## Making the right choice

Selecting the appropriate rootstock for specific soil and climate conditions is critically important for the long-term success of an orchard. Rootstocks can defend against soilborne diseases, pathogenic nematodes, and soil chemistry problems. They also influence horticultural characteristics such as tree vigor, branching, anchorage, nutrient uptake, date of crop maturity, and bloom timing. The most suitable rootstock will reduce the need for corrective action, improve profitability, and extend the economic life of an orchard. It is imperative that growers analyze their soil for biotic and abiotic conditions prior to choosing a rootstock.

Rootstock characteristics, as documented in this publication, are largely based on field and greenhouse studies performed by University of California farm advisors and specialists and USDA-ARS researchers over many decades. Most of these studies were funded by the Almond Board of California, through assessments paid by California almond growers and handlers, and we acknowledge and thank them for their support. Occasionally, data from outside California or from California field observations are included where research data are limited.



Iron chlorosis of almond on Nemaguard® (left) vs. Hansen<sup>®</sup> (right) rootstocks



Rootknot nematode on Krymsk 86<sup>®</sup> rootstock Crown gall on Hansen<sup>®</sup> rootstock



Sodium toxicity of Carmel on Nemaguard<sup>®</sup> rootstock







Atlas® Very slight overgrowth at graft union

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Rootstock effect on vigor and size of Nonpareil trees (Nickels<sup>®</sup> left, Lovell<sup>®</sup> right)

Characteristics of typical graft unions, and relative trunk sizes on various rootstocks

(Graft unions of specific variety and rootstock combinations may not resemble these examples)

Krvmsk 86<sup>®</sup>

often visible



**Empyrean 1**<sup>®</sup> Very slight overgrowt at graft union



Lovell® Rootstock larger than Slight overgrowth scion, surface roots at graft union



**Nickels**<sup>®</sup> Very smooth transition at graft union



Rootpac R<sup>®</sup> Moderate overgrowth at graft union, surface roots often visible



Marianna 2624® Significant overgrowth at graft union, surface roots often visible

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**UNIVERSITY OF CALIFORNIA** Agriculture and Natural Resources

