Australian Government
Department of Health and Ageing
Office of the Gene Technology Regulator

The Biology and Ecology of *Rosa x hybrida* (Rose)

December 2005

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PREAMBLE

This document addresses the biology and ecology of *Rosa x hybrida* (rose). Information included relates to the taxonomy and origins of cultivated roses, general descriptions of its morphology, reproductive biology, physiology, biochemistry, biotic interactions, toxicity, allergenicity and weediness. This document also addresses the potential for gene transfer to occur to closely related species. The purpose of this document is to inform risk assessments of genetically modified roses that may be released into the Australian environment.

SECTION 1 TAXONOMY

Rosa x *hybrida* (rose) is not a species in the botanical sense, but is a description used for most cultivated rose cultivars of the Hybrid tea or Floribunda types or classes. These cultivated roses have been derived over centuries through complex crosses involving a number of species of the genus *Rosa* (Phillips and Rix 1988). The *Rosa* genus belongs to the family Rosaceae and is closely related to apple, pear, quince, plum, cherry, blackberry, and strawberry. Examining the taxonomy of the *Rosa* can be a daunting and confusing task. The species are very variable and hybridize freely, making species delimitation difficult (Zieliński et al. 2004). The chromosome number of rose varies from 2n=2x=14 to 2n=8x=56, with most species being diploid or tetraploid. Commercial rose cultivars (*Rosa x hybrida*) tend to be either triploid or tetraploid (Rout et al. 1999). Classification is also problematic due to continuous variation of characters. In one section of *Rosa*, section Caninae, species are classified only by their unique meiotic system, not by visible characters. Apomixis has been reported in the species of section Caninae, in hybrids among section Caninae species (Gudin 2000), as well as in diploid *Rosa x hybrida* (Crespel et al. 2001). Apomixis would help to perpetuate inter-specific and intra-specific hybrids, adding further taxonomic confusion. The taxonomic difficulties of this species have resulted in reports of anywhere from 100 to 250 *Rosa* species, of which there are innumerable cultivars (Phillips and Rix 1988, Ross 1991).

SECTION 2 ORIGIN AND CULTIVATION

2.1 Centres of diversity

The *Rosa* genus is endemic to temperate regions of the northern hemisphere, including North America, Europe, Asia and the Middle East, with the greatest diversity of species found in western China (Phillips and Rix 1988). Fossil records of *Rosa* date back 35 million years to the Oligocene epoch (Cox 1998). There are no endemic *Rosa* species in the southern hemisphere.

2.2 Domestication and use

Roses have been observed and cultivated for thousands of years. They were frequently mentioned in records from the Middle East some 2000 to 3000 years ago and were cultivated extensively during the Roman era. The earliest records come from the Mediterranean area where the names Syria and Rhodes both translate to 'rose'. The oldest cultivated garden rose was *R x richardii,* which was grown and depicted in art work by the Minoan civilization in Crete over 3500 years ago (Mann 2002). The Romans grew roses in hothouses to make roses bloom out of season. The poet Martial (ca. A.D. 40-102) made reference to the high price of roses in winter and reported that the Egyptians grew roses (a cross between *R. gallica* and *R. moschata*) and transported them to Rome to maintain the winter supply (Sinclair and Thodey 1997). Following the demise of the Roman Empire, roses were maintained in monasteries for their reputed medicinal value. By the eighteenth century five broad rose classes had emerged, Gallica (*R. galllica*), Alba (*R. alba*), Damask (*R. damasenca*), Centrifolia (*R. centrifolia*), and Moss rose (*R. centrifolia moscosa*). These five classes shared a number of features such as double flower, fragrance, muted flower colours, frost hardiness and resistance to black spot and rust, spring flowering and were susceptible to mildew in some climates. As a group they are referred to as the Old European roses.

During the later part of the eighteenth century, the Old European roses were crossed with four roses from the China group (*R. chinensis* x *R. gigantia).* The China group had distinct features which appealed to rose breeders such as bright distinct colours, glossy foliage, a light branching habit and most importantly, they flowered constantly. The crossing of the China roses with the Old European roses gave rise to a number of new classes of roses. Breeding during the second half of the nineteenth century developed roses that flowered twice or perhaps three times in a season, were more compact and hardier than the China roses. This class was known as the Hybrid Perpetuals. Another class, the Tea roses, had also been developed, which had desirable floral characters and fragrance, but lacked frost hardiness. It was the cross between the Hybrid Perpetuals and the Tea roses that resulted in the Hybrid Tea class (*Rosa x hybrida*). In the last century, other species (e.g. *R foetida, R. multiflora*, and *R. chinesis minima*) have been bred into the Hybrid Tea class to generate new classes of roses such as Polyantha, Floribunda, and Minature roses (Ross 1991)

Hybrid Tea and Floribunda type roses are grown by commercial flower growers for the cut-flower market and for domestic and industrial landscaping. As well as *Rosa* x *hybrida*, a number of *Rosa* species have been introduced into Australia for cultivation, for use as ornamentals, as well as for the food and medicinal value of their hips.

