# A Greater Number of Rootstock Choices Can Provide a Partial Alternative to Methyl Bromide Fumigation

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**OVERVIEW**

From 2004 to 2007 we developed a nematode rootstock profile for roughly forty different *Prunus* rootstocks having the potential of becoming an alternative to Nemaguard rootstock. In conducting these studies we became aware that there may be as many as 80 *Prunus* rootstocks available across the globe. Some of these are not very different from those in our studies while others may be ones we have already screened but under a different name. In general we believe we have developed the nematode host status for the bulk of *Prunus* rootstocks currently available. Our studies received funding from CTFA and California Almond Board; the latter group being more interested in stocks imparting vigor greater than that of Nemaguard. An important bias in our study was to make sure we also searched among rootstocks having parentage quite different from that of Nemaguard. Although some of these studies were originally planned to be 6-month studies we quickly learned that our best answers were coming from studies that lasted two years as populations we thought were not resistant actually finally showed their resistance and vice versa. For ring nematode we planned on a 2-year study but we are now aware of a short-coming when evaluating Viking, Atlas and Hansen 536 rootstocks so half of the ring nematode tests will be continued into a third-year.

Three fourths of the rootstocks were resistant to root-knot nematode, an aggressive population of *Meloidogyne incognita*. There are other species and races of root-knot nematode but the population we chose did exhibit abundant virulence as it enabled the separation of Guardian from Nemaguard as well as a few other surprises. The thirty-one rootstocks with resistance to root-knot oftentimes had Nemaguard within their parentage but, not always. Other sources of resistance included Okinawa parentage and in one case the parentage also included Harrow Blood (HBOK). Hiawatha is also known for its root- knot resistance.

Only a single grouping of rootstocks provided resistance to *Pratylenchus vulnus*, root-lesion nematode. These stocks are named Krymsk 1 and Krymsk 2 and originate from the Black Sea area of the Ukraine. These two stocks contain *Prunus tomentosa* as one of the parents and this source we reported many years ago to possess resistance to this nematode. During these studies

we learned that this cross of *P. tomentosa and P. cerasiferae* also provides tolerance to feeding by root-lesion and root-knot nematodes.
We can also report there is moderate tolerance to root-lesion within Garnem rootstock however this rootstock is highly susceptible to ring nematode and therefore Bacterial Canker Complex. All the other rootstocks were susceptible to *P. vulnus* but several of the stocks were significantly more susceptible than Nemaguard so there are some rootstocks that should be avoided.

We did not find a single rootstock that could be referred to as resistant to ring nematode, *Criconemoides xenoplax*. Viking and Atlas came the closest to being called resistant but only when they had been in a commercial setting for at least three years. Lovell supports approximately 40% of the ring nematode population of Nemaguard, and Guardian approximately 60% of that of Nemaguard. In three replicated field tests monitored at 3 to 7 years after planting the ring nematode populations on Viking did not exceed 15% of that found on Nemaguard. As previously experienced with grape rootstocks, there must be fewer than 5% of the own-rooted population level for us to refer to a rootstock as resistant to ring nematode.

The *Prunus*/nematode profiles that we have developed from these studies have major value as an indicator of which rootstocks not to choose when searching for an alternative to Nemaguard. In the results section we indicate a short list of rootstocks having value as long as their limitations are also taken into account.

## OBJECTIVES

1) In greenhouse or small plot settings determine first year growth rate of Nemaguard compared to eight alternative rootstocks in the presence of replant soil with or without nematodes compared to fumigated soil.
2) Determine first and second year growth rate of eight alternative rootstocks in various field settings previously planted to Nemaguard or Marianna Plum.
3) Interact with farm advisors, extension specialists, or the Protected Harvest group to insert field diagnosis, use of new rootstocks, Roundup treatments, and other strategies into the overall replanting process where MB and Telone II will not be used.

## PROCEDURES

*Obj. 1*. In 2005 we installed in randomized complete blocks six replicates of six rootstocks, irrigated by drip for one full season. This was a small plot study. The rootstocks included Marianna 2624, Nemaguard, Viking, two sets of Torinel, Empyrean 2, and Atlas. We then harvested entire trees and their roots to determine tree biomass and nematode development.

