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Architectural Components of Compact Growth Habits in Diploid Roses

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Summary. **Criteria to determine the horticultural quality of ornamental plants include plant architecture, flower characteristics, and resistance to biotic and abiotic stresses. The architecture of a rose (*Rosa* sp.) bush is linked to flower yield and ornamental value. The Texas A&M University (TAMU) Rose Breeding and Genetics program has the objective of developing garden rose cultivars that flower heavily and exhibit a compact full shape. To determine which architectural traits are key for the development of this desired shape, five rose seedlings with a desirable compact growth habit and five with an undesirable growth habit were selected from TAMU diploid rose breeding germplasm. This comparison indicated that the key traits for the selection of compact growth habit are the number of primary shoots followed by the number of secondary and tertiary shoots produced.**

In the words of Alain Meilland in the foreword of the *Encyclopedia of Rose Science*: "no other flower is as universally loved and grown or has a more illustrious history than the rose" (Meilland, 2003). Rose is a member of one of the most important horticultural families, the rose family (Rosaceae) and is admired for its great diversity of floral and plant characteristics. Sales of roses in 2014 in the United States generated $203.5 million from the production of 36.6 million plants by 1808 growers (U.S. Department of Agriculture, 2015). According to the Green Industry Research Consortium National Survey, roses accounted for 3% of overall sales from 18 different horticultural production crop categories of the industry worth $25.9 billion. Rose industry sales equate to contributions to the U.S. economy of ≈$777 million. Most roses (65%) are sold through retail outlets, with the remaining 35% of rose sales coming from landscape services (Green Industry Research Consortium, 2013). In North America, the economic impact of landscape roses in Canada was estimated at $149 million, and the value in the United States was estimated at $928 million (Vineland Research and Innovation Centre, 2013). The rose industry has a large economic impact worldwide.

Rose has four subgenera, more than 100 species (diploid through decaploid) and more than 30,000 commercial cultivars (mostly diploid, triploid, and tetraploid). These cultivars exhibit wide interspecific and intraspecific cross compatibility (Blechert and Debener, 2005; Byrne and Crane, 2003; Cairns, 2000; Jian et al., 2010; Spiller et al., 2011; Ueckert et al., 2015; Zlesak, 2009), and a broad diversity of flower and plant growth habits. Zuzek et al. (1995) described diverse growth habits of roses defining descriptors, including arching, climbing, dense, groundcover, open, rugosa, spreading, and suckering. Given this diversity of forms, the role roses play in landscapes is extensive. They are found adorning roadsides, public parks, commercial spaces, and residential areas. Garden roses provide aesthetic value throughout the growing season due to both their vegetative and floral production.

Plant architecture of roses is linked to flower yield and ornamental value (Crespel et al., 2014). Previous architectural analysis of roses focused on morphological, topological, and geometrical traits, such as stem length and diameter, succession, branching, and branching angles (Godin et al.,1999). Traits identified as relevant for characterizing rose bush shape include plant height, the number and length of stems, leaf profile, the internode length, branching angles, the branching site, and branch order number (Crespel et al., 2013; Gitonga et al., 2014; Kawamura et al., 2015; Morel et al., 2009; Wu et al., 2019). Little is known about which traits are critical

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
1.6093	mile(s)	km	0.6214

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Table 1. Growth habits of parental lines from which diploid rose populations were developed.

Parent	Growth habit
'Basye's Thornless'[z]	Groundcover
'Old Blush'	Open bush
'Sweet Chariot'	Open bush
'Ducher'	Open bush
J06-30-3-6	Groundcover
'Vineyard Song'	Spreading bush
M4-4	Groundcover
J06-20-14-3	Groundcover
'Red Fairy'	Spreading bush

[z]Memorial rose (*Rosa wichuriana*).

