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The Effect of Rose Root Size on Drought Stress Tolerance and Landscape Plant Performance

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ABSTRACT

Four rose (*Rosa hybrida*) cultivars, Carefree Beauty™ ('BUCbi', CB), 'Frontenac,' (Fr), Polar Joy™ ('BAIjoy', PJ), and Ramblin' Red™ ('RADramblin', RR), were evaluated for landscape performance and drought stress. Plants were planted in an RCB design, with four blocks, during winter 2007 and irrigated regularly during growing seasons one and two. During years three and four, plants received no supplemental irrigation. In summer 2011, temperatures exceeded 37.7 °C (100 °F) for 65 days and pan evaporation rates exceeded 70 mm·wk^{-1}. Landscape performance was rated monthly on a scale of 0 to 10, with 10 being exceptional. Plants were rated for drought stress using a 0 to 5 scale, with higher values representing increased drought stress. Plant roots were harvested by digging in a circular pattern 60 cm from the plant stem. Individual roots were carefully dug beyond the original radius until the entire length was exposed. CB and PJ had the highest landscape performance ratings, while RR had the highest drought stress scores. Though RR and Fr were similar in height, width, and shoot dry weight, PJ and CB had higher root dry weights. Strong correlations were found between landscape performance and root dry weight and root fibrosity. Drought stress was strongly correlated with root mass.

KEY WORDS: Earth-Kind, shrub roses, *Rosa*

INTRODUCTION

The rose (*Rosa hybrida*) is among, if not the most popular garden plant in the world as well as one of the most important commercial cut flowers. In 2009, roses accounted for over $209 million in wholesale sales (USDA 2009). No other group of ornamental plants provides as wide a range of plant, flowering, and blossom traits. Roses combine the best characteristics of annual bedding plants (vibrant and continued color) and perennials (durability, long-life span, and low year-to-year maintenance), but with a wealth of flower forms, colors, and scents and plant forms and habits that few other plants can provide.

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An emerging issue for landscape plants, including roses, in Texas and other regions is limited water availability for landscape irrigation. Drought and above-normal temperatures have forced communities to limit landscape irrigation. In response, homeowners have proven to be mindful of water resource challenges and are prepared to make changes in their landscapes to accommodate limited water supplies (Hurd et al. 2006; Spinti et al. 2004; Israel et al. 1999). In Texas, public support for xeriscape gardens resulted in the passing of Senate Bill 198 in 2013, restricting Home Owners Associations from prohibiting xeriscape landscapes (Hopkins 2013).

Additionally, in some areas, salt levels in irrigation water have increased due to a decrease in available ground water supplies and a reliance on reclaimed water for landscape irrigation (Niu and Rodriguez 2008). Soil salinity negatively affects soil plant available water and plant physiological processes, and may decrease plant growth, development, and performance.

In roses, it is a common practice to graft rose cultivars with desired ornamental characteristics onto an aggressive rootstock known to perform well under particular environmental and edaphic conditions (Pemberton 2003), including its ability to improve performance under drought stress (Niu and Rodriguez 2009). 'Dr. Huey' is an example of a cultivar with an aggressive root system that produces significantly larger root biomass than the rootstocks *R. manetti* and *R. odorata* (Cabrera 2002). The impact on performance was found in a subsequent study where *R. odorata* was found to be poorly tolerant of drought stress (Niu and Rodriguez 2009).

Modern shrub roses are typically grown as own-root cultivars. Own-root cultivars have a longer life expectancy, tend to produce fuller plants, have no rootstock suckers, and no transfer of rose mosaic (Richer et al. 2005). Many of these roses are commonly grown without pesticides and have good heat and drought tolerance (Harp et al. 2009; Mackay et al. 2008). The Earth-Kind® program of Texas A&M AgriLife Extension has identified 23 rose cultivars that thrive with a 70% reduction in landscape irrigation (Harp et al. 2009; TDA 2013). The Earth-Kind cultivars 'Belinda's Dream,' 'Climbing Pinkie,' 'Mrs. Dudley Cross,' 'Reve d'Or,' and 'Sea Foam' were also found to be tolerant of high salinity conditions with little to no reduction in shoot growth, flower number, and leaf color, as determined by SPAD meter (Konica Minolta, Osaka, Japan) readings (Cai et al. 2014)

The mechanism of drought tolerance in roses is considered to be similar to other woody species. Roses can exhibit increased cuticular wax (Jenks et al. 2001) and increased lateral root growth (Davies et al. 1996) in response to water stress. Drought also results in decreased flower number (up to 70% less) and quality (Chimonidou-Pavlidou 2004).