2.3 Cultivation in Australia

Roses are found in the majority of northern hemisphere climates, ranging from the arctic to the tropics. Nearly all species are able to tolerate hot summers, and are hardy down to around -15^{o}C (Phillips and Rix 1988). Some of the species found in China are not hardy at cold temperatures (-10^{o}C), including *R. gigantea*. This species was used in the development of hybrid tea roses, and consequently hybrid teas are also susceptible to cold climates (Phillips and Rix 1988).

Roses will grow in all parts of Australia, but are more difficult to manage in hot tropical regions, due to the diseases such as black spot which are more prevalent in hot humid areas. It is thought that John and Elizabeth Macarthur of Camden Park were the first to introduce roses into Australia in the early 19 century. The first record of rose hybridisation in Australia occurred in 1845 when Mr. Bidwell introduced the hybrids ‘Imogen’ and ‘Perudita’ (Cox 1999). Today there are literally thousands of rose cultivars available to Australian growers. Seven introduced species have escaped cultivation, and two of these, *R. canina* and *R. rubiginosa*, are fully naturalised in Australia (i.e. they have established long-term, self-propagating wild populations). Ross (1991) notes that in 1840, self-sown seedlings of *R. canina* were collected along creeks in the hills near Adelaide to be planted as hedges. However, none of the cultivated complex hybrid rose varieties have become naturalised, despite many decades of cultivation.

2.4 Crop improvement

Modern *Rosa x hybrida* cultivars are the result of a long history of rose development through many centuries (see section 2.2 above). These roses are highly selected varieties which are vegetatively propagated. They are selected for defined traits such as flower bud and flower qualities (shape, colour, fragrance), stem length, and vase life. Breeding to modify a single characteristic generally results in changes to other characters as well. Thus, current crop improvement strategies incorporate molecular biology techniques to improve *Rosa x hybrida* (see review by Rout et al. 1999). Randomly amplified polymorphic DNA (RAPD) and restriction fragment length polymorphic (RFLP) markers have been used to determine genetic relatedness of siblings (Vainstein et al. 1995), for cultivar identification (Hubbard et al 1992), phylogenetic analysis within and among *Rosa* species (Debener and Mattiesch, 1999), and mapping rose genes for resistance to powdery mildew or black spot (Linde et al. 2004). Molecular markers have also been used to identify the source of crown gall disease in roses, which was found in many cases to be transmitted via infected rootstock material (Pionnat et al. 1999). In vitro propagation methods have been developed for rapid multiplication of cultivars and production of healthy, disease-free plants (see review by Pati et al 2005).

In the laboratory, the anthocyanin biosynthetic pathway of *Rosa x hybrida* has been genetically modified in the search for new flower colours (Souq et al 1996), and powdery mildew resistance enhanced by the addition of an antimicrobial protein gene (Xiangqian et al. 2003). Recent work on cloning and expression of 1-aminocyclopropane-1-caroxylate synthase from *Rosa* may lead to regulation of ethylene response in plants and potentially a longer vase life for roses, in which ethylene is a hormonal regulator of senescence of most plant organs (Wang et al. 2004).

2.4.1 Breeding

Many types of hybrid roses have arisen over the centuries, often at random, and have led to 29 groups or classes of cultivated roses, including Hybrid teas and Floribundas. Hybrid tea and Floribunda roses (*Rosa x hybrida*) are the most common roses of the twentieth century. Hybrid teas arose in the mid-nineteenth century, as crosses between Tea roses and Hybrid Perpetuals (Phillips and Rix 1988). The next major advance was the crossing of *R. foetida* into Hybrid teas for the introduction of yellow flower colour. Crosses between Hybrid teas and *R. wichuraiana* resulted in hardier varieties that were resistant to blackspot (Phillips and Rix 1988). In the last century, other species (e.g. *R. multiflora* or *R. chinesis minima*) have been bred into the Hybrid Tea class to generate new classes of roses such as Polyantha, Floribunda, and Minature roses (Ross 1991).

The modern cultivars of *Rosa x hybrida* tend to be triploid or tetraploid (Rout et al. 1999), so crossing among them may not generate viable seed. Conventional breeding programmes of the rose focus on improvements of various characteristics to enhance ornamental value including colour, size, form and keeping quality of the bloom and plant response to the environment. In the past, desirable traits were introduced through classical breeding, but there are limitations to this technique. The gene pool of *Rosa x hybrida* is limited for some traits, distant crosses are limited through incompatibility or differences in ploidy levels among parents, and characters such as uniform growth and synchronous flowering are polygenic (Rout et al 1999). Many cultivars have arisen through mutation. Haenchen and Gelfer (1978, in Rout et al. 1999) examined 5819 cultivars which arose from 1937 to 1976 and found that 865 (15%) had arisen through spontaneous mutation, though few cultivars from induced mutation breeding have been reported. Rose breeding is mainly carried out by amateurs or commercially by highly competitive companies, thus the genetic knowledge is often proprietary and unpublished (Gudin 2000).

Increased fragrance in cut roses is desired by consumers and is under selection by breeders. However, there does appear to be a negative correlation between 'real rose' fragrance and vase life. Post harvest longevity is gaining importance as rose production moves to developing countries. This trend requires longer and more complex shipping arrangements, thus as well as long vase life, thornless stems are highly desired for ease of handling and sorting. Other desirable traits are related to growing technology such as soil-less cultivation, efficient nutrient usage, and performance of cultivars on their own rootstocks, which are less expensive than grafts (Gudin 2000).