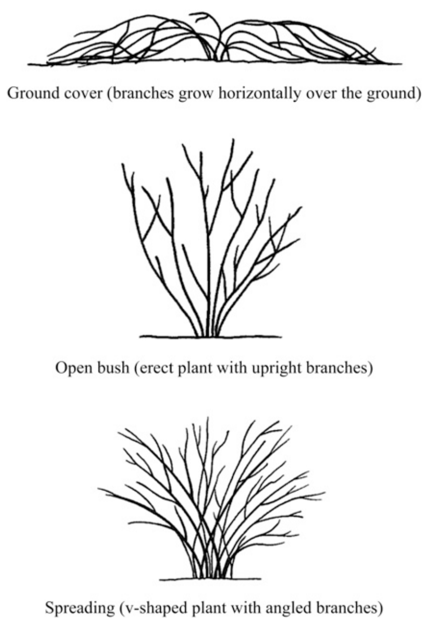

Fig. 1. Diverse growth habits of parental lines from which diploid rose populations were developed (Zuzek et al., 1995).

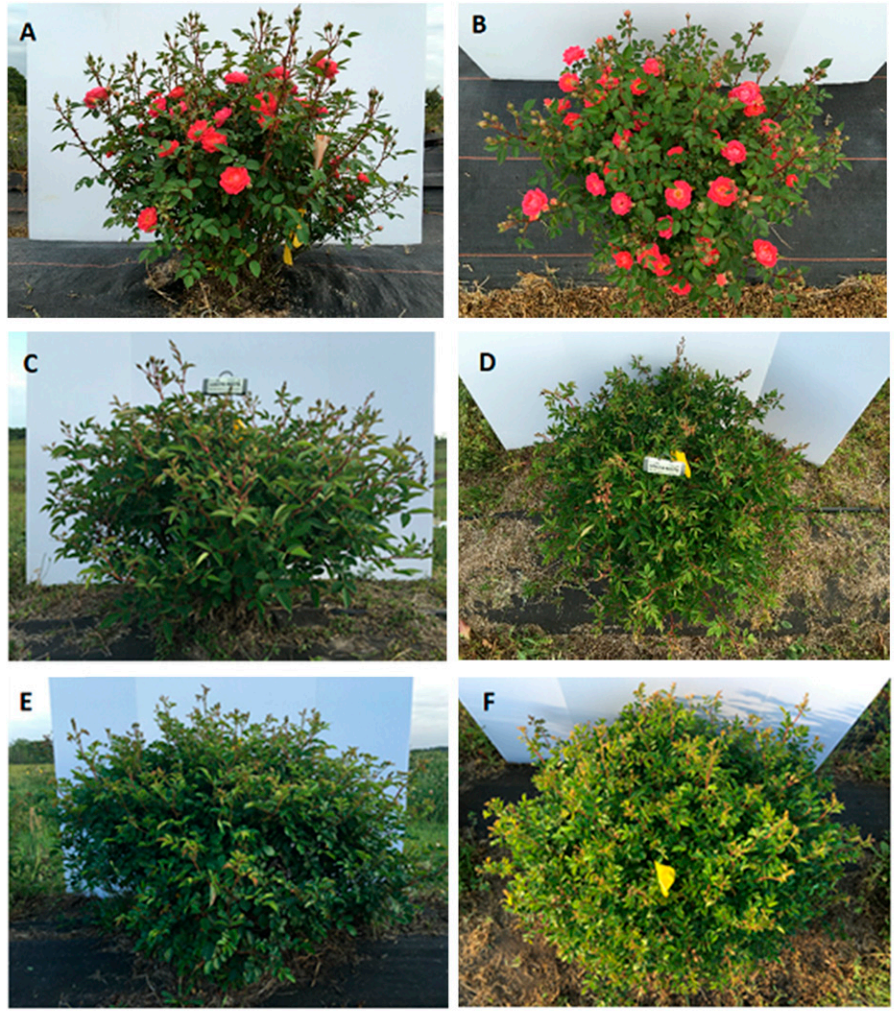

Fig. 2. Compact growth habit with evenly distributed, abundant flowers/shoots throughout the whole plant: (A, C, E) side view, (B, D, F) top view.

Fig. 3. Unnamed rose seedling with compact growth habit with undesirable perimeter flowers: (A) side view, (B) top view.

to the selection of specific bush shapes.