## Rootstocks

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|  |  |   |  | Horticultural Characteristics   |           |                    |                   | Abiotic Conditions     |                        |                           |                                 |  | Diseases                |                        |                        |                       |                       | ]                             | Nematodes   |                       |                          |  |
|--|--|---|--|---|-----------|--------------------|-------------------|------------------------|------------------------|---------------------------|---------------------------------|--|-------------------------|------------------------|------------------------|-----------------------|-----------------------|-------------------------------|-------------|-----------------------|--------------------------|--|
| Parentage  | Rootstock  | Genetic Background <sup>1</sup>                         | Comments   | Compatibility   | Anchorage | Vigor <sup>2</sup> | Suckering         | Excessive<br>Sodium    | Excessive<br>Chloride  | Lime-induced<br>Chlorosis | Excessive<br>Boron              | In-season<br>Waterlogging <sup>3</sup> | Oak Root<br>Fungus      | Crown Gall             | Phytophthora           | Verticillium<br>Wilt  | Replant<br>Disease    | Bacterial<br>Canker           | Rootknot⁴   | Ring⁵                 | Root Lesion <sup>6</sup> |  |
| Peach  | Guardian®  | P. persica  | Similar to Nemaguard but with good resistance to ring nematode and bacterial canker.   | Good  | Fair      | Moderately high    | Low               | Susceptible            | Susceptible            | Susceptible               | Susceptible                     | Sensitive                              | Susceptible             | Susceptible            | Moderately susceptible | Susceptible           | Unknown               | Tolerant                      | Resistant   | Tolerant              | Susceptible              |  |
|  | Lovell®  | P. persica  | Historical standard in Sacramento Valley heavier soils due to perceived better asphyxia tolerance than Nemaguard. Susceptible to rootknot nematode.  | Good  | Fair      | Moderate           | Low               | Susceptible            | Highly<br>susceptible  | Susceptible               | Highly<br>susceptible           | Sensitive                              | Susceptible             | Susceptible            | Moderately susceptible | Highly<br>susceptible | Highly<br>susceptible | Tolerant                      | Susceptible | Tolerant              | Susceptible              |  |
|  | Nemaguard®   | P. persica  | Historical standard rootstock for the San Joaquin Valley in well-drained soil. Being replaced by newer, better-suited rootstocks. Prone to zinc deficiency.  | Good  | Good      | Moderately high    | Low               | Highly<br>susceptible  | Susceptible            | Susceptible               | Susceptible                     | Sensitive                              | Susceptible             | Moderately susceptible | Moderately susceptible | Susceptible           | Highly<br>susceptible | Susceptible                   | Resistant   | Susceptible           | Susceptible              |  |
| Peach<br>Hybrids                                     | Cadaman®   | P. persica × P. davidiana                               | Similar to Nemaguard but better tolerance of alkaline and saline conditions.   | Good (limited experience)   | Good      | Moderately high    | Low               | Moderately<br>tolerant | Moderately<br>tolerant | Moderately<br>tolerant    | Highly<br>susceptible           | Sensitive                              | Susceptible             | Unknown                | Moderately susceptible | Highly<br>susceptible | Unknown               | Moderately<br>tolerant        | Resistant   | Susceptible           | Highly<br>susceptible    |  |
|  | Empyrean 1 <sup>®</sup><br>(Barrier 1 <sup>®</sup> ) | P. persica × P. davidiana                               | High vigor and salt tolerance similar to peach $\times$ almond hybrids but less susceptible to ring nematode. Fair anchorage may limit use in windy areas.   | Good (limited experience)   | Fair      | Very high          | Low               | Tolerant               | Moderately tolerant    | Moderately tolerant       | Susceptible                     | Sensitive                              | Susceptible             | Unknown                | Moderately susceptible | Susceptible           | Low<br>susceptibility | Assumed tolerant <sup>7</sup> | Resistant   | Tolerant              | Highly<br>susceptible    |  |
| Peach ×<br>Almond<br>Hybrids                         | Brights 5®   | P. dulcis × P. persica                                  | Similar to Hansen but with more moderate vigor.  | Good  | Good      | High               | Low               | Tolerant               | Tolerant               | Tolerant                  | Moderately tolerant             | Sensitive                              | Susceptible             | Moderately susceptible | Highly susceptible     | Susceptible           | Low<br>susceptibility | Highly<br>susceptible         | Resistant   | Highly susceptible    | Susceptible              |  |
|  | Cornerstone®   | P. dulcis × P. persica                                  | Similar to Hansen but with more moderate vigor.  | Good (limited experience)   | Good      | Very high          | Low               | Tolerant               | Tolerant               | Moderately<br>tolerant    | Assumed Moder<br>ately tolerant | Sensitive                              | Susceptible             | Highly<br>susceptible  | Highly<br>susceptible  | Susceptible           | Unknown               | Assumed<br>susceptible        | Resistant   | Highly<br>susceptible | Susceptible              |  |
|  | Flordaguard<br>× Alnem (F×A®)                        | P. dulcis × P. persica                                  | Similar to Hansen. New release by USDA-ARS. Limited experience.  | Good (limited experience)   | Excellent | Very high          | Low               | Tolerant               | Tolerant               | Tolerant                  | Moderately<br>tolerant          | Unknown                                | Unknown                 | Highly<br>susceptible  | Unknown                | Highly<br>susceptible | Unknown               | Unknown                       | Unknown     | Unknown               | Unknown                  |  |
|  | Hansen 536 <sup>®</sup>                              | P. dulcis × P. persica                                  | Standard peach × almond hybrid rootstock developed by the University of California. High vigor, excellent anchorage, high salt and alkalinity tolerance. Highly susceptible to ring nematode and bacterial canker. | Good  | Excellent | Very high          | Low               | Tolerant               | Tolerant               | Tolerant                  | Moderately<br>tolerant          | Sensitive                              | Highly<br>susceptible   | Highly<br>susceptible  | Highly<br>susceptible  | Highly<br>susceptible | Low<br>susceptibility | Highly<br>susceptible         | Resistant   | Highly<br>susceptible | Moderately<br>tolerant   |  |