*Obj. 2*. Trees to be planted include some that are ½ or ¼ Nemaguard parentage and a few with no Nemaguard parentage (Krymsk 1 and Flordaguard). They will be planted into a field with *P. vulnus* nematode and *M. incognita* nematode present. Trees will be planted on 8-foot spacings down the row with 15 feet between rows. In spring 2006 trees will be budded to a common plum or peach scion. The planting site consists of one row treated with Telone II adjacent to an untreated row with eight reps of each. Tree growth will be monitored along with nematode development. Selections include: Nemaguard, Empyrean 2, Monegro, Torinel, Viking,

Krymsk 1, open space, Marianna 2624, Krymsk 8, Flordaguard, Garnem, and Cadaman. One of our goals is to eventually monitor yield and fruit size from these trees.

*Obj. 3.* Interactions with personnel from the Protected Harvest group have been meager. This PI is submitting for a large grant to study the entire process of replanting without methyl bromide or Telone. If that grant is funded the work will be in grower settings and with the assistance of interested farm advisors.

## RESULTS AND DISCUSSION

Our nematode/Prunus rootstock profiles can be summarized into three charts where host status of the various rootstocks is compared to that of Nemaguard. The affinity of root-knot nematode, *Meloidogyne incognita*, for the various rootstocks is listed in Chart 1. Notice the lengthy list of rootstocks available for root-knot nematode resistance.

The affinity of root-lesion nematode, *Pratylenchus vulnus*, for the various rootstocks is listed in Chart 2. Notice the only source of resistance is Krymsk 1 and its parentage is *Prunus tomentosa*. Garnem, Bright's Hybrid and Hansen 536 exhibit moderate resistance. The remaining rootstocks are all susceptible to root-lesion nematode but there are some that are likely poorer hosts than others with Nemaguard approximately in the middle of the list.

The affinity of ring nematode, *Criconemoides xenoplax*, for the various rootstocks is listed in Chart 3. It was the development of this latter chart where we encountered greatest difficulties when comparing our two-year data sets with data that came from farm advisor trials in commercial field settings. Notice that we conducted tests on Viking in 04-05 and then repeated them in 06-07 only to find the same result but both these results are different from 3-year field tests. We will continue this trial for one more year before we publish any of our rootstock profiles. It appears that 2 years of evaluation against ring nematode is not as accurate as 3-year evaluations. Field evaluations indicate our data for Atlas, Viking and Hansen 536 are inaccurate and we do not currently have an explanation for this discrepancy.

In spring 2007 John Slaughter of Burchell Nursery assisted us with grafting of various scions onto various rootstocks. Our particular interest was scion compatibilities of Krymsk 1 and Flordaguard but he also grafted eight other rootstocks in which we still have interest. In Table 4 we have indicated the compatibility of Krymsk 1 for a dozen scions. It appears that these 12 scions have affinity for Krymsk 1 in the first year but with all the suckering we are seeing we anticipate perhaps some problems ahead. Meanwhile, we do have four-year old Krymsk 1 with nonpareil almond as a scion and it has never suckered. Perhaps Krymsk 1 needs to be disbudded at grafting time.

Roger Duncan, the farm advisor in Stanislaus Co, is conducting a field trial with a number of rootstocks that were not available when we first began this four-year study.
We sampled that site in 2005 and will do so again in 2007-08, see Table 5. We believe data from his research site are providing useful answers about ring nematode but also he has one HBOK rootstock under evaluation that is performing as well as Viking. Viking always starts out better in fumigated soil but Okinawa parentage may provide tolerance to the rejection component of the

replant problem. It does in Hansen 536. Apparently HBOK-1 is also slightly reduced in vigor when compared to Nemaguard.