2.4.2 Genetic modification

The first report of genetic modification (GM) of *Rosa* x *hybrida* was by Firoozabady et al. (1994), who developed an *Agrobacterium*-mediated system for cv. Royalty. A biolistic-mediated modification system was developed by Marchant et al. (1998) for cv. Glad Tidings. In an effort to modify flower colour, Souq et al. (1996) modified *Rosa* x *hybrida* using a gene encoding chalcone synthase to alter the anthocyanin biosynthetic pathway. Enhanced resistance to powdery mildew was observed in GM *Rosa x hybrid* cv. Carefree Beauty modified with an antimicrobial protein gene (Xiangqian et al. 2003). Genetically modified *Rosa x hybrida* rootstock cv. Moneyway containing *rol* genes from *A. rhizogenes* showed a threefold improvement in adventitious rooting of cuttings (van de Salm et al. 1997). To date there have been no reported releases of GM roses.

SECTION 3 MORPHOLOGY

3.1 Plant morphology

The genus *Rosa* is comprised of hundreds of species of prickly shrubs which may also have a climbing or trailing habit. The leaves are alternate, mostly odd-pinnate shaped and for most species, 5 to 15 cm long. The leaves are pinnate with as few as 3 and up to 13 leaflets and basal stipules. Leaflets usually have a serrated margin and often a few small thorns on the underside of the stem. Except for a few species in southeast Asia, which are evergreen or nearly so, the vast majority of roses are deciduous (Hortus Third 1976).

3.2 Reproductive morphology

The flowers of the species in *Rosa* can be solitary, corymbose, or panicled and have 5 petals (except for *R. sericiea* which often has only four petals), many stamen and many pistils. The ovary is inferior, developing below the petals and sepals. Flowers are usually white or pink but in a few species are yellow or red. Seeds (achenes) are hairy and produced in a fleshy pericarp called a rose hip. Mature rose hips are usually red, but a few (eg. *R. pimpinellifolia*) have dark purple to black hips. Hips contain from 5 to 25 seeds. Some rose hips (*R. canina and R. rugosa*) are very rich in vitamin C.

Many species of *Rosa* have been modified through selection and hybridisation to give rise to some 20,000 cultivars. The Hybrid Tea roses have been selected for their reliable recurrent blooming habit; a refined, high-centered bud and multi-petalled flower form (generally 25 to 35 petals, but up to 80 petals in some hybrids); colour range; long cutting stem; strong neck; glossy or semi-glossy, hard, leathery foliage; disease resistance; and rich or spicy fragrance (Lammerts 1945). However, for the cut flower industry there is a tendency to select flowers with little or no scent.

In contrast, the Floribunda roses have smaller flowers (about half the size of Hybrid Tea flowers), in large clusters of 10 or more on each stem, which tend to give a more prominent display. Hybrid Tea and Floribunda roses are the predominant garden and greenhouse cut-flower production roses. The first cultivar to be classified as a Hybrid Tea rose was 'La France', introduced in 1867 (Hortus Third 1976).

SECTION 4 REPRODUCTION

4.1 Reproductive development

Greenhouse production of cut roses is influenced by a number of cultural and environmental factors. Production of quality rose cut flowers depends on such factors as light levels (natural and artificial), plant architecture, temperature, CO_2 levels, pest management systems, timing of fertilizer application, media (soil, soil-less or hydrophonic system) and choice of cultivar (Lieth 1998, Särkkä 2004). The greenhouse rose is self-inductive, meaning that flowers are initiated autonomously in extending shoots (Halevy 1972a, in Särkkä 2004). Flowering is not regulated by photoperiod or temperature. Roses are generally classed as day neutral and flowering is recurrent throughout the year provided growing conditions are suitable (Zieslin and Moe 1985, in Särkkä 2004).

4.2 Pollination and pollen dispersal

Rose pollen tends to be large and heavy and is likely to be carried by insects rather than disperse by wind. Hybrid Tea and Floribunda roses are generally self-pollinated, a trait which has been enhanced through several centuries of breeding. The close proximity of the anthers and stigmata, coupled with the fact that modern hybrid roses have been selected both to contain more petals (generally 25 to 35) and for slow opening of the petals, has resulted in greatly reduced access by insects or wind. Pollen tends to be shed in the un-opened bloom, resulting in a high occurrence of self-pollination (Bell 1988).

4.3 Fruit development and seed dispersal

Seed dispersal of *R. canina* and *R. rubiginosa* (both considered weedy species in Australia) is generally by birds or other animals. The rose hips of *R. rubiginosa* are brightly coloured and appear to attract birds and other animals which then excrete the seed in a viable condition. Seeds of *R. rubiginosa* may remain viable in the soil for 3 or 4 years (Parsons and Cuthbertson 2001).

