.3
Rainbow Knock Out® (RADcor)	6.4 d-o	6.3 ± 0.3	5.7 ± 0.2	6.8 ± 0.3
White Pet	6.4 d-o	6.6 ± 0.3	6.3 ± 0.3	6.1 ± 0.3
Brite Eyes™ (RADbrite)	6.4 d-o	6.0 ± 0.2	6.2 ± 0.3	6.7 ± 0.2
Peggy Martin	6.3 d-o	6.5 ± 0.3	6.2 ± 0.2	6.1 ± 0.2
Sven (BAIsven)	6.3 d-o	5.4 ± 0.2	6.4 ± 0.2	6.6 ± 0.2
Centennial™ (BAIcent)	6.3 d-p	7.1 ± 0.3	6.0 ± 0.3	5.6 ± 0.2
Cinco de Mayo™ (WEKcobeju)	6.3 e-p	6.8 ± 0.2	6.1 ± 0.2	5.4 ± 0.2
Oso Easy® Peachy Cream™ (HORcoherent)	6.2 f-q	6.6 ± 0.2	6.0 ± 0.2	5.8 ± 0.3
Lady Banks White	6.2 g-q	6.2 ± 0.2	5.8 ± 0.2	5.7 ± 0.2
Cameron Bohls (PONbohls)	6.1 g-q	6.0 ± 0.0	6.0 ± 0.1	5.9 ± 0.1
Cinderella	6.1 g-q	6.6 ± 0.2	5.8 ± 0.3	5.5 ± 0.3
Carefree Marvel™ (MAIrameca)	6.1 g-r	6.0 ± 0.2	6.0 ± 0.4	5.7 ± 0.3
Seminole Wind (KORTersen)	6.0 h-r	6.1 ± 0.3	6.2 ± 0.3	5.4 ± 0.3
All the Rage™ (RAIrage)	6.0 h-r	6.3 ± 0.3	5.5 ± 0.2	6.0 ± 0.2
Macy's Pride™ (BAIcream)	5.9 i-s	6.6 ± 0.3	5.6 ± 0.2	5.6 ± 0.2
Sweet Fragrance™ (BAInce)	5.9 i-s	5.9 ± 0.0	6.0 ± 0.1	5.9 ± 0.1
Lady Banks Yellow	5.9 i-s	5.8 ± 0.3	5.4 ± 0.2	5.6 ± 0.2
Soncy	5.9 i-s	6.1 ± 0.3	5.1 ± 0.3	6.1 ± 0.2
Surrey (KORlanum)	5.8 j-s	5.4 ± 0.2	5.2 ± 0.2	6.2 ± 0.2
Chireno	5.7 k-s	6.6 ± 0.4	6.1 ± 0.2	4.3 ± 0.5
Aloha	5.6 l-s	5.6 ± 0.2	5.5 ± 0.2	5.4 ± 0.2
Parade	5.6 l-s	5.6 ± 0.2	5.6 ± 0.2	5.5 ± 0.2
Splendora (PONdora)	5.4 m-t	5.7 ± 0.3	5.9 ± 0.3	4.6 ± 0.3
Isle Krohn Superior	5.3 n-t	5.8 ± 0.2	4.7 ± 0.2	5.1 ± 0.2
Molineux™ (AUSmol)	5.3 n-t	5.2 ± 0.2	5.5 ± 0.2	4.4 ± 0.3
Dublin Bay (MACdub)	5.3 n-t	5.0 ± 0.2	4.9 ± 0.2	5.0 ± 0.3
Mrs. Oakley Fisher	5.3 n-t	4.3 ± 0.2	5.0 ± 0.2	5.6 ± 0.2

(Continued on next page)

Supplemental Table 3. (Continued) Average overall and yearly ratings for landscape performance of roses evaluated during 3 years under minimal-input conditions in north central Texas ranked in order of performance from best to worst.

Cultivar ^z	Landscape performance (0–10) ^y Across all years	Landscape performance [mean ± SE (0–10)]		
		2009	2010	2011
Julia Child™ (WEKvossutono)	5.2 o-t	5.2 ± 0.2	4.9 ± 0.2	4.8 ± 0.3
Antoine Rivoire	5.1 p-t	5.6 ± 0.2	4.5 ± 0.2	4.7 ± 0.3
Lady Hillingdon	5.0 q-t	4.9 ± 0.2	4.9 ± 0.1	4.9 ± 0.2
Autumn Sunset	4.7 st	4.9 ± 0.2	4.2 ± 0.3	4.1 ± 0.3
Meredith Bohls (PONmer)	4.2 t	4.4 ± 0.1	4.0 ± 0.2	3.5 ± 0.2

^zCultivar name or trademark followed by cultivar name in parentheses.

^yData presented in this column are least squares estimates of the means. Landscape performance rating was determined using a criterion-referenced scale from 0 (dead plant) to 10 (strong performance) with three indices (flower quantity and quality, foliage quantity and quality, and plant habit and vigor) as described by Mackay et al. (2008). Ratings were recorded once monthly during the growing season.

