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Genetic diversity and differentiation in roses: A garden rose perspective

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ABSTRACT

For the first time genetic diversity among modern garden rose cultivars has been evaluated using a set of 24 microsatellite markers covering most chromosomes. A total of 518 different alleles were obtained in the set of 138 rose cultivars and this led to the conclusion that in terms of genetic diversity cut roses can be considered as a subgroup of the garden roses.

Genetic differentiation among types of garden roses (F_{st} = 0.022) was four times that among cut roses, and similar in magnitude to the differentiation among breeders, due to the fact that horticultural groups and breeders overlap largely in classification. Winter hardy Svejda's cultivars (Canadian Explorer roses) showed the least similarities to European roses, and introgression from wild species for winter hardiness was clearly visible. Roses of Harkness and Olesen shared a similar genepool. Comparison of the differentiation among linkage groups indicated that linkage group 5 is potentially a region containing important QTLs for winter hardiness. Linkage group 6 contains the largest amount of genetic diversity, while linkage group 2 is the most differentiated among types of garden roses.

1. Introduction

The genus *Rosa* consists of over 100 species, mostly from Asia but some native to North America, Europe and northwest Africa. Many of these species are thought to have arisen by hybridisation, often accompanied by polyploidization, either naturally or during cultivation (De Riek et al., 2013; Zhang et al., 2013). The wild ancestors of domesticated ornamental roses are found mainly in the sections (sect.) *Synstylae* (*R. moschata*, *R. wichurana* and *R. multiflora*), *Gallicanae* (*R. gallica*), *Indicae* (*R. chinensis* and *R. gigantea*) and *Pimpinellifoliae* (*R. foetida*) (Wylie 1954). Smaller contributions are from *R. spinosissima* in section *Pimpinellifoliae* and *R. cinnamomea* and *R. rugosa* in section *Cinnamomeae* (Smulders et al., 2011). This subset of wild species has enabled the enormous diversity of roses in shape, colour, and fragrance.

Variability of species and intraspecific hybridisations make genetic relationships within the genus *Rosa* complicated (Koopman et al., 2008), especially for cultivars. The most common grouping of ornamental roses is on the basis of usage into cut roses, garden roses and rootstocks (Shepherd, 1954; Gudin, 2000; Debener and Linde, 2009). Rootstock roses are wild or semi-wild genotypes, mostly *R. canina* (sect. *Caninae*, dogroses), which are pentaploid, and *R. laxa* (sect. *Cinnamomae*), which is tetraploid. Cut and garden roses belong to the hybrid tea roses; they are mostly tetraploid. Cut roses are under strict selection criteria such as absence of stem bending, production (high number of stems per m^2), thornlessness, and long vase life. At the same time various ornamental traits, including flower colour and shape, are bred to be quite diverse. In contrast garden roses are a varied group, as they are not bred and valued only for flowers, but also as potted plants, for hedging, for landscaping, for hip production and even for the production of components for food and cosmetic industry. In such a wide spectrum of cultivar uses it is not possible to implement a simple classification system. Traditionally garden rose cultivars are placed in one of three main groups: wild, old garden and modern garden roses (Table 1).

Hybridisation with and introgression from wild species is more common in garden rose breeding than it is in cut rose breeding. Specific traits, such as winter hardiness, are introduced from wild relatives (*R. rugosa, R. arkansana*, etc.). Each breeder uses a source for a trait of interest from wild species or cultivars with the preferred trait. In general, breeders are specialised for one or a few rose types and want to be recognisable by their cultivars so they use a set of germplasm that is different from other breeders. As a consequence it is possible to distinguish breeders on the basis of

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Table 1
Rose classification, morphological characteristics and origin of rose types.

Group	Circumscription	Cultivar group	Morphology	Information on ancestry
Wild	Natural species and hybrids		Low-maintenance shrubby, once flowering phenotypes tolerant to poor soil and shade.	–
Old Garden Roses	All roses that existed before the introduction of La France, first modern rose in 1867.	Alba	Strong growing shrubs with well-scented white to pale pink flowers and few thorns. Foliage and stems tend to be greyish.	An ancient groups of roses derived from *R. canina* and *R. gallica*, probably introduced by the Romans.
		Gallica	*R. gallica* is a species native to southern and central Europe eastwards to Turkey and the Caucasus. Cultivars of this species and hybrids close to appearance are considered as a cultivar group. It is an ancient group of short, compact shrubs with most commonly double or semi double once blooming flowers. The flower colour range from white (rare) to pink to the darkest purple.	The exact ancestry is unknown and other species may be involved.
		Damask	Once-blooming, thorny shrubs with intensely fragrant white to pink flowers. They are especially valued for their natural oils.	DNA analysis showed that damask roses evolved as a result of natural double crossing of *R. gallica* with *R. moschata* crossed again with *R. fedtschenkoana*. This hybridisation probably happened in Central Asia
		Centifolia or Provence	Known also as Cabbage rose thanks to the large number of petals. They are fragrant and extremely hardy roses with white or pink flowers.	It is a complex hybrid mainly derived from Gallica and Alba or Damask roses.
		Moss	The main characteristic of this rose group is mossy growth of sepals, calyx and stems. They can be once- or repeat-blooming.	Appeared as a mutation of Centifolia roses in 18th century. Later more compact and repeat-flowering hybrids evolved from the Damask roses.
		Portland	Small group of shorter, more compact shrubs with ability to repeat bloom in autumn. The flower colour range from white to pink and red.	It is a small group of hybrids derived from a rose named after plant collecting of Portland around 1780. DNA analysis showed that they are hybrids of Gallica and Damask roses.
		China	This is the class upon which modern roses are built. China roses are characterised by moderate fragrance and small blooms carried over twigs. They bloom repeatedly through summer and late autumn	The China roses, based on *R.chinensis*, have been cultivated in East Asia for centuries. From 18th century they have been cultivated in Western Europe.
		Tea	Tea roses are introduced in 19th century. They are repeat-blooming roses, named for their scent which reminds of Chinese black tea. The colour range includes pastel shades of white, pink and yellow apricot. They have individual flowers with petals that tend to roll back at the edge.	The Tea-scented China roses are hybrids of *R. chinensis* and *R. gigantea*.
		Burbon	This group originated from Bourbon on the coast of Madagascar. They are vigorous shrubs with glossy foliage that bloom repeatedly.	Probably they developed as a result of a cross between Damask and Old Blush China roses.
		Noisette	The first Noisettes were small-blossomed, winter-hardy climbers, but later introgression of Tea rose genes created a Tea-Noisette subclass with larger flowers, smaller clusters, and considerably reduced winterhardiness.	The first Noisette rose was bred by John Champneys as a seedling of China roses and *R. moschata.*
		Hybrid Perpetual (HP)	They are repeat- or once-blooming cultivars with tendency for massive spring blooming. The flower colour palette is limited to white, pink and red.	Represents a group of roses derived from Asian and European cultivars (Chinas, Bourbons, Noisette).
		Hybrid Musk	They arose when the era of Old Garden Roses was finished; still they are classed with them as their growth type is similar to Old Garden Roses. Hybrid musks are disease resistant cultivars characterised by repeat-blooming and clustered flowers. They are recognised by strong musk scent.	This group was mainly developed by Joseph Pemberton. *R. multiflora* is confirmed as a parent and R. moschata also figures in Hybrid Musk pedigrees.
		Hybrid Rugosa (HRG)	This is a group of vigorous, extremely disease resistant and fragrant cultivars characterised by recurrent blooming and double flat flowers.	Hybrid musk derived from R. rugosa from Japan and Korea in 1880s.