November 2022

ALMOND BOARD OF AUSTRALIA

ALMOND ROOTSTOCKS

AL16006 - Evaluation of Prunus rootstocks for Australian almond production - stage 2

This technical document presents the findings from the Evaluation of Prunus Rootstock project - AL16006 undertaken by the Almond Board of Australia (ABA). The aim of this trial was to evaluate the performance of prunus rootstocks under Australian growing environments. By improving our understanding of rootstock performance it will enable better decisions to be made about rootstock selection to suit growing conditions thereby improving profitability and sustainability. In 2021 76% (44,408 hectares) of Australian almond plantings were grafted to Nemaguard. While Nemaguard has several advantages, such as: nematode tolerance, easy propagation, relatively cheap, and moderately vigorous, it has some significant disadvantages such as: moderate vigour; moderate water and nutrient use efficiency; susceptibility to calcareous soils and lime induced chlorosis; susceptibility to root pathogenic disorders in a replant situation; and only moderate tolerance to salinity. Over the last decade there has been an increase in the availability of prunus rootstocks imported into Australia but there is limited information available on their performance in Australian soils and growing environments.

The rootstock evaluation trial site was established by the ABA at Lindsay Point, South Australia in 2013 (project AL11012) on a site previously planted to almonds that were approximately 40 years of age when removed. The trial was established on 3.74-hectares of typical Mallee soils with 30 to 60cm topsoil (loam-sand to sandy-clay-loam) overlying carbonate subsoils. Eleven rootstocks were chosen for their high or medium vigour for comparison against Nemaguard. Rootstocks were sourced through commercially licensed nurseries, grafted to Nonpareil (50%), Carmel (25%) and Peerless (25%), and planted in a randomised block design with four replicates to enable statistical analysis. A 'spare' Nemaguard treatment was included to complete the trial layout. Trees were planted at a density of approximately 342 trees per hectare (7.3m row x 4m tree spacings) and managed using standard commercial management practices for irrigation and fertilizer applications across all replications with additional foliar sprays and composted manure delved in. Performance measures were collected for the following traits: ease of propagation; flowering; production (seasonal and accumulated yield); vigour; tree habit; water stress; tree nutrition; fruit (crackout, size, weight); graft compatibility; suckering; iron chlorosis; nematode resistance; and fungal pathogen incidence.

This factsheet provides a summary of the observations from the rootstock evaluation trial and characteristics for each rootstock (Appendix 1) in comparison to Nemaguard. Results are specific to the soil characteristics and management practices applied at the trial site. For more information, please refer to the final report available for download from Hort Innovation website (link).

Presented in Figure 1 is the cumulative yield from 2016 to 2021. There were seven top performing rootstocks GF749, Monegro, Felinem, Garnem, Hansen 536, and Brights Hybrid producing similar cumulative yields that were not statistically different from each other. Of the top seven all but Brights Hybrid had significantly higher cumulative yields than Nemaguard. GF749 was significantly higher than both Nemaguard and spare Nemaguard. Nemaguard, Adafuel, Cornerstone (see note) and GF557 showed some differences between the high yielding seven but not for all rootstocks. All rootstocks produced yields significantly higher than Krymsk 86 for this site.

Hort Innovation Strategic levy investment | ALMOND FUND

This project has been funded by Hort Innovation using the almond research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Table 1 provides a summary of key measurements taken during the project listed in order of their cumulative yield as illustrated in Figure 1. Using trunk circumference (mm) as a measure of tree growth the production efficiency (kg/cm^2) was calculated by dividing the average annual yield with the tree trunk area (yield / growth). In 2017 Adafuel, Cornerstone and GF557 had significantly higher production efficiencies compared to Garnem, Brights Hybrid, Nemaguard, Hansen 536 and Krymsk 86 rootstocks. However, the significance of these differences was lost after 2017 meaning trees with larger trunks were no more, or less, productive than trees with smaller trunks after their 4th leaf.