## ROOTSTOCKS OF FURTHER INTEREST TO STONE FRUIT GROWERS

**Viking Rootstock**
Bare root trees of Viking rootstock [(plum x almond) X Nemaguard] have always grown best for us when planted to fumigated soil compared to non-fumigated. This has occurred whether they were planted to soil with nematodes but no replant problem; or when planted to the replant problem alone. The nursery has long indicated that roots of Viking should not be allowed to dry out just prior to planting but from our studies young roots of Viking are susceptible to many types of root feeding or obvious damage that might occur in their first leaf or just prior to planting. Strip fumigation will benefit the first-year growth of these trees and in the second year any poor growth can usually be overcome. This rootstock needs to be on the top of the rootstock list for any stone fruit replanting that occurs in sandy or loamy sand soils where ring nematode is known to occur. In many of these sandy soils there is also present the root-lesion nematode. Viking is a slightly better host for root-lesion than Nemaguard. It appears to be equal to Nemaguard in its resistance to root-knot nematodes. Viking exhibits affinity to all the same scions as Nemaguard.

**Hansen 536 Rootstock**
This hybrid of Titan almond x Okinawa peach can impart 20% more vigor than Nemaguard. Those growers not wishing to fumigate can achieve excellent first-year stands by treating the previous Nemaguard orchard with Roundup and waiting a full year.
Hansen 536 is of parentage that provides tolerance to the rejection component of the replant problem. It displays adequate resistance to root knot nematode when following Nemaguard. It displays resistance to root-lesion nematode that is somewhat better than that of Nemaguard. However, its downfall is that it is a superior host of ring nematode so it should not be planted into soils having high water infiltration capability, primarily sands or well structured clay loam soils. This is a rootstock suited to fine sandy loam or silty textured soils where plenty of vigor is not a problem.

**HBOK rootstocks**
We have not evaluated this grouping of stocks as thoroughly as others discussed here. One selection, HBOK-10, was as resistant to root-knot as Nemaguard but supported half the number of root-lesion as Nemaguard. Another selection HBOK-50 supported five-fold the population of root-lesion that Nemaguard supported while providing root-knot nematode resistance. Then, in a 3-year-old field trial of Roger Duncan it was apparent HBOK-1 showed ring nematode protection greater than that of Lovell and similar to that of Viking among the replicated rootstocks. This grouping of selections needs greater investigation because Okinawa parentage could likely provide greater tolerance to the rejection component of the replant problem.

**Krymsk 1**
This is the only rootstock we have identified to provide resistance to root-lesion nematode. It is dwarfing by as much as 50% of that of Nemaguard. It hosts ring nematode at about the same level as Nemaguard so avoidance of sandy soils would be important. It has a resistance

mechanism to root-knot nematodes within root tissues older than 60 days but at its root tips it is susceptible to root-knot. Lovell, for example, is root- knot susceptible even within tissues that are five years old. Krymsk 1 rootstock has peculiar grafting affinities and the scions may not fully express incompatibility in their first year. It also suckers, thus there is need to obtain nursery stock that has been disbudded below the graft union.

**Guardian**

This rootstock is an offspring of the 1937 Stribling 37 rootstock. It does support some populations of root-knot nematode, *M. incognita*, but like Krymsk 1 can limit nematode infection to its youngest roots. It is preferred for the protection it offers against ring nematode but our evaluations indicate that protection is not quite as good as that offered by Lovell. Against the root-lesion nematode it has performed similar to Nemaguard.

This rootstock offers vigor similar to Nemaguard and will be useful in Bacterial Canker sites that have received a good pre-plant fumigation.

## FUTURE EXPIREMINATION

Based on the above rootstock information we now have at least two rootstocks worthy of field evaluation in settings where pre-plant fumigation is not planned. These include Krymsk 1, particularly in sites where root-lesion nematode is prevalent and HBOK, particularly HBOK-1 in sites where ring nematode is prevalent. In ring nematode sites where strip fumigation is permissible it is Viking and Guardian rootstocks that should be considered. Wherever there is an 8 to 10 foot wide strip application the rejection component is adequately controlled but nematodes are missed beyond that zone. Where trees are to be replanted without fumigation we will be treating the previous Nemaguard trees with Roundup, waiting a full year and then replanting on one of these two rootstocks that looks promising.

