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Review

Disease resistance breeding in rose: Current status and potential of biotechnological tools

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ABSTRACT

The cultivated rose is a multispecies complex for which a high level of disease protection is needed due to the low tolerance of blemishes in ornamental plants. The most important fungal diseases are black spot, powdery mildew, botrytis and downy mildew. Rose rosette, a lethal viral pathogen, is emerging as a devastating disease in North America. Currently rose breeders use a recurrent phenotypic selection approach and perform selection for disease resistance for most pathogen issues in a 2–3 year field trial. Marker assisted selection could accelerate this breeding process. Thus far markers have been identified for resistance to black spot (Rdrs) and powdery mildew and with the ability of genotyping by sequencing to generate 1000s of markers our ability to identify markers useful in plant improvement should increase exponentially. Transgenic rose lines with various fungal resistance genes inserted have shown limited success and RNAi technology has potential to provide virus resistance. Roses, as do other plants, have sequences homologous to characterized R-genes in their genomes, some which have been related to specific disease resistance. With improving next generation sequencing technology, our ability to do genomic and transcriptomic studies of the resistance related genes in both the rose and the pathogens to reveal novel gene targets to develop resistant roses will accelerate. Finally, the development of designer nucleases opens up a potentially non-GMO approach to directly modify a rose's DNA to create a disease resistant rose. Although there is much potential, at present rose breeders are not using marker assisted breeding primarily because a good suite of marker/trait associations (MTA) that would ensure a path to stable disease resistance is not available. As our genomic analytical tools improve, so will our ability to identify useful genes and linked markers. Once these MTAs are available, it will be the cost savings, both in time and money, that will convince the breeders to use the technology.

Contents

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1. General aspects

1.1. Rose as an important ornamental crop

Roses were independently domesticated in both Europe and China several thousands of years ago for a range of uses including medicinal, floral, garden and fragrance [1–3]. The introduction of Chinese remontant roses to Europe in the 18th century [4] transformed the European rose from a once blooming rose into a remontant rose with a wider range of colors, growth types, flower sizes, fragrances and adaptation. Since then, intensive selection and later planned breeding work throughout the world that intercrossed a wide range of rose species with the cultivated forms has developed thousands of cultivars [5]. This transformed the rose into the most popular ornamental plant in the world. Thus because of the breeding history, the domesticated rose is an interspecific complex which consists of tetraploid, triploid, and diploid cultivars [6,7]. Currently, the vast majority of new rose cultivars are produced by private breeders.

Roses are one of the most important ornamental crops in the world with a yearly estimated production of 18 billion cut stems, 60–80 million potted roses and 220 million roses for the landscape [8–10]. The estimated value of the cut rose and garden rose market in the world twenty years ago was $11.7 billion dollars per year [11]. In 2008, the world rose production was estimated to be valued at 24 billion Euros [12]. More recently the value of the Dutch rose cut flower market was estimated at $10 billion [13] and that of the North American landscape rose industry was estimated at $1 billion [14]. Thus the rose industry on a world wide scale has an economic impact in the 10s of billions of dollars.

1.2. Impact of diseases on rose production

A wide range of pathogens including fungi, bacteria, viruses, nematodes and phytoplasmas attack the cultivated rose throughout the world. These pathogens cause reduced growth and plant death as well as can drastically affect the ornamental value of a plant by causing leaf and flower mosaics, distortion, spotting, discoloration, necrosis and abscission. Except for a few pathogens that typically attack the roots such as nematodes, crown gall and various soil borne diseases, the major pathogens attacking roses affect the economic part of the plant: the flower or the leaves. As the cosmetic appearance of an ornamental plant is key to its marketability and consumer acceptance, a high degree of pest/disease control is required for the rose [15].

Losses due to various diseases of roses are poorly documented. It is known that diseases such as black spot and rose rosette can reduce the marketability of a rose crop as the symptoms develop and lead to plant death within several years. In an experiment that compared rust infection of the rootstock during propagation, it was shown that a rust infection of the rootstock reduced scion growth and flower production by 50% and 25%, respectively, which drastically reduced the quality and number of saleable plants [16]. The major diseases of rose, such as black spot and powdery mildew are generally controlled by preventative fungicide sprays every 7–14 days when the conditions are optimal for disease development. This can easily mean 20 sprays or more per year. In a survey of growers (China, South America, United States, Europe) that produced roses (field, potted and cut flowers) the cost disease and pest control ranged from about $7000/ha/year to $32,000/ha/year with about half of this going toward disease control. The highest cost estimate is from cut flower production from Europe. Beyond the cost of the protection, issues with safety, environmental contamination and the development of pesticide resistant pathogens/pests have come to the forefront which has stimulated the development of integrated pest management protocols.

Recently there has been a strong trend in garden rose demand by consumers and development by breeders for roses [17–19] that need little care and are resistant to the predominant diseases of the region. This has stimulated more research into the host plant resistance of the major diseases of rose: black spot and powdery mildew among others.

The few public programs in North America and Europe that research rose genetics generally focus their research on disease resistance rather than releasing new rose cultivars. Thus it is the private breeding programs that create the vast majority of the new rose cultivars released in the world [17]. A survey done of 16 active garden rose breeders revealed that all of them screened their seedlings either without or with a minimal spray program. These trials are run for 2–3 years depending on the natural level of inoculum in the field. Many times these seedling fields are planted alongside other established trials in which diseased plants are present as a source of disease inoculum and in several cases the seedlings are purposely planted at a high density to encourage disease and infected seedlings are not removed until the end of the trial to ensure sufficient disease pressure. A few breeders will do selection among young (1–2 months of age) rose seedlings in a greenhouse to discard those most susceptible to powdery mildew although others do not do this as they do not consider the resistance of a young seedling reflective of the resistance seen in an older plant.

As most breeders only do their seedling selection in one location, they are limited by their location and natural field inoculum levels with respect to how effectively they can select for resistance to a particular pathogen. For example, in the eastern United States, using a 3-year selection cycle is effective in the evaluation of black spot resistance whereas it would be ineffective for the selection for resistance to powdery mildew which is common in the coastal region of the west coast. Nevertheless, given the lack of knowledge of which races of each pathogen is in each site, the stability of the resistance is not known until the 2nd phase of testing which is done in multiple sites in a range of environments and hopefully a greater diversity of pathogen. For example, in the United States, good natural field inoculum levels can be found for powdery mildew, downy mildew and rust along the cool humid regions of the west coast and for black spot and cercospora in the warmer humid eastern half of the country. Thus the major commercial testers and testing programs in the USA tend to have evaluation sites on both sides of the country. Many rose breeders also send their new candidate varieties to collaborators internationally for multiple site testing prior to the final variety registration.