|  | Nickels®   | P. dulcis × P. persica                                  | Similar to Hansen but better adapted to nursery propagation and storage practices.<br>More tolerant of wet spring soils due to higher chilling requirement.  | Good  | Very good | Very high          | Low               | Moderately<br>tolerant | Moderately<br>tolerant | Tolerant                  | Moderately<br>tolerant          | Sensitive                              | Susceptible             | Highly<br>susceptible  | Highly<br>susceptible  | Susceptible           | Unknown               | Highly<br>susceptible         | Resistant   | Highly<br>susceptible | Susceptible              |  |
|  | Titan Hybrids<br>(Titan II®, SG 1®, etc.)            | P. dulcis × P. persica                                  | More vigorous than Hansen with possibly better wet-soil tolerance.   | Good  | Good      | Very high          | Low               | Tolerant               | Tolerant               | Tolerant                  | Moderately<br>tolerant          | Sensitive                              | Susceptible             | Unknown                | Moderately susceptible | Susceptible           | Unknown               | Highly<br>susceptible         | Resistant   | Unknown               | Unknown                  |  |
| Plum<br>Hybrids                                      | Krymsk 86®<br>(plum × peach)                         | P. cerasifera × P. persica                              | Excellent anchorage and general tolerance to root diseases. Lower vigor in sandy soil.<br>Susceptible to sodium, chloride, boron, and all nematodes. Incompatible with Independence.                               | Good with Nonpareil. Incompatible with Independence. <sup>8</sup> Marginal with Monterey and Shasta | Excellent | Moderate           | Low /<br>Moderate | Susceptible            | Highly<br>susceptible  | Susceptible               | Susceptible                     | Tolerant <sup>3</sup>                  | Moderately<br>Resistant | Susceptible            | Resistant              | Susceptible           | Susceptible           | Susceptible                   | Susceptible | Susceptible           | Susceptible              |  |
|  | Marianna 40®<br>(plum × plum)                        | P. cerasifera × P. munsoniana                           | Better vigor and anchorage and less suckering than Marianna 2624. Assumed resistance to oak root fungus and <i>Phytophthora</i> but experience is limited.   | Assumed similar to M 2624   | Very good | Moderate           | Low               | Unknown                | Unknown                | Unknown                   | Assumed susceptible             | Tolerant <sup>3</sup>                  | Resistant               | Unknown                | Assumed resistant      | Unknown               | Unknown               | Assumed<br>susceptible        | Resistant   | Susceptible           | Susceptible              |  |
|  | Marianna 2624®<br>(plum × plum)                      | P. munsoniana × P. cerasifera                           | Standard in soils infested with oak root fungus and <i>Phytophthora</i> . Incompatible with Nonpareil and Independence. Root suckering and low vigor are common.   | Incompatible with Nonpareil and<br>Independence. Marginal with Monterey                             | Good      | Moderately low     | High (variable)   | Tolerant               | Tolerant               | Susceptible               | Susceptible                     | Tolerant <sup>3</sup>                  | Resistant               | Moderately tolerant    | Resistant              | Unknown               | Highly<br>susceptible | Highly<br>susceptible         | Resistant   | Susceptible           | Susceptible              |  |
|  | Rootpac 20 <sup>®</sup><br>(plum × sand cherry)      | P. besseyi × P. cerasifera                              | Dwarfing rootstock (about 65% of Nemaguard) used in Super High-Density plantings in Spain.<br>Limited experience in California.  | Variable (limited experience)   | Unknown   | Very low           | High              | Unknown                | Unknown                | Unknown                   | Assumed susceptible             | Unknown                                | Unknown                 | Susceptible            | Resistant              | Unknown               | Unknown               | Assumed<br>susceptible        | Unknown     | Unknown               | Unknown                  |  |
|  | Rootpac R <sup>®</sup><br>(plum × almond)            | P. cerasifera × P. dulcis                               | Best suited for alkaline, heavy soils high in chloride. Not well suited for sandy soils (low vigor) or where excess sodium and boron are a problem. Performance has been variable in UC trials.                    | Good with Nonpareil (limited experience)  | Good      | Moderate to low    | Moderate          | Susceptible            | Tolerant               | Tolerant                  | Susceptible                     | Tolerant <sup>3</sup>                  | Unknown                 | Unknown                | Resistant              | Susceptible           | Highly<br>susceptible | Assumed<br>susceptible        | Resistant   | Highly<br>susceptible | Susceptible              |  |
| Complex Hybrids<br>(peach, almond,<br>plum, apricot) | Atlas®   | P. persica × (P. dulcis ×<br>(P. cerasifera × P. mume)) | Similar to Nemaguard but may have higher yield efficiency. Intolerant to cold storage or dehydration when planted bare root.   | Good  | Fair      | Moderately high    | Low               | Susceptible            | Susceptible            | Moderately tolerant       | Highly<br>susceptible           | Sensitive                              | Susceptible             | Moderately tolerant    | Highly<br>susceptible  | Tolerant              | Unknown               | Susceptible                   | Resistant   | Susceptible           | Highly<br>susceptible    |  |
|  | Viking®  | P. persica × (P. dulcis ×<br>(P. cerasifera × P. mume)) | Slightly more vigorous than Nemaguard but good tolerance to ring nematode, bacterial canker, salt, and alkaline conditions. Excellent anchorage.   | Good  | Excellent | Moderately high    | Low               | Moderately<br>tolerant | Moderately tolerant    | Moderately tolerant       | Moderately tolerant             | Sensitive                              | Susceptible             | Moderately<br>tolerant | Highly<br>susceptible  | Susceptible           | Unknown               | Tolerant                      | Resistant   | Tolerant              | Susceptible              |  |





<sup>1</sup> As per Rubio-Cabetas, et al., 2017.

- <sup>2</sup> Vigor of rootstocks with plum parentage is often significantly lower in sandy soil.
- <sup>3</sup> Wet soil in-season can worsen incompatibility symptoms.
- <sup>4</sup> Rootknot nematode resistance infers *Meloidogyne incognita*, *M. arenaria*, and *M. javanica*, not the peach rootknot nematode *M. floridensis*.
- <sup>5</sup> Ring = (Mesocriconema (=Criconemella) xenoplax).
- <sup>6</sup> Root lesion = *Pratylenchus vulnus*.
- <sup>7</sup> Assumed susceptibility or resistance is based on other rootstocks with similar parentage, but insufficient data exists for confirmation.
- <sup>8</sup> Sporadic incompatibility symptoms have been observed with Independence on Krymsk 86, while some orchards have performed acceptably.