**Table 1. Ranking of *Prunus* rootstocks against *M. incognita***

| | A 2-year study nematodes/gr root |
|---|---|
| *Pistacia atlantica* | 0 |
| **Nemaguard** | **0** |
| Garnem | 0 |
| Bright's Hybrid-4 | 0 |
| Julior | 0 |
| Bright's Hybrid-1 | 0 |
| Hansen 536 | 0 |
| Flordaguard | 0 |
| Torinel | 0 |
| Empyrean 2 | 0 |
| Hiawatha | 0 |
| Cornerstone | 0 |
| Viking | 0 |
| Empyrean 1 | 0 |
| Okinawa | 0 |
| Cadaman | 0 |
| Pumiselect | 0 |
| Ishtara | 0 |
| Monegro | 0 |
| Atlas | 0 |
| Nickels | 0 |
| Flor x Alnem | 0 |
| Krymsk 8 | 0 |
| RedGlow | 0 |
| Citation | 0 |
| MRS 2-8 | 0 |
| HBOK 50 | 0 |
| Flor x weep peach | 0 |
| Bright's Hybrid-5 | 0 |
| HBOK-10 | 0.08 |
| Empyrean 101 | 0.29 |
| Empyrean 3 | 0.91 |
| Controller 9 | 11.6 |
| Guardian | 12.1 |
| Krymsk 1 | 15.9 |
| Paramount | 17 |
| **Lovell** | **31** |
| Krymsk 2 | 31.4 |
| Controller 5 | 42.9 |
| Krymsk 86 | 51.6 |
| | P=0.05 |

**Table 2. Ranking of *Prunus* rootstocks against *P. vulnus***

| | A 2-year study | as % of | Soil counts reported as a % of those on Nemaguard | | | |
|---|---|---|---|---|---|---|
| | nematodes/gr root | Nemaguard 2-year trial | 3-year field trial | | 7-year field trial | |
| Krymsk 2 | 0.03 | 0.40% | | | | |
| Krymsk 1 | 0.17 | 2.4 | | | | |
| *Pistacia atlantica* | 0.2 | 2.8 | | | | |
| Garnem | 0.3 | 4.2 | | | | |
| Bright's Hybrid -4 | 0.5 | 7 | | | | |
| Bright's Hybrid -5 | 0.6 | 8.4 | | | | |
| Hansen 536 | 0.61 | 8.6 | | 22 | | 187 |
| Bright's Hybrid-1 | 0.63 | 8.9 | | | | 189 |
| Paramount | 1.2 | 16.9 | | | | |
| Controller 9 | 1.6 | 22.5 | | | | |
| Flordaguard | 1.6 | 22.5 | | | | |
| HBOK-10 | 3.3 | 46 | | | | |
| Empyrean 2 | 5 | 70.4 | | 294 | | |
| Torinel | 5.3 | 75 | | | | |
| Guardian | 6.2 | 87.3 | | 111 | | 138 |
| Hiawatha | 6.8 | 96 | | | | |
| **Nemaguard** | **7.1** | **100** | (actual # 1.8) | **100** | (actual # 305) | **100** |
| **Lovell** | **7.4** | **104** | | **411** | | **247** |
| Cornerstone | 8.5 | | | | | |
| Viking | 8.9 | | | 211 | | 100 |
| Empyrean 1 | 9 | | | 1133 | | |
| Okinawa | 9.7 | | | | | |
| Cadaman | 10.8 | | | 1344 | | |
| Krymsk 86 | 11 | | | | | |
| Pumiselect | 11.7 | | | | | |
| Ishtara | 13.7 | | | | | |
| Citation | 17.4 | | | | | |
| Monegro | 17.7 | | | | | |
| Atlas | 23.9 | | | 1177 | | 204 |
| Nickels | 26.3 | | | 22 | | 183 |
| Flor x Alnem | 27.2 | | | | | |
| Krymsk 8 | 28.9 | | | | | |
| Redglow | 32.3 | | | | | |
| MRS 2-8 | 37.7 | | | | | |
| HBOK-50 | 39 | | | | | |
| Flor x Weep peach | 40 | | | | | |
| Controller 5 | 51.6 | | | | | |
| Empyrean 101 | 57.6 | | | | | |
| Julior | 71.4 | | | 38,611 | | |
| Empyrean 3 | 72.8 | | | | | |
| | | | P=0.05 | | | |