SECTION 5 PHYSIOLOGY AND BIOCHEMISTRY

5.1 Seed dormancy and germination

Rose seeds generally require a period of stratification before they will germinate. *Rosa multiflora* requires about 6 weeks of moist chilling at 3°C for optimum germination, but other species such as *R. rugosa* and *R. hygonis* require 4 to 6 months, and *R. blanda* 10 months of stratification prior to germination. *Rosa canina* germinates best if the seeds are kept moist at room temperature for two months followed by an additional 2 months at 0°C (Hartmann and Kester 1975). However, in Australia seeds of *R. canina* and *R. rubiginosa* may germinate at anytime of the year provided moisture is available (Parsons and Cuthbertson, 2001). Hybrid rose seeds germinate best after 2 to 3 months at 1 to 4°C, however, a few seeds may germinate with no cold treatment at all. Germination appears to be prevented by inhibitors in the seed coat as well as mechanically by the pericarp (the wall of the rose hip) (Hartmann and Kester 1975).

5.2 Growth and development

Propagation of roses by seed is used in breeding new cultivars or in the production of rootstock plants of some species such as *R. canina*. Once a new hybrid rose has been selected, it is propagated asexually, with T-budding of the hybrid rose onto a vigorous rootstock the most common method. Asexual propagation of the hybrid rose is used because the rootstock tends to be more winter-hardy and disease-resistant than the hybrid rose. More importantly, the asexually propagated hybrid rose will be a clone of the original selection, preserving all the characteristics for which it was selected. In contrast, any seed derived progeny will segregate and have characteristics that differ from the original hybrid rose parent.

Rootstock plants for grafting can be propagated from seed, but most often are clonally propagated using soft or hardwood cuttings. In areas of severe cold winters, hardwood cuttings are taken in late fall or early winter from the previous year's canes (6 to 10mm diameter). Bundles of 15 to 20cm long cuttings are stored in damp peatmoss at about 4°C for the winter and then planted out in the nursery in spring. In milder climates, hardwood cuttings can be taken in the fall and planted directly to the nursery. Hardwood cuttings are ready for T-budding in the first spring after planting in the nursery. Softwood cuttings are taken from current season's growth anywhere from early spring to late summer. The timing depends on the new growth becoming partially mature. Rooting of the softwood cuttings occurs in 10 to 14 days under ideal nursery conditions (shading, adequate moisture and good soil contact) and these cuttings can be ready for T-budding in the fall (Hartmann and Kester 1975).

Different rootstock plants are utilized depending upon the utility of the hybrid rose. For garden roses, rootstocks such as *R. multiflora* and *R. canina* have been commonly used, whereas for greenhouse rose flower production, *R. x noisettiana* and *R. ordorata* have been excellent rootstock choices. *R. multifora* is popular because it is thornless and not prone to suckering. *R. canina* has been used as the rootstock for standard roses and *R. fortuneana* has been a suitable choice for sandy soils (Hatmann and Kester 1975, Bell 1988).

5.3 Biochemistry of rose flower colour and scent

More than 400 volatile compounds have been identified in the floral scent of various rose cultivars. These compounds are generally classed into five groups based on their functions: hydrocarbons, alcohols, esters, aromatic esters, and others. Representatives from one of these five groups usually dominate the floral scent of most rose cultivars. The damask rose (*R. damascena)* is the most important species used to produce rose water, attar of rose and other essential oils in the perfume industry (Lavid et al. 2002).

Rose flower colour is primarily composed of structurally simple cyanidin 3,5-diglucoside (also called anthocyanin, Otaga et al. 2005). Anthocyanins are part of a diverse family of aromatic molecules called flavonoids, derived from phenylalanine and malonyl-coenzyme A (Winkel-Shirley 2001). Anthocyanins are the biggest subclass of plant flavanoids and in most cases are responsible for the orange to blue colours of flowers and other plant organs. Flavonoids are water-soluble pigments such which accumulate in the vacuoles. There are three major types of anthocyanins that contribute to flower colour (Zuker et al. 2002):

- delphinidins that produce blue or purple flower colour;
- cyanidins that produce red or magenta flower colour; and
- pelargonidins that produce orange, pink or brick red flower colour