^xData followed by different letters within the column indicate they were significantly different at $P < 0.05$ according to Fisher's least significant difference.

Supplemental Table 4. Monthly average bloom number of roses grown in north central Texas.

Month	Blooms (no.) Across all years	Blooms [mean ± SE (no.)]		
		2009	2010	2011
April	84.4 a ^z	n/a ^y	92.9 ± 9.2	76.6 ± 11.9
May	41.8 b	46.1 ± 4.1	27.2 ± 2.9	57.2 ± 5.4
June	27.3 c	37.4 ± 3.3	27.2 ± 3.9	18.5 ± 1.7
July	27.2 c	12.4 ± 1.7	62.8 ± 5.2	5.3 ± 0.6
August	15.9 d	27.1 ± 2.4	9.6 ± 1.3	11.4 ± 0.9
September	30.5 c	14.7 ± 1.6	46.2 ± 4.4	28.7 ± 2.6
October	44.7 b	20.3 ± 1.6	29.8 ± 3.4	79.1 ± 6.0

^zData followed by different letters within the column indicate they were significantly different at $P < 0.05$ according to Fisher's least significant difference. Least squares estimates were mathematically transformed using a cubic equation ($r^2 = 0.998$) for presentation purposes.

^yData not available because data were not collected in Apr. 2009.

Supplemental Table 5. Average overall and yearly ratings for the bloom number of roses evaluated over 3 years under minimal-input conditions in north central Texas ranked in order from most to least average blooms.