**Table 3. Ranking of *Prunus* rootstocks against *Criconemoides xenoplax***

| | 2-yr soil counts expressed as a % of Nemaguard | Values reported as a % of that on Nemaguard | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3-yr field trial | | 7-yr field trial | | 7-yr field trial | |
| **Lovell** 04-05 | **48** | | 1 | | 26 | | |
| **Lovell** 06-07 | **34** | | | | | | |
| Flordaguard | 40 | | | | | | |
| Hiawatha | 56 | | | | | | |
| UCB1 Pistachio | 58 | | | | | | |
| Guardian | 61 | | 111 | | 44 | | |
| Pumiselect | 63 | | | | | | |
| Bright's Hybrid -1 | 67 | | | | 153 | | 147 |
| Bright's Hybrid-5 | 68 | | | | | | |
| Torinel | 71 | | | | | | |
| Hansen 536 | 73 | | 7300 | | 119 | | 430 |
| E54-043 | 75 | | | | | | |
| Viking 06-07 | 78 | | | | | | |
| Krymsk 1 | 94 | | | | | | |
| Viking 04-05 | 95 | | 0 | | 13 | | 0 |
| Cadaman | 96 | | 94 | | | | |
| **Nemaguard 04-07** | **100** | (38.1) | **100** | (423) | **100** | (375) | **100** |
| Del Rey Plum | 108 | | | | | | |
| MRS 2-8 | 109 | | | | | | |
| Marianna 2624 | 113 | | | | | | |
| Empyrean 1 | 117 | | 13 | | | | |
| Cornerstone | 117 | | 6200 | | | | |
| D63-182 | 118 | | | | | | |
| Nickels | 119 | | 578 | | 104 | | 159 |
| Krymsk 86 | 121 | | | | | | |
| E54-043 | 130 | | | | | | |
| Monegro | 140 | | | | | | |
| Ishtara | 148 | | | | | | |
| Garnem | 193 | | | | | | |
| Atlas | 234 | | 0 | | 95 | | 9 |
| Empyrean 2 | 323 | | 92 | | | | |
| Julior | 406 | | 4870 | | | | |

**Table 4. First-year grafting affinity of Krymsk 1 rootstock for various scions**

| | % take | % trees w/ sprouts |
|---|---|---|
| Spring Flare Nectarine | 100 | 100 |
| Spring Flame Peach | 100 | 100 |
| J40.111 Peach | 66 | 100 |
| July Flame Peach | 100 | 100 |
| Glacier White Peach | 100 | 100 |
| | | |
| Black Splendor Plum | 83 | 100 |
| Owen T Plum | 100 | 60 |
| Tulare Giant Prune | 100 | 100 |
| French Prune | 100 | 80 |
| Castlebrite Apricot | 100 | 80 |
| | | |
| Padre Almond | 100 | 83 |
| Nonpareil Almond | 100 | 80 |

**Table 5. Field trial data from Roger Duncan field trial, Stanislaus Co.**

| | ring nema | root lesion | root knot |
|---|---|---|---|
| Rootstock | | | |
| Nickles | 1705 | 24 | 11 |
| K119-50 | 1348 | 5.8 | 165 |
| Hansen 536 | 1239 | 148 | 0.2 |
| Hiawatha | 937 | 35 | 4.4 |
| *Prunus subhirtella* | 895 | 11 | 426 |
| Controller 9 | 860 | 38 | 125 |
| **Nemaguard** | **676** | **218** | **1** |
| Controller 5 | 656 | 82 | 161 |
| Flordaguard | 587 | 107 | 0.2 |
| Cadaman | 521 | 3.7 | 0 |
| St Anthony | 463 | 27 | 50 |
| HBOK-32 | 413 | 108 | 5.3 |
| Atlas | 281 | 106 | 18 |
| Guardian | 275 | 2.8 | 66 |
| *Prunus mira* | 273 | 5 | 0 |
| Compass | 249 | 172 | 4.5 |
| **Lovell** | **215** | **101** | **12.4** |
| HBOK-15 | 171 | 434 | 0 |
| Viking | 163 | 14 | 1 |
| HBOK-1 | 163 | 61 | 0 |
| *Prunus ferganensis* | 66 | 3.8 | 153 |
| HBOK-17(1 rep only) | 6 | 0 | 56 |