Root traits associated with tolerance of drought stress include small, fine root diameters, long root length, and root density, and an increased root–shoot ratio can compensate for water deficits and increased stomatal conductance (Comas et al. 2013). Therefore, the purpose of this experiment was to determine the association between root architecture and performance of four own-root rose cultivars under severe drought stress conditions.

METHODS AND MATERIALS

During winter of 2007, four planting beds were tilled to a depth of 20 cm, tilling in an additional 8 cm of composted horse bedding, and adding 8 cm of organic mulch to the surface. The mulch was maintained at a minimum depth of 6 cm throughout the experiment. A 1.7 L / hr drip irrigation system was installed with manual controls. Once prepared, 20 own-root rose cultivars (Table 1) were randomly planted into each of the four beds. Experimental design was an RCB with four blocks and each cultivar appearing once per block. During the first two years, plants were irrigated regularly to ensure proper plant establishment. During the third and fourth year, no supplemental irrigation was applied. No fertilizers or pesticides were applied with the exception of periodic use of glyphosate for weed control. Plants also were not pruned, except for the removal of dead or physically damaged branches. Cultivars were rated monthly during the growing season, April through November, for landscape performance and drought tolerance.

Table 1. Twenty rose cultivars evaluated for landscape performance in a minimal-input garden in North Central Texas.

Trademark Name	**Cultivar Name**	**Rose Class**
Alexander Mackenzie	*Rosa* 'Alexander Mackenzie'	Shrub
Sunrise Sunset	*Rosa* 'BAIset'	Shrub
Quadra	*Rosa* 'Quadra'	Kordesii
John Cabot	*Rosa* 'John Cabot'	Kordesii
Morden Blush	*Rosa* 'Morden Blush'	Shrub
Prairie Joy	*Rosa* 'Prairie Joy'	Shrub
George Vancouver	*Rosa* 'George Vancouver'	Shrub
Ole	*Rosa* 'Ole'	Shrub
Sea Foam	*Rosa* 'Sea Foam'	Trailing Rose
Yellow Submarine	*Rosa* 'BAIine'	Shrub
William Baffin	*Rosa* 'William Baffin'	Kordesii
John Davis	*Rosa* 'John Davis'	Kordesii
Polar Joy	*Rosa* 'BAIore'	Tree Form
Bright Eyes	*Rosa* 'RADbrite'	Shrub
Ramblin' Red	*Rosa* 'RADramblin'	Climber
Summer Wind	*Rosa* 'Summer Wind'	Shrub
Lena	*Rosa* 'Lena'	Shrub
Carefree Beauty	*Rosa* 'BUCbi'	Shrub
Frontenac	*Rosa* 'Frontenac'	Shrub
Sven	*Rosa* 'Sven'	Shrub

Landscape performance was on a 0 to 10 scale, based upon the following criteria: 1) flower number and quality; 2) foliage cover and quality; and 3) plant habit and vigor. Scores were assigned as follows: 10 = no deductions in any criteria; 9 = a minor deduction in one criterion; 8 = a minor deduction in two criteria; 7 = a minor deduction in all criteria or a moderate deduction for one; 6 = a moderate deduction for one criterion and a minor deduction for another; 5 = a moderate deduction for one criterion and a minor deduction for two criteria; 4 = moderate deductions for two criteria; 3 = severe deduction for one criteria and a moderate or minor deduction for another; 2 = severe deduction for two criteria; 1 = severe deduction for three criteria; and 0 = dead plant. Drought stress ratings were assigned on a 0 to 5 scale. A score of 0 was no signs of drought stress. Scores above zero were determined by giving one point for each 20% of the foliage exhibiting drought stress symptoms (wilting, color fade, discoloration, and marginal necrosis).