Cultivar ^z	Blooms (no.) ^y	Blooms [mean $\pm$ SE (no.)]		
	Across all years	2009	2010	2011
Red Cascade (MOORcap)	152.8 a ^x	129.8 $\pm$ 24.1	142.1 $\pm$ 21.0	192.2 $\pm$ 51.2
Lena (BAIlena)	143.8 ab	106.8 $\pm$ 21.7	212.9 $\pm$ 41.3	127.6 $\pm$ 32.2
Ole (BAIole)	122.0 ab	65.6 $\pm$ 8.5	112.5 $\pm$ 26.5	169.1 $\pm$ 35.9
Oso Happy [®] Candy Oh! (ZLEMartinCiper)	115.5 ab	63.3 $\pm$ 12.5	144.5 $\pm$ 24.6	133.7 $\pm$ 42.5
White Pet	103.3 a-c	74.8 $\pm$ 14.6	81.8 $\pm$ 12.9	106.6 $\pm$ 20.1
Alister Stella Gray	97.6 b-d	80.3 $\pm$ 13.8	120.6 $\pm$ 22.6	77.4 $\pm$ 12.6
Knock Out [®] (RADrazz)	70.5 c-e	52.0 $\pm$ 8.0	94.4 $\pm$ 20.7	62.4 $\pm$ 12.8
Rouletii	66.4 c-f	45.3 $\pm$ 5.1	81.4 $\pm$ 11.4	73.1 $\pm$ 20.5
Blushing Knock Out [®] (RADyod)	66.2 c-f	45.8 $\pm$ 7.6	103.5 $\pm$ 26.4	46.2 $\pm$ 13.7
Cinderella	63.0 c-f	37.6 $\pm$ 6.9	56.5 $\pm$ 9.2	113.6 $\pm$ 20.3
Sven (BAIsven)	61.9 d-f	44.2 $\pm$ 7.3	67.2 $\pm$ 8.9	67.7 $\pm$ 10.5
Rainbow Knock Out [®] (RADcor)	60.8 d-f	40.5 $\pm$ 6.5	76.0 $\pm$ 9.4	58.4 $\pm$ 16.7
Pink Knock Out [®] (RADcon)	59.3 d-f	10.5 $\pm$ 3.0	88.6 $\pm$ 20.0	48.5 $\pm$ 11.7
Chuckles	56.5 ef	33.0 $\pm$ 10.8	43.3 $\pm$ 7.2	77.9 $\pm$ 29.4
Peggy Martin	55.5 ef	27.2 $\pm$ 8.4	12.9 $\pm$ 3.3	15.6 $\pm$ 3.8
Pink Double Knock Out [®] (RADtkopink)	50.3 ef	36.0 $\pm$ 36.0	83.7 $\pm$ 28.2	30.8 $\pm$ 9.9
Sunrise Sunset [™] (BAIset)	50.2 ef	24.7 $\pm$ 3.8	56.4 $\pm$ 10.1	71.7 $\pm$ 14.5
Double Knock Out [®] (RADtko)	49.7 ef	52.0 $\pm$ 9.4	81.8 $\pm$ 27.6	27.6 $\pm$ 5.7
Cameron Bohls (PONbohls)	48.6 ef	32.5 $\pm$ 6.3	73.4 $\pm$ 16.4	37.6 $\pm$ 5.7
Madame Berkeley	46.3 ef	18.6 $\pm$ 4.3	63.6 $\pm$ 14.9	43.0 $\pm$ 11.4
Coral Knock Out [®] (RADral)	45.0 ef	37.9 $\pm$ 7.9	53.8 $\pm$ 13.8	45.6 $\pm$ 9.1
Penelope	36.9 f	43.5 $\pm$ 8.1	50.8 $\pm$ 17.1	29.1 $\pm$ 9.2
Super Hero [™] (BAIsuhe)	34.2 f	9.8 $\pm$ 1.6	31.4 $\pm$ 8.9	51.2 $\pm$ 11.1
Carefree Marvel [™] (MEIrameca)	33.3 f	56.3 $\pm$ 10.8	23.4 $\pm$ 5.6	34.1 $\pm$ 11.2
Karen Poulsen	32.2 f	34.5 $\pm$ 7.8	28.6 $\pm$ 6.7	40.0 $\pm$ 8.9
Home Run [®] (WEKcisbako)	31.7 f	36.0 $\pm$ 7.0	45.5 $\pm$ 6.3	31.8 $\pm$ 5.0
Crepuscle	30.5 f	28.6 $\pm$ 7.6	55.4 $\pm$ 16.6	14.2 $\pm$ 3.5
Surrey (KORlanum)	30.1 f	12.8 $\pm$ 1.7	10.4 $\pm$ 1.7	26.6 $\pm$ 3.9
Sunny Knock Out [®] (RADsunny)	28.5 f	26.8 $\pm$ 5.0	25.1 $\pm$ 6.1	19.8 $\pm$ 4.1
Lady Banks White	27.2 f	0.0 $\pm$ 0.0	69.1 $\pm$ 40.1	0.0 $\pm$ 0.0
Katy Girl (PONgirl)	23.7 f	9.0 $\pm$ 1.7	39.3 $\pm$ 10.8	26.5 $\pm$ 6.0
Cinco de Mayo [™] (WEKcobeju)	22.5 f	11.4 $\pm$ 1.3	13.2 $\pm$ 2.3	35.9 $\pm$ 7.0
McClinton Tea	22.3 f	11.0 $\pm$ 2.1	20.1 $\pm$ 4.7	29.4 $\pm$ 10.6
My Girl [™] (BAIgirl)	20.6 f	18.1 $\pm$ 3.4	24.0 $\pm$ 8.1	16.8 $\pm$ 3.0
Dublin Bay (MACdub)	20.1 f	19.3 $\pm$ 3.3	28.8 $\pm$ 6.2	21.3 $\pm$ 4.6
Jean Bach Sisley	19.2 f	20.4 $\pm$ 5.2	20.7 $\pm$ 4.6	20.0 $\pm$ 7.0
Seminole Wind (KORtersen)	18.9 f	11.3 $\pm$ 2.5	21.3 $\pm$ 5.0	21.0 $\pm$ 5.1
Splendora (PONdora)	18.6 f	9.4 $\pm$ 1.2	16.6 $\pm$ 3.2	31.6 $\pm$ 5.6
Meredith Bohls (PONmer)	18.2 f	26.2 $\pm$ 5.5	19.2 $\pm$ 4.5	15.5 $\pm$ 3.3
Easy Does It [™] (HARpageant)	18.0 f	7.7 $\pm$ 1.5	22.6 $\pm$ 5.7	18.3 $\pm$ 5.3
All the Rage [™] (RAIrage)	17.5 f	12.3 $\pm$ 2.2	16.3 $\pm$ 2.0	26.4 $\pm$ 4.1
Julia Child [™] (WEKvossutono)	17.0 f	16.5 $\pm$ 2.8	10.1 $\pm$ 1.6	24.7 $\pm$ 5.3
Deanna	16.7 f	13.0 $\pm$ 1.5	28.5 $\pm$ 5.4	14.2 $\pm$ 2.9
Sweet Fragrance [™] (BAInce)	15.5 f	7.0 $\pm$ 1.2	4.2 $\pm$ 0.9	12.1 $\pm$ 2.5
Molineux [™] (AUSmol)	15.0 f	17.2 $\pm$ 6.0	12.2 $\pm$ 2.5	17.8 $\pm$ 4.5
Parade	14.7 f	8.9 $\pm$ 1.6	15.5 $\pm$ 3.7	15.5 $\pm$ 4.3
Chireno	14.0 f	22.0 $\pm$ 5.9	20.5 $\pm$ 5.4	4.8 $\pm$ 1.5
Oso Easy [®] Peachy Cream [™] (HORcoherent)	13.3 f	41.0 $\pm$ 19.3	23.8 $\pm$ 8.6	136.6 $\pm$ 70.5
Soncy	12.6 f	8.9 $\pm$ 1.8	8.2 $\pm$ 2.0	15.3 $\pm$ 5.8
Centennial [™] (BAIcent)	11.2 f	5.1 $\pm$ 1.0	15.6 $\pm$ 5.2	8.1 $\pm$ 2.4
Belinda's Dream	10.3 f	4.2 $\pm$ 1.4	12.7 $\pm$ 2.7	8.3 $\pm$ 2.4
Macy's Pride [™] (BAIcream)	10.2 f	7.4 $\pm$ 1.4	6.4 $\pm$ 1.5	12.3 $\pm$ 3.5
Aloha	9.4 f	3.6 $\pm$ 1.0	9.5 $\pm$ 3.1	9.0 $\pm$ 3.5
Lady Hillingdon	8.9 f	4.0 $\pm$ 0.9	7.7 $\pm$ 1.2	13.2 $\pm$ 3.3
Brite Eyes [™] (RADbrite)	8.6 f	1.1 $\pm$ 0.3	12.1 $\pm$ 2.0	10.6 $\pm$ 1.9
Antoine Rivoire	6.8 f	9.8 $\pm$ 1.9	6.9 $\pm$ 1.6	6.9 $\pm$ 2.1