The focus of the TAMU Rose Breeding and Genetics program is the development of garden roses for the modern garden. One of the most important trends in home landscapes and gardens is low maintenance, in other words, easy-care (American Nurseryman, 2016). A rose that is low maintenance needs to be resistant to both biotic and abiotic stresses and have a full plant structure without consistent pruning. Recent surveys and studies indicate that consumer preferences for new rose traits include disease resistance, compactness, moderate height (from waist to shoulder height is preferable), a high number of evenly distributed flowers, and fragrance (Boumaza et al., 2009; Chicago Botanic Garden, 2016; Lütken et al., 2015; Waliczek et al., 2018). The objectives of the Rose Breeding and Genetics Program are to develop disease-resistant, heat-tolerant, compact plants with high flower count that are uniformly distributed on the plant and produced throughout the growing season. This research aims to identify

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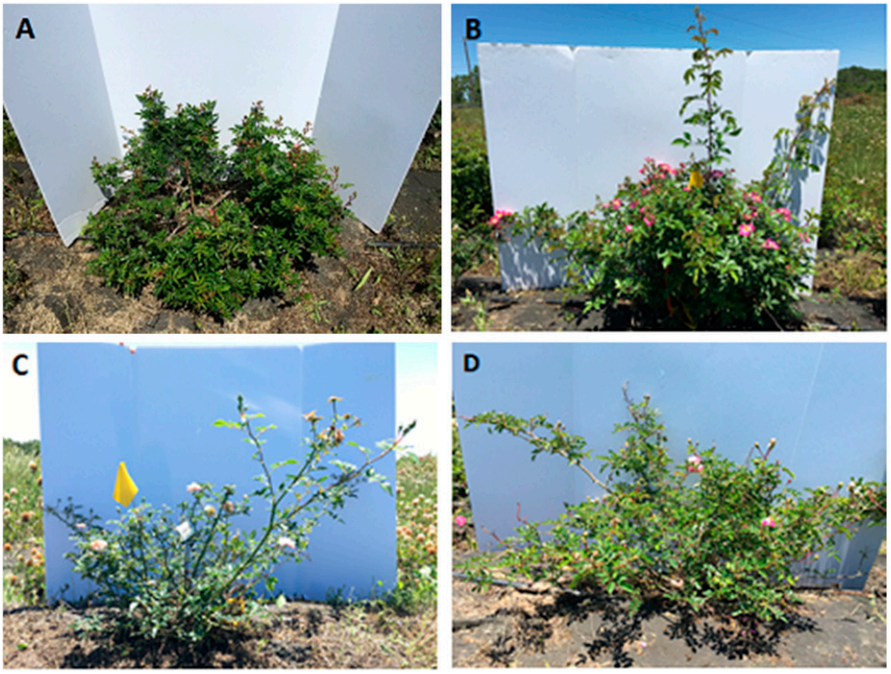

Fig. 4. Unnamed rose seedlings with undesirable growth habit: (A) an empty center, (B) long flower shoot, (C, D) noncompact and open shape.

the key growth traits responsible for the compact structure of the rose plant.

Materials and methods

Diploid rose populations derived from the hybridization of rose parents with diverse growth habits (Table 1, Fig. 1) (Wu et al., 2019; Zuzek et al., 1995) were planted in Mar. 2014 in double rows in a field ≈2 miles from TAMU in College Station, TX (lat. 30.65°N, long. 96.32°W). Individual plants were planted at a 1 × 1 × 3.5-m spacing on raised beds in rows oriented east to west. Black cloth weed barrier was placed around the rose bushes for weed control. Irrigation was applied as needed to maintain sufficient moisture for good growth. No pesticides were applied during the evaluation. The roses were pruned in Mar. 2015 to remove dead tissue and to synchronize the growth of the seedlings. In December, at the end of the growing season in 2015 when the plants were ≈2 years old, five rose seedlings with a desirable compact branching structure and five with an undesirable structure were selected. The desirable rose plants had a compact shape and evenly distributed, abundant flowers or shoots throughout the whole plant (Fig. 2). The undesirable rose plants had a plant form with an empty center [flowers on the outside and not in the middle of the plant (Figs. 3 and 4A)], long flowering shoots (Fig. 4B), and/or an open shape (Fig. 4C and D). All data were collected in 1 d.

Six rose plant architectural traits were measured: plant height (centimeters), number of primary shoots (shoots that develop within 2 inches from the base of the plant), length of the primary shoots, number of nodes on the primary shoots, number of secondary shoots per primary shoot, and number of tertiary shoots per primary shoot. The means of the six architectural traits were compared between rose growth habits with a Student's *t* test (JMP version 12; SAS Institute, Cary, NC).