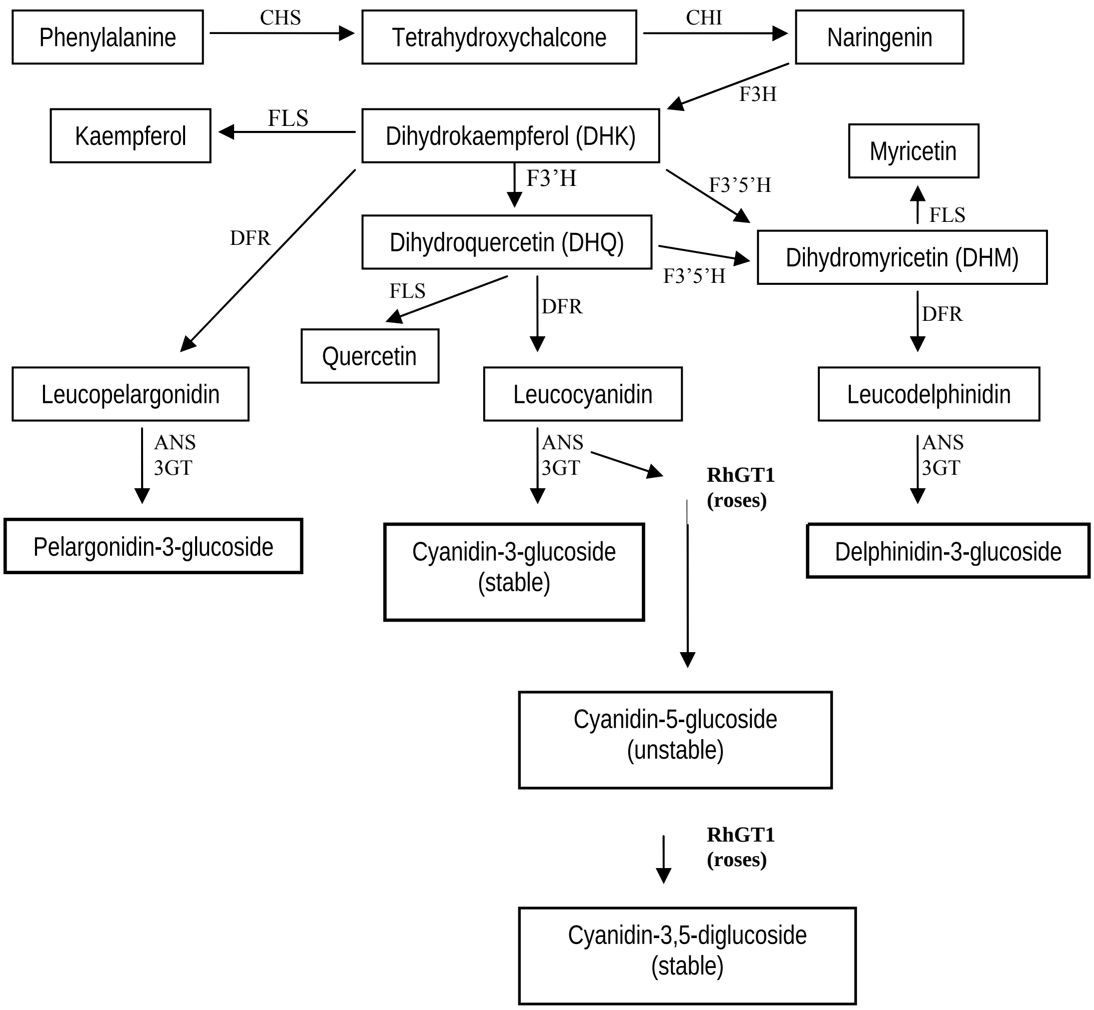
Roses do not normally have blue pigments because they lack that part of the anthocyanin biosynthetic pathway that produces delphinidins or blue pigments.

In the anthocyanin biosynthetic pathway (figure 2) an intermediate compound called anthocyanidin is generated in the conversion of leucocyanidin to cyanidin 3-glucoside. Anthocyanidin is unstable and through gylcosylation at the 3'-OH residue becomes the stable compound cyanidin 3-glucoside. This is the first stable anthocyanin produced in most plant species.

Recently, Ogata et al. (2005) discovered that anthocyanin biosynthesis in *Rosa x hybrida* follows a slightly different pathway. In roses, the unstable anthocyanidin is glycosylated by RhGT1 (glycosyltransferase from *Rosa x hybrida*) first at the 5'OH and then at the 3'-OH positions to form cyanidin 3,5-diglucoside, which is the first stable anthocyanin produced in roses.

The stable anthocyanidin 3-glucosides (eg. pelargonidin-, cyanidin-, or delphinidin-3-glucoside) often undergo further modification such as glycosylation, acylation, and methylation and these modification patterns vary among species and cultivars. It is this modification pattern, as well as vacuolar pH, metal ion complexes and co-pigmentation with flavonoids that contributes to variations in flower colour (Fujiwara et al 1998). In many plant species, anthocyanins exist in their acylated forms (see review by Nakayama et al. 2003). There are two major types of acyl substituents of anthocyanins, aromatic and aliphatic acyl groups, which are usually linked to a hydroxy group of a glycosyl moiety of anthocyanins. Aromatic acylation makes anthocyanins more stable and bluer due to intramolecular stacking of the anthocyanins with polyphenols. Aliphatic acylation of anthocyanin is important for pigment solubility in water, protecting and stabilizing anthocyanins, and uptake of anthocyanins into vacuoles.

In *in vitro* aqueous systems anthocyanin apparently exists as several distinct forms, depending upon pH. At acidic pH (pH < 2), anthocyanin is present in its cationic flavylium form (red in colour in aqueous solution). At physiological pHs (4 – 7), anthocyanins is spontaneously tautomerised to 7-quinonidal and 4-quinonoidal base isomers (bluish-purple to blue in colour). At pHs higher than 5, anthocyanins also undergo hydration to produce a colourless carbinol puesobase species. This hydration process is closely related to the instability of the anthocyanin colouration at these pHs (Nakayama et al. 2003).