At the termination of the study, four cultivars, two each of the cultivars with the highest (Carefree Beauty™ and Polar Joy™) and lowest landscape scores ('Frontenac' and Ramblin' Red™) were selected for root evaluation. All plants (n = 16) of these four cultivars were carefully removed and physical plant data collected for both roots and shoots. Plants were dug by measuring a 0.6 m radius around the plant and carefully digging by hand. Roots extending beyond this radius were identified and followed to the end. Shoots were removed from the roots by cutting through the crown with a chainsaw. Shoots and roots were measured and dried for 72 hrs at 70 °C.

Landscape performance rating, drought rating, shoot height, shoot width, root width, root depth (deepest point), diameter of crown, average root diameter of largest roots (three largest, 10 cm from crown), percent fibrous roots (fibrosity, visual estimate of percentage of root architecture made up of roots smaller than 2 mm in diameter), and root:shoot ratio (dry and fresh weight) data were compared using Proc ANOVA (SAS 9.3, SAS Institute. Cary, NC). Duncan's Means Separation Test was used to compare means ($P \leq 0.05$). Proc CORR was performed to identify correlations between landscape performance and drought stress scores and physical root characteristics.

RESULTS

Mean high temperature for June, July, August, and September in Commerce is 33 °C (92 °F), 36 °C (96 °F), 37 °C (98 °F), and 33 °C (91 °F), respectively, with fewer than 18 days above 37.7 °C (100 °F) (NWS, 2011). Average precipitation during the same period is 320 mm. During summer 2011, average monthly temperature was 2–3 °C higher throughout the summer, and temperatures exceeded 37.7°C (100 °F) 65 times (Table 2). Precipitation was 72% below normal during the same time period of a normal year. The hot, dry conditions led to pan evaporation rates in excess of 70 mm/wk. By September, over 95% of Texas, including Hunt County, was considered to be in Extreme or Exceptional drought conditions (Svoboda 2011).

Because of the extreme conditions, soil moisture levels dropped to dangerously low levels. As determined gravimetrically and through time domain reflectometry (TDR), soil water content ranged from 0.019 to 0.079 m^3 H_2O/m^3 soil, well below the 0.110 m^3 H_2O/m^3 soil typical of soils in this region at the permanent wilting point. To ensure plant survival, irrigation was applied once in both July and August. On both occasions, soils were wet to field capacity (water content by volume of 0.3 m^3 H_2O/m^3 soil), as determined by TDR.

The cultivars Carefree Beauty™ (CB) and Polar Joy™ (PJ) had the highest landscape performance in 2011, while Frontenac (Fr) and Ramblin' Red™ (RR) had the lowest (Table 3). Throughout summer 2011, only RR routinely had blooms, though all foliage had dropped by July. PJ was routinely penalized due to a high level of suckering. Absent this trait, PJ easily could have had the highest landscape performance rating of all cultivars.

In terms of observable drought ratings, RR was a poor performer with an average rating of 4.75 (Table 3). All RR plants suffered from drought stress, with no score below 4 recorded in any block. PJ and Fr had the fewest observable symptoms. Due to the severity of the drought stress damage, these scores did not improve even after irrigation was applied in July and August.

Table 2. Climatic conditions during summer 2011 for Commerce, TX (Readings were compiled from a Texas A&M University – Commerce weather station).

Month	Mean High Temperature (°C)	Days above 37.7 °C (100 °F)	Total Precipitation (mm)	Pan Evaporation* (mm)
June	35.4	4	22	272
July	38.2	28	19	286
Aug	39.4	27	11	308
Sept	33.2	6	38	231

*Pan evaporation data obtained from U.S. Army Corps of Engineers data for Jim Chapman Lake, approximately 10 miles from the study site.