(Continued on next page)

Supplemental Table 5. (Continued) Average overall and yearly ratings for the bloom number of roses evaluated over 3 years under minimal-input conditions in north central Texas ranked in order from most to least average blooms.

Cultivar ^z	Blooms (no.) ^y	Blooms [mean $\pm$ SE (no.)]		
	Across all years	2009	2010	2011
Autumn Sunset	5.7 f	5.3 $\pm$ 1.2	8.6 $\pm$ 3.5	2.7 $\pm$ 0.7
Lady Banks Yellow	4.5 f	0.0 $\pm$ 0.0	12.5 $\pm$ 8.1	0.0 $\pm$ 0.0
Isle Krohn Superior	3.3 f	1.9 $\pm$ 0.7	1.5 $\pm$ 0.6	8.1 $\pm$ 2.7
Mrs. Oakley Fisher	1.4 f	1.8 $\pm$ 0.5	2.8 $\pm$ 0.6	6.5 $\pm$ 1.6

^zCultivar name or trademark followed by cultivar name in parentheses.

^yData followed by different letters within the column indicate they were significantly different at $P < 0.05$ according to Fisher's least significant difference. Least squares estimates were mathematically transformed using a cubic equation ($r^2 = 0.99$) for presentation purposes.

Supplemental Table 6. Average monthly bloom coverage of roses grown in north central Texas.

Month	Bloom coverage (%) ^z	Bloom coverage [mean $\pm$ SE (%)]		
	Across all years	2009	2010	2011
April	19.4 a ^y	n/a ^x	23.5 $\pm$ 1.6	15.3 $\pm$ 1.2
May	11.4 b	15.9 $\pm$ 0.8	7.0 $\pm$ 0.5	11.2 $\pm$ 0.6
June	9.3 c	11.8 $\pm$ 0.6	5.8 $\pm$ 0.6	10.5 $\pm$ 0.7
July	8.1 d	4.8 $\pm$ 0.5	14.8 $\pm$ 0.9	4.7 $\pm$ 0.5
August	5.9 e	6.1 $\pm$ 0.4	4.3 $\pm$ 0.3	7.3 $\pm$ 0.6
September	7.5 d	7.6 $\pm$ 0.6	8.9 $\pm$ 0.5	6.1 $\pm$ 0.5
October	10.9 b	11.4 $\pm$ 0.7	8.4 $\pm$ 0.5	12.8 $\pm$ 0.7

^zBloom coverage represents the estimated percentage of the plant covered in open blooms.

^yData followed by different letters within the column indicate they were significantly different at $P < 0.05$ according to Fisher's least significant difference.

^xData not available because data were not collected in Apr. 2009.

Supplemental Table 7. Mean overall and yearly ratings for bloom coverage of roses grown under minimal-input conditions in north central Texas ranked in order of performance from best to worst.