By 2020, GF749 (4.98m) and Garnem (4.98m) had produced significantly taller trees than Nemaguard (4.65m), Cornerstone (4.78m) and Krymsk 86 (4.78m) but not significantly taller than other rootstocks.

Note: Cornerstone was planted one season later than other rootstocks in 2014 and as a result only reached 7th leaf maturity and yield compared to other rootstocks reaching 8th leaf maturity and yield. These results were further complicated in that while these trees were younger, they received the same fertilizer and irrigation amounts as the older trees enabling tree growth and yields for Cornerstone to catch up to that of other rootstocks. These factors made it difficult to directly compare Cornerstone performance against other rootstocks in this trial.

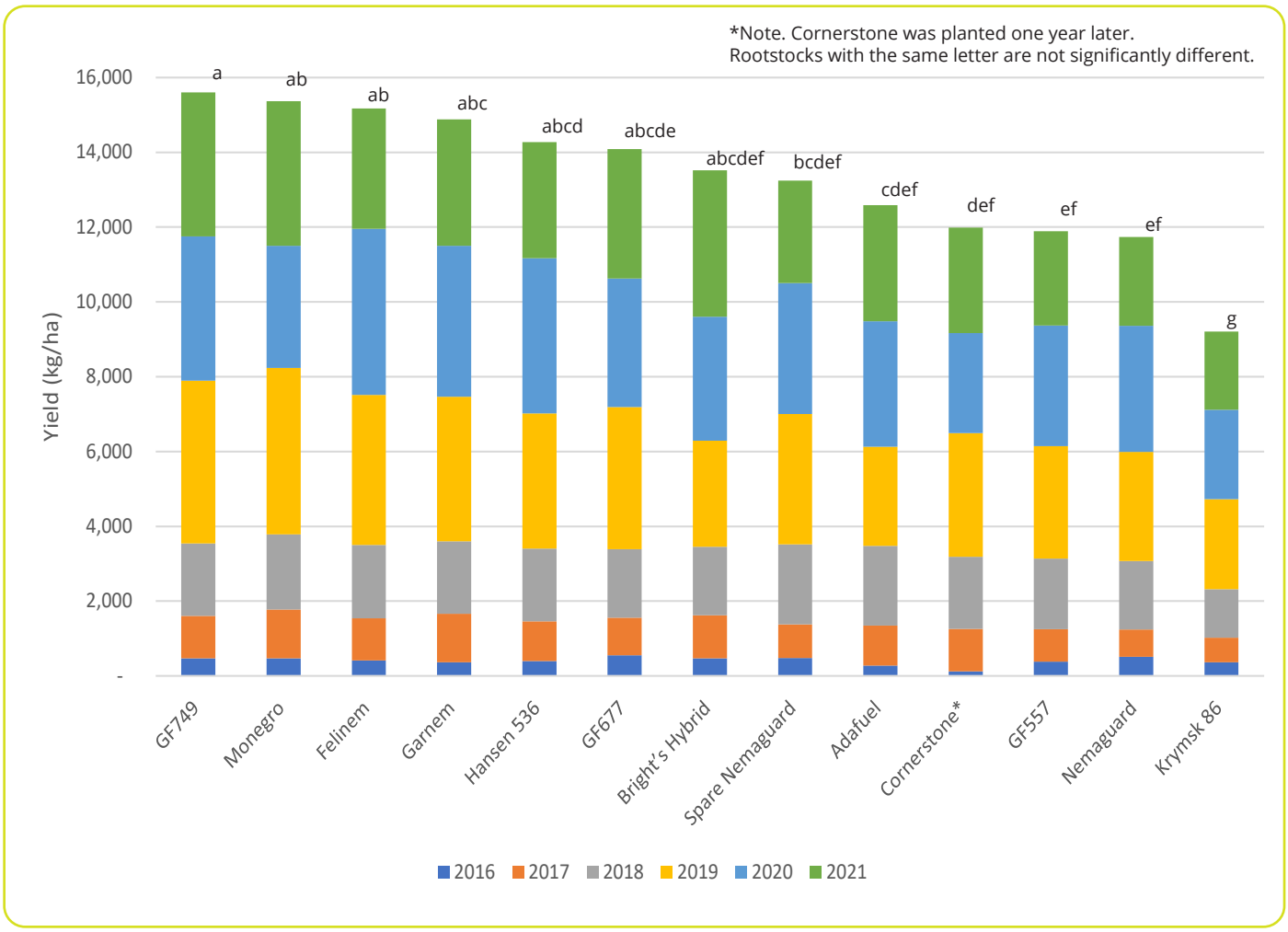


Figure 1. Cumulative yield (kg/ha). Note: Rootstocks that share the same letter do not differ at the 5% levels using Fishers protected Least Significant Difference (LSD).

Leaf analyses indicated a significant correlation between yield and leaf calcium (Ca) and magnesium (Mg) levels. Rootstock with the highest uptake of both Ca and Mg were observed for Hansen 536, Garnem and Monegro. These rootstocks were in the top six highest yielding (cumulative yield) rootstocks with GF749 having high Ca and mid-range Mg levels. The lowest levels of leaf Ca and Mg were observed for the two Nemaguard rootstocks and Krymsk 86.

In 2021, there was a significant correlation between yield and leaf sodium with high sodium levels correlating with low yields. The lowest levels of leaf sodium were observed for GF557, Monegro and GF749 and the highest levels were observed in Krymsk and Nemaguard. Both Krymsk and Nemaguard have been found to be poor excluders of sodium and chloride and may have contributed to low yield performance even when soil salinities were below the level of 1.5dS/m considered to affect yield.

Table 1. Summary observations

Rootstock	2020 Trunk circumference (mm)	Fishers LSD*	2021 average yield (unadjusted) (kg/cm^2)	Cumulative yield (kg/ha)	Fishers LSD*	2017 Production effciency (kg/cm^2)	Fishers LSD*	2020 average height (m)	Fishers LSD*
GF749	572.29	abc	3,846.56	15,597.21	a	0.077	ab	4.975	c
Monegro	608.75	cd	3,871.64	15,369.32	ab	0.084	ab	4.875	bc
Felinem	605.42	cd	3,211.19	15,168.62	ab	0.077	ab	4.925	bc
Garnem	572.10	abc	3,377.87	14,876.85	abc	0.061	bc	4.975	c
Hansen 536	619.58	d	3,103,80	14,276.15	abcd	0.040	c	4.900	bc
GF677	569.50	abc	3,464.41	14,088.51	abcde	0.080	ab	4.925	bc
Brights Hybrid	560.42	ab	3,914.46	13,519.39	abcdef	0.059	bc	4.925	bc
Spare Nemaguard	556.25	a	2,735.75	13,243.15	bcdef	0.070	ab	4.825	bc
Adafuel	600.21	bcd	3,106.40	12,587.77	cdef	0.095	a	4.925	bc
Cornerstone**	540.40	a	2,823.53	11,987.40	def	0.095	a	4.775	a
GF557	564.58	ab	2,520.11	11,885.96	ef	0.092	a	4.875	bc
Nemaguard	549.8	a	2,373	11,737.62	f	0.057	bc	4.650	a
Krymsk 86	568.8	abc	2,089	9,204	g	0.04	c	4.775	a
Standard Error		14	N/A		1,147		0.010		0.081
P value		<0.01	N/A				0.008		0.012
LSD		40.2	N/A		2,321		0.028		0.164