Key to enzymes:

3GT: Flavonoid 3-glucosyltransferase
CHS: chalcone synthase
F3'H: flavonoid 3' hydroxylase
RhGT1:rose glucosyltransferase
ANS: anthocyanidin synthase
DFR: dihydroflavonol 4-reductase
F3'5'H: flavonoid 3',5' hydroxylase
CHI: chalcone isomerase
F3H: flavanone 3-hydroxylase
FLS: flavonol synthase

Figure 2. Anthocyanin biosynthetic pathway (Holton and Cornish 1995) and additional rose pathway (Ogata et al. 2005).

SECTION 6 BIOTIC INTERACTIONS

6.1 Weeds

Commercial greenhouse production of roses as cut or potted flowers generally involves culture in sterile soil, sterile soil-less media, or by hydroponics, thus reducing the opportunity for weeds to be present. Field production of roses, either commercially or in the home garden, often incorporates the use of weed mats or mulches to reduce or eliminate weeds. Weeds infesting field or garden production of roses may be controlled by cultivation, mulches, and possibly herbicides.

6.2 Insects

Aphids (*Macrosiphum rosae* and other species), also called greenfly or blackfly, are the most common rose pests. They attack young shots, particularly in dry weather, leading to the distortion of shots and stunting. Ladybird beetles (*Hippodamia parenthesis*) can be used as a biological control or there are numerous sprays available to control aphids.

Caterpillars of various flies and moths (such as the apple moth, *Tortrix postvittana*) also like young shoots, and some will eat developing buds. They are rarely a huge problem in Australia, as their numbers tend to be low and can easily be controlled manually.

The **red spider mite** (*Tetranychus telarius*) causes damage to rose plant leaves, turning leaves to yellow. This insect pest can be controlled biologically by *Phytoseiulus persimilis* or insecticidal sprays.

Thrips (*Thrips imaginis*) generally cause aesthetic damage due to infestations in the flowers. They can be controlled biologically using predatory mites, lady beetles, and soil-dwelling mites, or through the use of sprays.

White rose scale (*Aulacaspis rosae*) and other scale insects can infest rose plants causing weakening of the plant, increased susceptibility to other diseases, and possible death. Pruning can eliminate infected branches and shoots. The parasitic wasps *Aphytis melinus*, *Aphytis lignanensis*, and *Comperiella* spp. are used in Australia in many Integrated Pest Management (IPM) programs to control scale insects.

Fuller's rose weevil (*Asynonychus cervinus*) generally feed on leaves, young shoots and buds. Several biological controls (parasitic wasps, praying mantises) and cultural controls available.

Swarms of **Japanese beetles** are very destructive to rose plants, by eating flowers and leaves, fortunately the Japanese beetle has not yet arrived in Australia.

Insect pest references: Phillips and Rix 1988; Mann 2002; Botanic Gardens Trust, Plant Disease Diagnostic Unit, <www.rbgsyd.gov.au>.

6.3 Diseases

Black spot (*Diplocarpon rosea*) is the most common disease to affect roses and most types are susceptible. The disease appears as more or less circular black spots on the leaves (generally one spot per leaflet), which can then turn yellow and fall prematurely. Is not too serious for modern roses, but some species (especially the yellow-flowered rose species) can be completely defoliated by this disease in wet summers.

Mildew (*Sphaerotheca pannosa*) is a fungal disease which first appears as tiny blisters followed by a fine powdery deposit on the surface of leaves and shoots, and is usually favoured by warm humid weather. It is not very damaging to the rose plant, and is more an aesthetic problem. There is variable resistance (from none to high) among the rose varieties including the hybrid tea roses.

Rust (*Phragmidium* sp.) can be a serious disease in some climates, but can be controlled through spraying. It occurs less commonly than black spot or powdery mildew, and appears as bright orange powdery spots on the underside of leaves with the upper leaf surface becoming speckled with yellow.

Anthracnose (*Spaceloma rosarum*) occasionally affects roses in Australia, and appears as black spots on the leaves (generally several spots per leaflet). Anthracnose is often misdiagnosed as black spot.

The above fungal diseases of roses can be controlled through the use of various sprays and/or in conjunction with cultural practices such as removal of leaf litter from under roses and not composting the rose leaf litter.

Honey fungus (*Armillaria mellea*) and **Cinnamon fungus** (*Phytopthora cinnamonii*) are soil borne fungi which can destroy the roots of roses. Fortunately, roses are not overly susceptible to cinnamon fungus and honey fungus is rare in Australia.

Crown Gall (*Agrobacterium tumefaciens*) is a soil-borne bacterium that causes gall like growths. Disease may also be spread via infected rootstock.

Rose wilt virus is most noticeable in spring is young leaflets which recurve so that the leaf is balled up with a thick and brittle texture.

Disease references from: Phillips and Rix 1988; NSW Dept of Agriculture, 1961; Mann 2002.

SECTION 7 TOXICITY AND ALLERGENICITY

Roses are widely cultivated and have a long history of safe use. *Rosa* species have been used for centuries as a source of oils for the fragrance industry, hips for herbal teas, infusions, jams, preserves, and more recently, rose hips have been used in the floral industry. The handling of rose plants is not harmful to humans (e.g. no known dermatological reactions), and *Rosa x hybrida* plants are not heavily thorned.