Cultivar ^z	Bloom coverage (%) ^y	Bloom coverage [mean $\pm$ SE (%)]		
	Across all years	2009	2010	2011
Lena (BAIlena)	25.8 a ^x	27.4 $\pm$ 3.9	26.1 $\pm$ 4.1	19.7 $\pm$ 4.1
Rainbow Knock Out [®] (RADcor)	19.3 ab	13.3 $\pm$ 1.8	22.9 $\pm$ 3.3	21.1 $\pm$ 3.0
Knock Out [®] (RADrazz)	18.1 a-c	16.9 $\pm$ 2.6	20.4 $\pm$ 4.5	12.8 $\pm$ 1.5
Sunrise Sunset [™] (BAIset)	16.8 a-d	15.6 $\pm$ 2.0	15.5 $\pm$ 2.8	19.3 $\pm$ 3.7
Pink Knock Out [®] (RADcon)	16.7 a-c	21.8 $\pm$ 4.3	20.7 $\pm$ 4.2	8.4 $\pm$ 1.6
White Pet	15.6 a-f	18.1 $\pm$ 2.9	15.2 $\pm$ 1.7	15.2 $\pm$ 2.3
Double Knock Out [®] (RADtko)	14.8 a-g	19.5 $\pm$ 3.3	17.2 $\pm$ 4.4	7.6 $\pm$ 1.1
Sven (BAIsven)	14.7 a-g	16.6 $\pm$ 2.2	11.7 $\pm$ 1.7	19.1 $\pm$ 2.6
Coral Knock Out [®] (RADral)	14.5 a-h	12.8 $\pm$ 2.3	17.0 $\pm$ 4.0	16.0 $\pm$ 2.6
Easy Does It [™] (HARpageant)	14.5 a-i	13.0 $\pm$ 2.0	19.7 $\pm$ 4.5	9.3 $\pm$ 1.4
Alister Stella Gray	14.4 a-i	15.0 $\pm$ 2.2	17.5 $\pm$ 3.3	14.9 $\pm$ 2.4
Ole (BAIole)	14.1 b-j	19.5 $\pm$ 2.6	12.9 $\pm$ 2.5	13.5 $\pm$ 2.1
Cinderella	13.7 b-j	12.3 $\pm$ 1.6	12.6 $\pm$ 1.8	15.8 $\pm$ 2.0
Chuckles	13.3 b-j	11.8 $\pm$ 2.9	9.6 $\pm$ 1.5	19.2 $\pm$ 4.0
Home Run [®] (WEKcisbako)	13.2 b-j	15.0 $\pm$ 2.3	13.9 $\pm$ 2.1	12.6 $\pm$ 2.2
Julia Child [™] (WEKvossutono)	13.0 b-j	12.8 $\pm$ 1.7	9.6 $\pm$ 1.5	17.9 $\pm$ 2.1
Katy Girl (PONgirl)	12.8 b-j	6.9 $\pm$ 1.0	17.4 $\pm$ 4.9	13.8 $\pm$ 2.9
Blushing Knock Out [®] (RADyod)	12.7 b-k	14.3 $\pm$ 2.9	18.9 $\pm$ 4.2	6.2 $\pm$ 1.6
Karen Poulsen	12.6 b-l	12.1 $\pm$ 2.2	7.6 $\pm$ 1.4	18.0 $\pm$ 3.4
Cinco de Mayo [™] (WEKcobeju)	12.5 b-l	11.0 $\pm$ 1.6	8.0 $\pm$ 1.1	20.3 $\pm$ 3.3
Rouletii	12.2 b-l	11.5 $\pm$ 1.6	13.7 $\pm$ 2.0	8.1 $\pm$ 1.1
Pink Double Knock Out [®] (RADtkopink)	12.0 b-m	14.8 $\pm$ 2.4	15.4 $\pm$ 4.4	5.4 $\pm$ 1.0
Red Cascade (MOORcap)	11.5 b-m	10.0 $\pm$ 2.0	8.2 $\pm$ 1.8	15.9 $\pm$ 4.9
Surrey (KORlanum)	11.3 b-n	14.0 $\pm$ 2.4	7.0 $\pm$ 1.0	13.7 $\pm$ 1.8
Super Hero [™] (BAIsuhe)	11.0 b-o	8.1 $\pm$ 1.2	8.8 $\pm$ 1.4	14.2 $\pm$ 2.5
Oso Happy [®] Candy Oh! (ZLEMartinCipar)	10.3 b-p	8.3 $\pm$ 1.6	10.1 $\pm$ 1.5	13.3 $\pm$ 4.0