**Note: Rootstocks that share the same letter do not differ at the 5% levels using Fishers protected LSD.*

***Cornerstone was planted one year later than other rootstocks*

Flowering observations were recorded at each flowering stage including start, full bloom and end of flowering. The days of flowering are presented in Figure 2 compared to Nemaguard flowering dates showing the maximum and minimum number of days for each flowering stage. In general, some rootstocks appear to bring forward the start of flowering when compared with Nemaguard. For example, GF749 and Adafuel started flowering, on average, two days earlier, GF557 one day earlier, and Krymsk 86 half a day earlier. Conversely, flowering start times appeared delayed for Felinem by 1.5 days and Hansen 536 by 0.75 days. Flowering periods were shorter for Krymsk 86 (22.5 days), GF557 and Adafuel (24.75 days), and GF749 (25 days) and longer for Garnem (27 days) and Monegro (27.25 days) when compared with Nemaguard (26 days). End of flowering appeared to be more variable for all rootstocks compared to Nemaguard. These observations were only taken for replicate 1 and were therefore not statistically analysed.

A hull split assessment was done in 2021 recording the timing of hull split for each rootstock with the number of fruit reaching stage 3 presented in Figure 3 and the number of fruit reaching stage 6 presented Figure 4. Nuts on Krymsk 86 matured rapidly reaching 97% stage 3 hull split significantly earlier (18 January 2021) than GF749, Monegro and Brights Hybrid. All rootstocks had reached 100% stage 3 hull split by the 25 January except for Brights Hybrid which had only 53% of nuts reaching 100% stage 3 hull split on the same day.