Results and discussion

As seen in the characterization of the germplasm from which these plants were derived, substantial phenotypic variation was seen in plant height (18–62 cm), number of primary shoots (6–52 shoots per plant), primary shoot length (26–62 cm), number of nodes per primary shoot (6–13), and number of secondary/tertiary shoots per primary shoot (0–5/0–7, respectively). These ranges are similar to what was reported in the germplasm level indicating the current sample is representative of the germplasm (Wu et al., 2019).

The comparison of the architectural traits between desirable compact and undesirable growth habits (Table 2) indicated that both types were similar in plant height, shoot length, and number of nodes per shoot. The key traits that differentiated these groups were primarily number of primary shoots and, secondarily, number of secondary and tertiary shoots produced. These traits determined the fullness of the plant, an important factor aesthetically. A rose plant with many primary shoots looked full; although, fewer primary shoots can be compensated for by more secondary and tertiary shoots. A desirable compact growth habit had more than 30 primary shoots, frequently combined with multiple secondary and tertiary shoots. This compact growth habit requires minimal pruning to maintain a symmetrical look.

The narrow sense heritability (h^2) of these traits is relatively low (h^2 = 0.16 to 0.27), whereas the broad sense heritability (H^2) varies from moderate [number of secondary/tertiary shoots per primary shoot (H^2 = 0.34/0.48, respectively)] to high [number of primary shoots (H^2 = 0.92)] (Wu et al., 2019). Of the three traits, the number of primary shoots is most readily improved, as it has the highest additive and nonadditive genetic variance. Furthermore, given its low genotype × environment (G × E) variance, selection would be effective during the first growth phase of the rose plant. The other two traits will be more challenging because of lower heritabilities and large G × E effects. Selection for the number of secondary/tertiary shoots per basal shoot should be assessed during both growth phases and for substantial progress, additional germplasm with higher genetic variance for these traits may be required.

Identifying the key growth indicators of the number of primary and secondary/tertiary shoots simplifies selection and facilitates the development of new compact rose cultivars. The ultimate goal is to select rose plants that not only have compact growth, but also bloom consistently throughout the year. Future work should track the flowering behavior

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Table 2. The architectural traits of rose seedlings selected with desirable compact and undesirable growth habits evaluated in the field in Dec. 2015 at College Station, TX.

Rose seedlings with desirable growth habits selection (parentage)	Plant ht (cm)[z]	Primary shoots (no.)	Primary shoot length (cm)	Nodes (no./ primary shoot)	Secondary shoots (no./primary shoot)	Tertiary shoots (no./primary shoot)
11112-N005 (M4-4 × 'Vineyard Song')	45	52	34	6	1	0
10071-N010 ('Vineyard Song' × J06-20-14-3)	58	36	40	12	5	7
10074-P35 (J06-20-14-3 × 'Sweet Chariot')	36	51	37	9	3	0
10074-N078 (J06-20-14-3 × 'Sweet Chariot')	56	50	48	8	5	5
10043-N049 ('Sweet Chariot' × M4-4)	60	42	32	7	5	6
Mean for desirable growth habit	51.0	46.2	38.2	8.4	3.8	3.6
Rose seedlings with undesirable growth habits selection (parentage)						
10074-N011 (J06-20-14-3 × 'Sweet Chariot')	45	10	35	6	1	0
10038-N100 ('Old Blush' × J06-30-3-6)	38	6	43	7	2	0
10071-N006 ('Vineyard Song' × J06-20-14-3)	38	23	61	13	0	0
12062-N001 ('Old Blush' × 'Red Fairy')	62	16	62	12	4	0
10075-N013 (M4-4 × 'Sweet Chariot')	18	10	26	6	1	0
Mean for undesirable growth habit	40.2	13.0	45.4	8.8	1.6	0.0
Significance: desirable vs. undesirable habit[y]	NS	***	NS	NS	*	*

[z]1 cm = 0.3937 inch.
[y]NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

of the plant throughout the year to understand the relationship between shoot development and the pattern of flower opening among the various levels of inflorescences.

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