Sunny Knock Out [®] (RADsunny)	10.2 b-p	11.7 $\pm$ 1.5	11.0 $\pm$ 2.2	8.5 $\pm$ 1.6
Dublin Bay (MACdub)	10.1 b-p	7.1 $\pm$ 1.1	13.4 $\pm$ 3.0	8.7 $\pm$ 1.5
Cameron Bohls (PONbohls)	9.8 b-q	7.2 $\pm$ 1.0	9.5 $\pm$ 1.5	10.6 $\pm$ 1.1
Meredith Bohls (PONmer)	9.6 b-q	9.0 $\pm$ 1.7	7.9 $\pm$ 1.4	9.6 $\pm$ 1.5
All the Rage [™] (RAIrage)	9.5 b-q	8.5 $\pm$ 1.1	7.4 $\pm$ 0.8	10.5 $\pm$ 1.5
My Girl [™] (BAIgirl)	9.3 c-q	9.3 $\pm$ 1.2	6.9 $\pm$ 1.0	10.8 $\pm$ 1.4
Brite Eyes [™] (RADbrite)	9.3 c-q	3.5 $\pm$ 0.8	16.4 $\pm$ 3.9	8.4 $\pm$ 1.2
Lady Hillingdon	9.0 c-q	6.1 $\pm$ 1.0	9.4 $\pm$ 1.3	10.5 $\pm$ 1.6
Molineux [™] (AUSmol)	8.4 d-q	9.9 $\pm$ 2.2	7.6 $\pm$ 1.1	8.2 $\pm$ 1.3
Splendora (PONDora)	8.3 d-q	8.0 $\pm$ 1.6	8.2 $\pm$ 1.9	7.3 $\pm$ 0.9
Penelope	7.9 d-r	5.4 $\pm$ 1.3	13.5 $\pm$ 4.9	4.6 $\pm$ 1.0
Crepuscle	7.9 d-r	8.0 $\pm$ 2.1	13.5 $\pm$ 3.0	7.0 $\pm$ 1.5
Seminole Wind (KORtersen)	7.7 e-r	5.5 $\pm$ 1.5	7.1 $\pm$ 1.1	9.1 $\pm$ 2.9
Deanna	7.4 f-r	7.5 $\pm$ 0.7	8.6 $\pm$ 1.4	4.6 $\pm$ 0.6
Madame Berkeley	7.3 f-s	6.8 $\pm$ 1.4	11.0 $\pm$ 2.6	8.8 $\pm$ 1.7
Oso Easy [®] Peachy Cream [™] (HORcoherent)	7.2 f-s	6.0 $\pm$ 0.8	8.1 $\pm$ 1.5	7.1 $\pm$ 1.3
Sweet Fragrance [™] (BAInce)	7.0 f-s	9.1 $\pm$ 1.6	4.3 $\pm$ 0.9	8.3 $\pm$ 1.6
Centennial [™] (BAIcent)	6.8 g-s	6.7 $\pm$ 1.3	8.8 $\pm$ 2.2	4.1 $\pm$ 0.8
Jean Bach Sisley	6.8 g-s	7.7 $\pm$ 1.9	7.1 $\pm$ 1.8	4.8 $\pm$ 1.0
Parade	6.6 g-s	6.5 $\pm$ 1.0	7.0 $\pm$ 1.2	4.4 $\pm$ 0.7
Macy's Pride [™] (BAIcream)	6.3 h-s	7.0 $\pm$ 1.1	5.8 $\pm$ 1.3	4.7 $\pm$ 0.8
Carefree Marvel [™] (MEIrameca)	6.2 i-s	9.4 $\pm$ 1.7	5.1 $\pm$ 0.9	5.4 $\pm$ 1.2
Belinda's Dream	6.1 j-s	6.3 $\pm$ 1.6	10.7 $\pm$ 2.2	4.1 $\pm$ 1.1
McClinton Tea	5.1 k-s	6.0 $\pm$ 1.5	4.8 $\pm$ 0.9	4.6 $\pm$ 1.0
Soncy	5.1 l-s	5.1 $\pm$ 0.9	5.6 $\pm$ 1.2	4.8 $\pm$ 1.4
Antoine Rivoire	4.8 m-s	6.7 $\pm$ 1.3	3.9 $\pm$ 0.9	3.6 $\pm$ 0.8
Peggy Martin	4.5 n-s	5.4 $\pm$ 2.1	1.4 $\pm$ 0.5	10.4 $\pm$ 4.8
Mrs. Oakley Fisher	4.3 o-s	2.3 $\pm$ 0.5	3.3 $\pm$ 0.5	5.1 $\pm$ 1.0
Aloha	3.9 p-s	2.7 $\pm$ 0.6	4.4 $\pm$ 1.1	2.7 $\pm$ 0.8
Chireno	3.8 p-s	5.5 $\pm$ 1.5	4.8 $\pm$ 1.2	1.5 $\pm$ 0.4