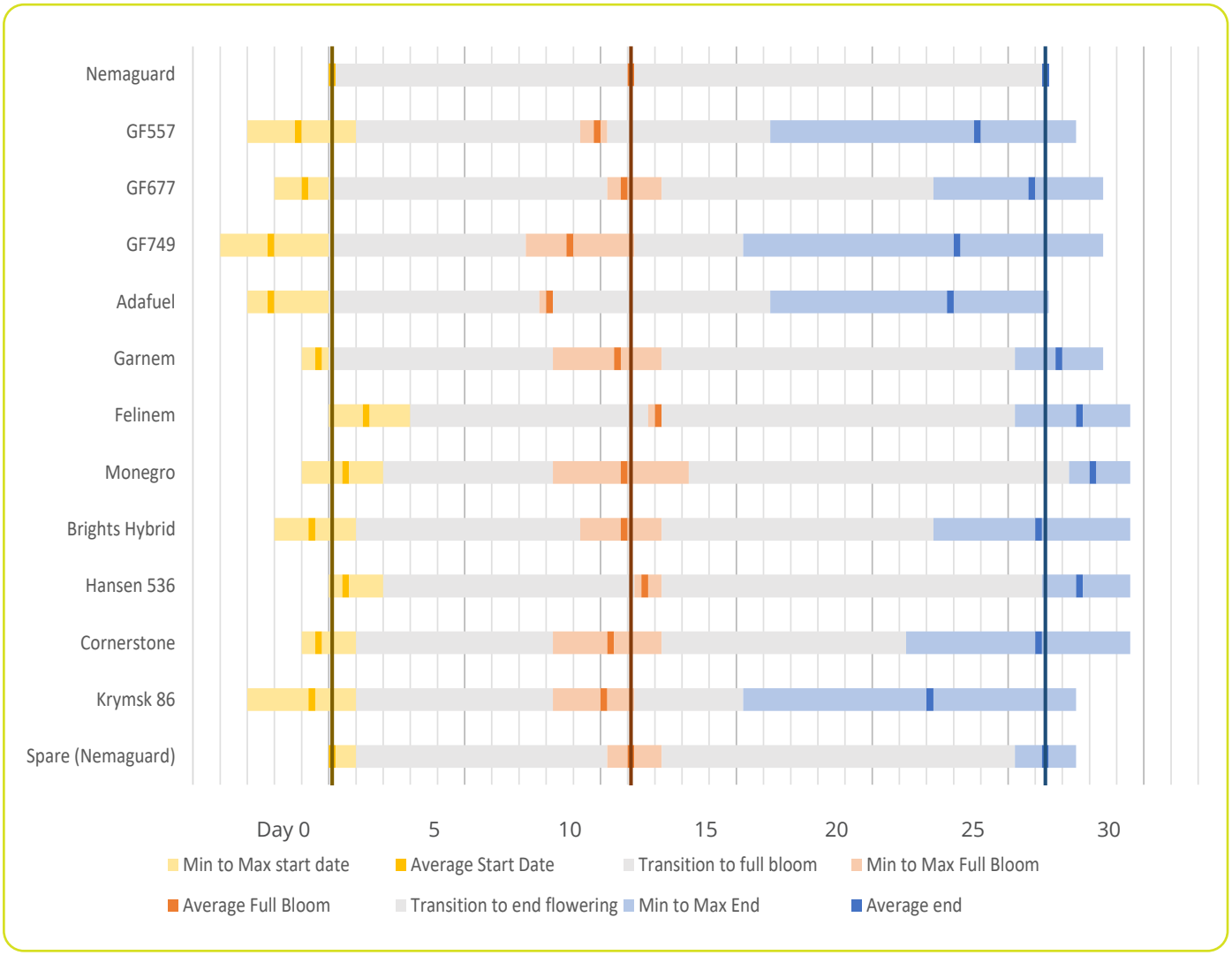