Table 3. Landscape performance and drought stress ratings for four rose cultivars grown in exceptional drought conditions.

Cultivar	Landscape Performance*	Drought Stress Ratings*
Carefree Beauty™ (‘BUCbi’)	5.5a	1.5b
Polar Joy™ (‘BAIjoy’)	4.75ab	0.25a
‘Frontenac’	3.5b	0.5a
Ramblin’ Red™ (‘RADramblin’)	1.25c	4.75c

*Scores with different letters in columns indicate significant differences using Duncan’s Means Separation Test ($P \leq 0.05$).

Fr was the smallest with an average height of 103.5 cm and width of 44.2 cm (Table 4). In contrast, CB was the widest at 87.9 cm, and PJ was the tallest at 160.8 cm. Carefree Beauty™ had the highest shoot dry weight and CB and PJ had the highest root dry weights, with their root dry weights nearly doubling those of Fr and RR. While CB, PJ, and RR were similar in terms of height, width, and shoot fresh weight, the root dry weight of RR was much lower.

CB had a higher ($P \leq 0.01$) percentage (53.25%) of fibrous roots than PJ (30.3%), RR (27.3%), or Fr (11.0%). The cultivars with the best landscape and drought ratings, PJ and CB, also had greater root mass than Fr (Table 4).

No differences ($P \geq 0.05$) were found between the cultivars in shoot width, shoot height, root diameter, or root depth. Depth was not different among the cultivars, as plant roots extended throughout the bed, but did not penetrate into the subsoil.

Landscape ratings had a strong negative correlation ($r = -0.65$) with drought stress ratings. However, results in this test were not significant ($P \geq 0.05$) and need further study. Landscape ratings were very strongly correlated with fibrosity ($r = 0.76$, $P \leq 0.05$), root fresh weight ($r = 0.88$, $P \leq 0.01$), and root dry weight ($r = 0.89$, $P \leq 0.01$). Drought stress ratings had a very strong negative correlation with root dry weight ($r = -0.70$, $P = 0.05$). A moderate negative correlation ($r = -0.30$) was found between drought stress and root fibrosity; however, this relationship was not significant ($P \geq 0.05$) and needs further exploration.

Table 4. Physical measurements of four rose cultivars grown in exceptional drought conditions.

Rose	Shoot Height (cm)	Shoot Width (cm)	Shoot Dry Weight (kg)	Fibrosity (%)	Root Fresh Weight (kg)	Root Dry Weight (kg)
Carefree Beauty™ ('BUCbi')	119ns	88ns	3.5ns	53.3a	1.9ns	1.3ab
Polar Joy™ ('BAIjoy')	161ns	74ns	2.1ns	30.3b	2.0ns	1.5a
Frontenac	104ns	44ns	0.7ns	11.0b	0.9ns	0.5c
Ramblin' Red™ ('RADramblin')	144ns	65ns	1.6ns	27.3b	0.9ns	0.7bc

*Scores with different letters indicate significant differences using Duncan's Means Separation Test.

CONCLUSION AND DISCUSSION

Rose performance under severe drought stress is an important consideration for Texas and the southwestern U.S. where summer precipitation is routinely less than evapotranspiration. Water available for landscape irrigation is decreasing and homeowners and landscapers need plant materials capable of maintaining their quality under drought conditions.

The rose cultivars with the highest landscape ratings and lowest drought stress ratings, CB and PJ, also had root characteristics that correlated well with plant performance, increased fibrosity, and root biomass. As there were no differences in above-ground shoot length, shoot width, and dry weight, it is likely that the increased below-ground biomass allowed for a longer maintenance of plant quality as drought stress increased.

Since all cultivars used in this study are own-root cultivars, the selection of stronger performing cultivars in dry climates could be indirectly related to identifying cultivars with favorable root characteristics, in addition to shoot and leaf characters, ensuring maximum water availability during times of drought. Plant breeders can also choose to focus their breeding efforts towards developing cultivars with aggressive root systems capable of capitalizing on scarce resources in moisture deficient soils.

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