(Continued on next page)

Supplemental Table 7. (*Continued*) Mean overall and yearly ratings for bloom coverage of roses grown under minimal-input conditions in north central Texas ranked in order of performance from best to worst.

Cultivar ^z	Bloom coverage (%) ^y	Bloom coverage [mean $\pm$ SE (%)]		
	Across all years	2009	2010	2011
Autumn Sunset	3.7 q-s	2.0 $\pm$ 0.4	4.6 $\pm$ 1.7	2.5 $\pm$ 0.6
Isle Krohn Superior	2.9 r-s	1.3 $\pm$ 0.4	0.9 $\pm$ 0.3	3.6 $\pm$ 0.9
Lady Banks White	2.5 st	0.0 $\pm$ 0.0	10.3 $\pm$ 5.0	0.0 $\pm$ 0.0
Lady Banks Yellow	1.8 t	0.0 $\pm$ 0.0	0.5 $\pm$ 0.4	0.0 $\pm$ 0.0

^zCultivar name or trademark followed by cultivar name in parentheses.

^yData presented in this column are least squares estimates of the means. Bloom coverage represents the estimated percentage of the plant covered in open blooms.

^xData followed by different letters within the column indicate a significant difference ($P \leq 0.05$) according to Fisher's least significant difference.

Supplemental Table 8. Mean drought stress rating of roses grown during 2010–11 in north central Texas.

Cultivar ^z	Drought rating (%) ^y	Drought rating [mean $\pm$ SE (%)]	
	Across both years	2010	2011
Lady Banks Yellow	2.9 a ^x	3.1 $\pm$ 1.5	2.1 $\pm$ 0.7
Lady Banks White	2.9 ab	4.1 $\pm$ 1.6	1.8 $\pm$ 0.6
Madame Berkeley	3.4 a-c	2.9 $\pm$ 1.2	3.0 $\pm$ 0.7
Alister Stella Gray	3.4 a-d	3.6 $\pm$ 1.7	4.5 $\pm$ 1.3
Rouletii	3.6 a-d	1.6 $\pm$ 0.5	4.2 $\pm$ 0.9
Rainbow Knock Out [®] (RADcor)	3.8 a-c	2.7 $\pm$ 1.0	5.9 $\pm$ 1.9
Red Cascade (MOORcap)	3.9 a-f	2.8 $\pm$ 1.2	5.6 $\pm$ 1.5
Katy Girl (PONGirl)	4.3 a-g	2.7 $\pm$ 1.3	6.9 $\pm$ 1.5
Julia Child [™] (WEKvossutono)	4.7 a-h	2.2 $\pm$ 1.1	7.3 $\pm$ 1.6
Cinco de Mayo [™] (WEKcobeju)	4.8 a-i	2.8 $\pm$ 0.9	7.3 $\pm$ 1.8
Jean Bach Sisley	5.5 a-i	5.0 $\pm$ 1.8	5.0 $\pm$ 1.2
Chireno	5.5 a-i	4.0 $\pm$ 1.0	8.2 $\pm$ 2.5
Surrey (KORlanum)	5.9 a-i	3.9 $\pm$ 1.2	7.1 $\pm$ 1.7
Chuckles	5.9 a-i	7.0 $\pm$ 2.1	5.4 $\pm$ 1.3
Pink Knock Out [®] (RADcon)	6.0 a-i	4.2 $\pm$ 1.9	7.9 $\pm$ 1.7
Penelope	6.0 a-i	7.3 $\pm$ 2.4	5.4 $\pm$ 1.6
Cinderella	6.2 a-i	4.8 $\pm$ 1.5	6.5 $\pm$ 1.6
Deanna	6.3 a-i	3.4 $\pm$ 1.2	7.7 $\pm$ 1.6
Parade	6.4 a-i	1.9 $\pm$ 0.6	9.7 $\pm$ 2.0
McClinton Tea	6.4 a-i	5.3 $\pm$ 1.6	6.9 $\pm$ 1.6
Macy's Pride [™] (BAIcream)	6.4 a-i	2.2 $\pm$ 0.8	13.2 $\pm$ 3.6
Belinda's Dream	6.5 a-i	3.8 $\pm$ 0.9	6.7 $\pm$ 1.5
Mrs. Oakley Fisher	6.5 a-i	6.6 $\pm$ 2.4	7.6 $\pm$ 2.3
Aloha	6.9 a-i	4.5 $\pm$ 1.9	10.6 $\pm$ 2.6
Crepescule	7.0 a-i	3.5 $\pm$ 1.2	9.3 $\pm$ 2.5
Home Run [®] (WEKcisbako)	7.1 a-i	5.1 $\pm$ 1.8	8.2 $\pm$ 1.9
Pink Double Knock Out [®] (RADtkopink)	7.1 a-i	8.3 $\pm$ 2.6	6.6 $\pm$ 1.5
Knock Out [®] (RADrazz)	7.1 a-i	5.4 $\pm$ 1.7	8.7 $\pm$ 1.9
Easy Does It [™] (HARpageant)	7.3 a-i	7.0 $\pm$ 2.4	7.9 $\pm$ 1.7
Brite Eyes [™] (RADbrite)	7.9 a-i	11.5 $\pm$ 3.7	5.2 $\pm$ 1.1
Double Knock Out [®] (RADtko)	8.0 a-i	7.2 $\pm$ 2.4	10.8 $\pm$ 3.1
Peggy Martin	8.0 a-i	7.9 $\pm$ 2.7	7.8 $\pm$ 1.7
Blushing Knock Out [®] (RADyod)	8.9 a-i	5.0 $\pm$ 1.6	12.7 $\pm$ 3.0
Seminole Wind (KORTersen)	9.1 a-i	6.6 $\pm$ 1.7	11.3 $\pm$ 3.1
Super Hero [™] (BAIsuhe)	9.2 a-i	8.9 $\pm$ 2.5	7.5 $\pm$ 1.8
Sweet Fragrance [™] (BAInce)	9.5 a-i	3.2 $\pm$ 1.0	14.6 $\pm$ 2.8
Oso Easy [®] Peachy Cream [™] (HORcoherent)	9.7 a-i	9.8 $\pm$ 3.5	10.1 $\pm$ 2.1
Oso Happy [®] Candy Oh! (ZLEMartinCipar)	9.9 a-i	7.6 $\pm$ 2.3	11.3 $\pm$ 2.5
Antoine Rivoire	10.3 a-i	6.0 $\pm$ 2.0	13.5 $\pm$ 2.8
Sunrise Sunset [™] (BAIset)	10.3 a-i	11.4 $\pm$ 3.2	10.8 $\pm$ 2.7
Centennial [™] (BAIcent)	10.4 a-i	9.6 $\pm$ 3.1	12.3 $\pm$ 3.2
Soncy	10.5 a-i	11.0 $\pm$ 2.8	8.6 $\pm$ 1.8
Molineux [™] (AUSmol)	10.9 a-i	7.6 $\pm$ 2.2	12.1 $\pm$ 2.3
My Girl [™] (BAIgirl)	11.0 a-i	12.4 $\pm$ 3.9	12.3 $\pm$ 3.5
Lady Hillingdon	11.3 b-i	6.3 $\pm$ 2.1	16.3 $\pm$ 3.6
All the Rage [™] (RAIrage)	11.4 b-i	12.7 $\pm$ 3.9	12.4 $\pm$ 3.8
Splendora (PONdora)	11.7 c-i	9.8 $\pm$ 2.9	13.0 $\pm$ 3.0
Cameron Bohls (PONbohls)	12.3 c-i	7.2 $\pm$ 2.1	15.2 $\pm$ 3.2
Karen Poulsen	12.4 c-i	8.5 $\pm$ 2.3	14.9 $\pm$ 3.6
Ole (BAIole)	12.5 c-i	7.2 $\pm$ 2.2	16.8 $\pm$ 3.0
White Pet	12.8 c-i	11.0 $\pm$ 3.2	14.0 $\pm$ 2.5
Coral Knock Out [®] (RADral)	12.8 c-i	9.1 $\pm$ 2.6	14.4 $\pm$ 3.4
Dublin Bay (MACdub)	13.2 c-i	10.6 $\pm$ 3.6	16.6 $\pm$ 4.2
Carefree Marvel [™] (MEIrameca)	14.2 d-i	16.6 $\pm$ 4.4	15.1 $\pm$ 4.1
Sunny Knock Out [®] (RADsunny)	14.7 e-i	13.2 $\pm$ 3.3	15.4 $\pm$ 3.3
Autumn Sunset	15.1 e-i	13.3 $\pm$ 4.7	16.6 $\pm$ 3.6
Sven (BAIsven)	15.4 f-i	8.7 $\pm$ 2.2	20.8 $\pm$ 3.5