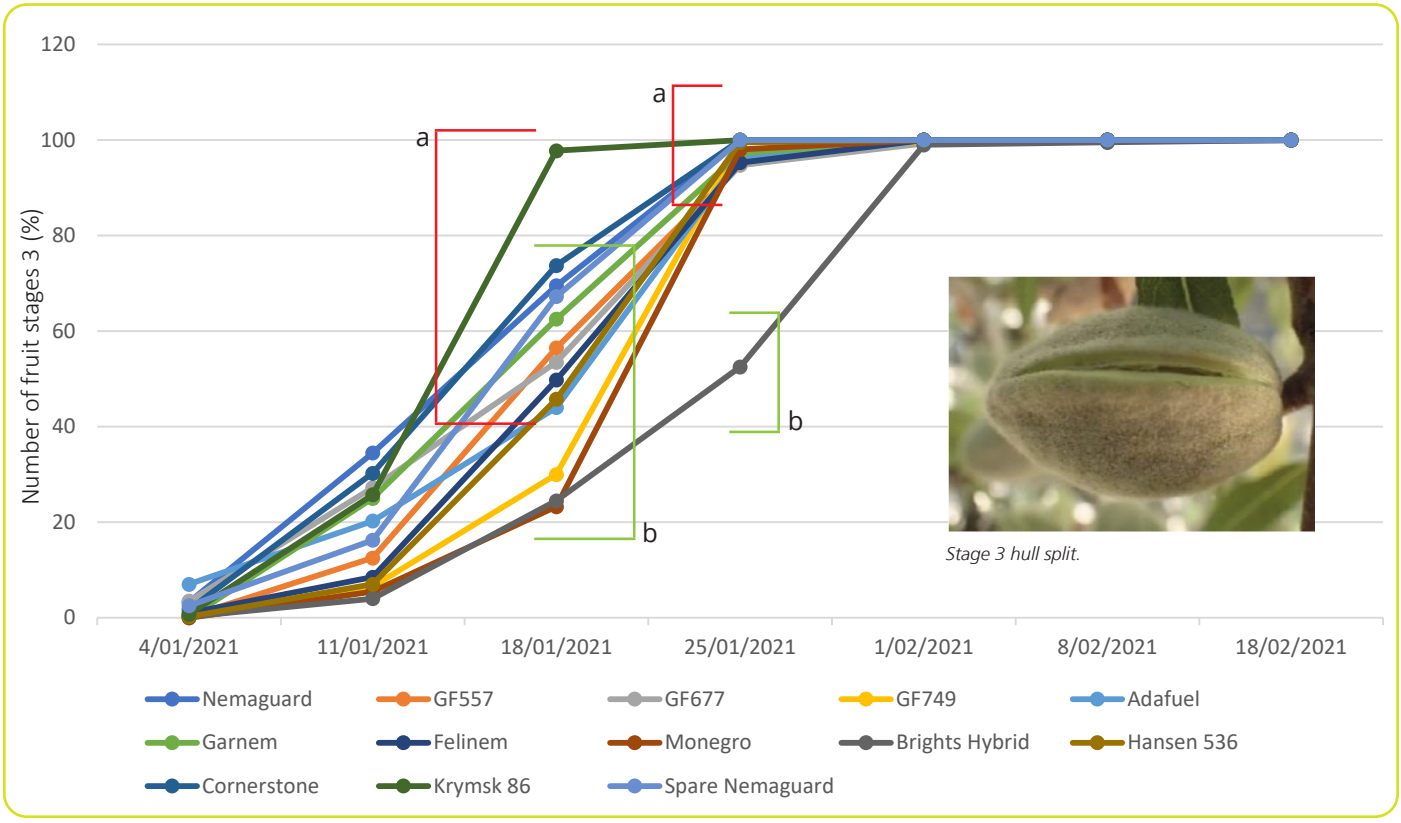