Roses are not a common cause of allergic reactions. Rose pollen is large and sticky, being insect borne, not air borne. People working with roses or rose hips may develop sensitivity to dust or pollen.

7.1 Toxicity

There have been no reports in the literature of toxicity of the roses (plants parts including pollen) or rose products (rose oil, rose hips, or other rose derived foods).

7.2 Allergenicity

Allergy to flowers in the cut flower industry is rarely reported in the literature. A few cases of flower allergy developing into occupational asthma have been reported for exposure to freesia, chrysanthemums and tulips (Piirila 1994). The risk factors associated with the prevalence of work-related asthma-like symptoms among florists in Turkey include work intensity, work duration, workplace size, atopy, and family history of respiratory and allergenic problems (Akpinar-Elci et al. 2004). However, the study did not look specifically at the allergic effect of roses, instead using a skin-prick test for atopy to a flower mix which included *Aster, Chrysanthemum, Dahlia* and *Solidago,* but not *Rosa* species. Studies focusing on roses have suggested the possibility of occupational rose allergy developing in people working in rose cultivation (Ünlü et al. 2001), rose oil extracting plants (Akkaya et al. 2004), and processing powdered rose hips (Kwaselow et al. 1990).

The study by Kwaselow et al. (1990) examined only 13 workers at a processing plant which made vitamin C tablets from ground rose hips in Detroit, Michigan. Eight of the 13 were positive for rose hip skin test and 6 of these (6/8 or 75%) had asthma symptoms. Five of the 13 workers were negative for the rose hip skin test and 3 of these (3/5 or 60%) had asthma symptoms. The number of workers examined was low and there was no statistical analysis presented for interpretation of the data. Only three workers had skin tests done with other potential causal agents (e.g. ascorbic acid, vitamin C tablets). At least one of the workers had asthma prior to working in the rose hip processing plant and data on the other workers was not presented. At best this study suggests a possible link between the allergy to powdered rose hip and occupational asthma.

The study by Akkaya et al. (2004) examined 52 workers from 4 different rose oil extracting plants in Turkey, as well as 30 control subjects. The study demonstrated a statistically significant, 8-fold increase, in *Rosa domescena* pollen hypersensitivity in workers compared to the control group. However, there was no significant difference in the pulmonary function measured, suggesting no link between hypersensitivity and occupational asthma.

The study by Ünlü et al (2001) surveyed 600 workers employed in rose cultivation in Turkey. Of the 600, twenty (3.3%) were found to suffer from allergenic disorders such as rhinitis, rhinoconjunctivitis or both. There was no control population for comparative purposes, thus it is not known if this is significantly different from the general population. Fourteen of the twenty workers examined had increased IgE levels but seven of these workers were also positive to other allergens in the skin prick test, suggesting other allergens may have caused their increased IgE levels. These results suggest that an IgE mediated reaction to *Rosa domescena* may be responsible for the respiratory symptoms of the some of the 20 workers examined and indicates the need for further investigation using proper controls.

A study by Demir et al. (2002) suggested that villagers in Turkey who worked in the rose industry may develop allergy to roses, but did not rule out a number of other agricultural causes of their allergy-like symptoms. Their study lacked a control population which did not have a history of exposure through working in the rose cultivation. Interestingly, their study seemed to suggest that villagers' complaints about allergy symptoms were reduced 3-fold during the rose season as compared to the rest of the year. This may indicate some beneficial effect of working with the roses during the flowering season.

The American Academy of Allergy Asthma and Immunology (AAAAI) website <www.aaaai.org> suggests that respiratory reactions to rose pollen must be quite rare as they could find no documented cases. This was likely due to the fact that rose pollen is heavy and sticky, designed for insect pollination rather than wind dispersal. Rose oil, which has been used in fragrance free soap and other "all natural" products, may be a more common allergen than previously recognized and further testing of this product is suggested by the AAAAI.

SECTION 8 WEEDINESS

Roses are long-living plants and may be found in isolation in situations where deliberately planted roses have been left unattended (e.g. abandoned homes or gardens, or in cemeteries). Cut flower varieties are less hardy, but if grafted onto root stocks may still survive for decades, if left unattended. There are no reports in the literature of *Rosa* x *hybrida* cultivars becoming weedy species.

Seven introduced *Rosa* species have escaped cultivation. Two of these, *R. canina* and *R. rubiginosa*, are fully naturalised and have become noxious weeds in temperate Australia. The other five have weed status. However, no cultivated complex hybrid rose types (*Rosa x hybrida*) have become naturalised, despite a long history of cultivation. *R. canina* is a noxious weed, although it is not widespread. Areas in which it is found include the central western slopes and south western plains of NSW, in the Grampians of Victoria, in the Adelaide plains, Mount Lofty Ranges, mid-Murray district and lower south east of South Australia, and in settled areas in Tasmania. *R. rubiginosa* is a common noxious weed, and occurs in all Australian states, except the Northern Territory. The species has probably been in Australia since early settlement. It is considered to be an important weed in the cooler, high rainfall areas of NSW, Victoria and South Australia, and also extends to more arid areas. It is widespread in Tasmania, mainly on roadsides. It is also found in Western Australia and the cooler areas of Queensland, but is not considered an important weed in these areas (Parsons and Cuthbertson 2001).