(Continued on next page)

Supplemental Table 8. (*Continued*) Mean drought stress rating of roses grown during 2010–11 in north central Texas.

Cultivar ^z	Drought rating (%) ^y	Drought rating [mean ± SE (%)]	
	Across both years	2010	2011
Isle Krohn Superior	16.2 g-i	16.8 ± 5.2	19.0 ± 4.3
Meredith Bohls (PONmer)	16.6 hi	9.5 ± 2.4	22.9 ± 4.3
Lena (BALLena)	16.9 i	10.9 ± 2.8	23.0 ± 4.3

^zCultivar name or trademark followed by cultivar name in parentheses.

^yData presented in this column are least squares estimates of the means. Drought ratings were assigned based on the percentage of leaves showing drought stress symptoms (wilting, leaf margin browning and necrosis, chlorosis, and branch dieback without observed disease).

^hData followed by different letters within the column indicate a significant difference ($P \leq 0.05$) according to Fisher's least significant difference.

Supplemental Table 9. Average monthly drought stress rating of roses grown during 2010–11 in north central Texas.

Month	Drought score ^z	Drought score (mean ± SE)	
	Across all years	2010	2011
April	0.17 a ^y	0.3 ± 0.0	0.1 ± 0.0
May	0.31 a	0.3 ± 0.1	0.3 ± 0.2
June	4.57 b	2.3 ± 0.4	6.9 ± 0.8
July	6.49 c	1.5 ± 0.4	11.5 ± 0.9
August	9.40 d	6.9 ± 0.6	11.9 ± 0.8
September	19.2 e	16.3 ± 1.0	22.0 ± 0.9
October	20.4 e	19.9 ± 1.1	20.7 ± 1.0

^zDrought ratings were assigned based on the percentage of leaves showing drought stress symptoms (wilting, leaf margin browning and necrosis, chlorosis, and branch dieback without observed disease).

^yData followed by different letters within the column indicate a significant difference ($P \leq 0.05$) according to Fisher's least significant difference. Data were transformed using arcsine square root transformations and back-transformed for presentation purposes. Smaller numbers indicate fewer drought stress symptoms.