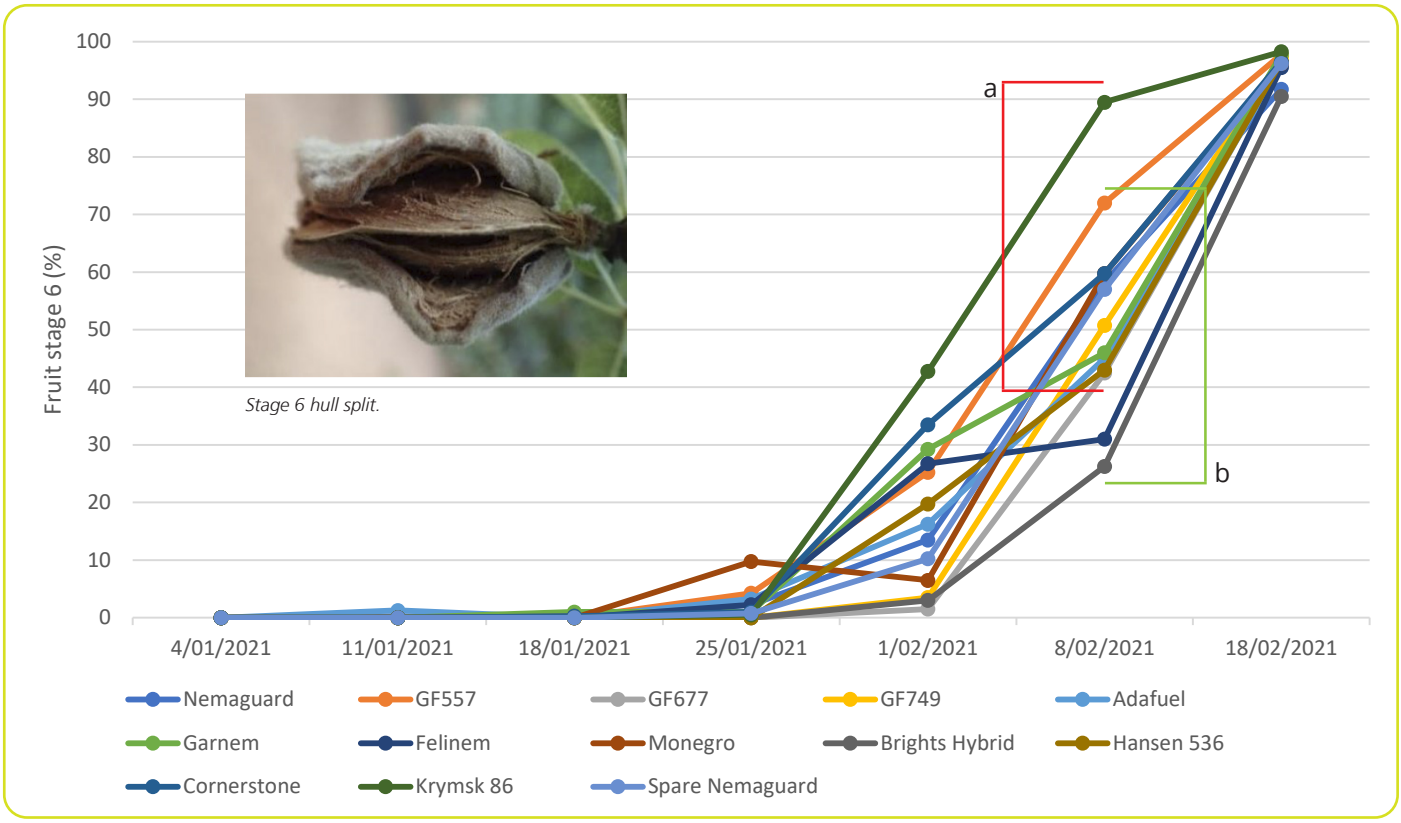