R. canina is a strongly growing prickly scrub, and grows in woods, scrub and hedgerows of temperate lowlands and lower mountain slopes, and occurs on a wide range of soils. The species disperses locally due to seedling development around the base of clumps, as well as growth from root stocks and layering. Animals and birds are also responsible for seed dispersal. Seeds germinate in autumn and spring, but can germinate at any time of the year, provided there is enough moisture in the soil. Seedlings are slow growing and easily damaged, but are hardy and long-living once established. *R. canina* was considered one of the best stocks in which to graft hybrid roses, and most tree roses are still grown on this plant.

R. rubiginosa invades disturbed bushlands and open unimproved grasslands in Australia, and grows on a wide range of soil types. It reproduces from perennial roots and seeds, and seeds can germinate at any time of the year. Seedlings lack early vigour, and are often out-competed by other plants. However, seedling survival is enhanced in disturbed habitat (e.g. eroded areas, rabbit scratches). The species was originally spread through deliberate plantings, but this has long since stopped. Seed dispersal by animals and birds is now the only method of spread for this plant. Some fruit and seed movement may occur along streams and in flowing water. Seeds remain viable in the soil for 3 to 4 years. Like *R. canina*, *R. rubiginosa* are hardy plants once established, and may survive for hundreds of years (Parsons and Cuthbertson 2001).

Wild *Rosa* species are insect pollinated and are capable of cross- and self-pollination. Pollinating insects can include bumble bees, honey bees, wasps, and flies. Insect pollination is constrained under glasshouse conditions, particularly where there is cut flower production. Rose flowers are cut before the petals are open, thereby limiting the opportunity for insect pollination. Rose hybrids grown in gardens are more accessible to insect pollination.

Unlike wild rose species, hybrid rose varieties do not necessarily produce significant amounts of viable pollen, and they may be infertile. Hybrid rose pollen viability is affected by humidity and temperature when in storage. Pollen collected for breeding purposes generally remain viable for many weeks, if stored appropriately.

Breeding has produced successful interspecific hybridisation between different *Rosa* species, and between species and more complex hybrids. Hybridisations can lead to hybrids that range from fertile to completely sterile. Fertile hybrids can occur where the parents have the same or different ploidy levels. Section *Caninae* of the *Rosa* genus is particularly prone to hybridisations. *R. canina* and *R. rubiginosa* are from this section. Fertile hybrids between these two species are known in the UK, however there are no reported incidences of these hybrids in Australia. There is no record of hybrids between hybrid tea or floribunda roses with *R. canina* and *R. rubiginosa* in Australia.

SECTION 9 POTENTIAL FOR GENE TRANSFER

9.1 Intraspecific gene transfer

Generally, modern roses, including the Hybrid Teas and Floribudas (*Rosa x hybrida*) have been developed through traditional breeding among thousands of existing cultivars. Most of the modern cultivars of *Rosa x hybrida* tend to be triploid or tetraploid (Rout et al. 1999), so crossing among them may not generate viable seed.

There are a number of factors which make the rose a difficult model for genetic analysis. These factors include high heterozygosity, ploidy levels, and difficulties in sexual reproduction. Because of these problems, Gudin (2000) has suggested that hybridization among modern cut rose or garden cultivars can result in hip set as low as 25%, with only 4 seeds per hip, and only 18% seed germination.

Due to their low sexual reproduction status (Gaudin 2001), and a tendency to be self-pollinated (Bell 1988), there appears to be little opportunity for successful crosses to occur naturally among the *Rosa x hybrida* cultivars.

9.2 Interspecific gene transfer

The history of the development of our modern day roses indicates that interspecific gene transfer is possible among many of the *Rosa* species and that hybridization has occurred naturally. It is this inter-species hybridization which helps makes the taxonomy of *Rosa* difficult. However, some species with important disease resistance gene, such as *R. banksia* are apparently impossible to breed from (Ross 1991). Another species, *R. foetida persiana,* was crossed into the Hybrid Teas to bring in a range of colours (yellow, bronze, sunset and orange) which until then had not existed in garden roses. However, the success of the cross with *R. foetida persiana* was the result of a rare fertile seedling (Ross 1991). Similarly, the cross between *R. rugosa* and *R. Wichriaiana* was almost completely sterile, but a few fertile seedlings (amphidiploids) were obtained and have been used as valuable breeding stock to introduce new traits or combinations into cultivated roses (Hortus Third 1976). Section *Caninae* of the *Rosa* genus is particularly prone to hybridisations. *R. canina* and *R. rubiginosa*, which are weedy species in Australia, are from this section. Although fertile hybrids between these two species are known in the UK, there are no reported incidences of these hybrids in Australia. There is no record of hybrids between Hybrid tea or Floribunda roses with *R. canina* and *R. rubiginosa* in Australia. It is highly likely that wild species of roses will have to be exploited in the creation of cultivars that will offer new aesthetic characteristics and resistance to biotic and abiotic stress (Gudin 2001).

An extensive search of the relevant literature did not reveal evidence of gene transfer between roses and unrelated plant species.

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