Figure 2. Flowering observations 2017 - 2020. Variation in flowering dates compared to Nemaguard.



Stage 3 hull split.

Figure 3. Percentage of hull spilt at stage 3 or beyond (2020-2021 only).



Stage 6 hull split.

Figure 4. Percentage of hull spilt at stage 6 or beyond (2020-21 only).

GF749
PEACH X ALMOND

PERFORMANCE SUMMARY

GF749 was among the top seven highest performing rootstocks in terms of cumulative yield. Results are specific to the soil characteristics and management practices applied to the trial site. GF749 was able to produce consistently high yields with a good balance between canopy growth and crop production. There was some variability between replicates and ongoing monitoring will be important to see if these trends continue. GF749 has medium to high susceptibility to one or more species of Root-knot nematodes and future monitoring will determine if increased nematode populations at this site will impact future yields.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on GF749 had similar average growth (572mm) compared with Nemaguard (547mm, Figure 5).

Trees grown on GF749 produced one of the taller canopies averaging a height of 4.98m, significantly higher than Nemaguard 4.65m but similar to spare Nemaguard 4.83m. Visual observations suggest that while the inner scaffold has pushed canopy growth the canopy remained open in its 8th leaf enabling good light interception (Figure 8).

PRODUCTION

GF749 produced consistently high yields each season for mature crops compared with Nemaguard (Table 2). Between 2019 and 2021 (6th to 8th leaf) there was only one outlying yield that was below 2,000kg/ha in 2020 for Replicate 3 (Figure 6).

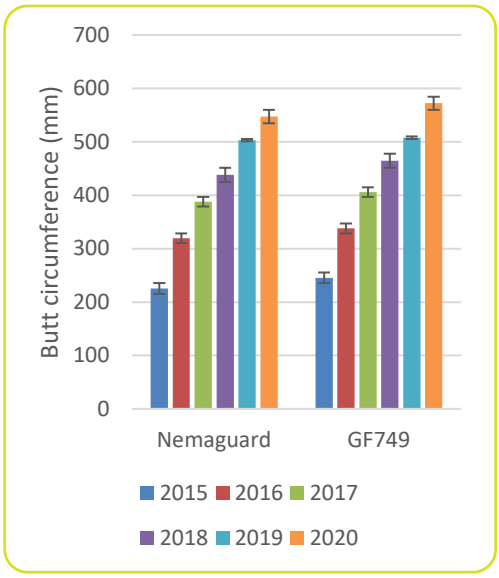


Figure 5. Average trunk circumference.

Table 2. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
GF749	469	1,133	1,939	4,355	3,855	3,847	15,597
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

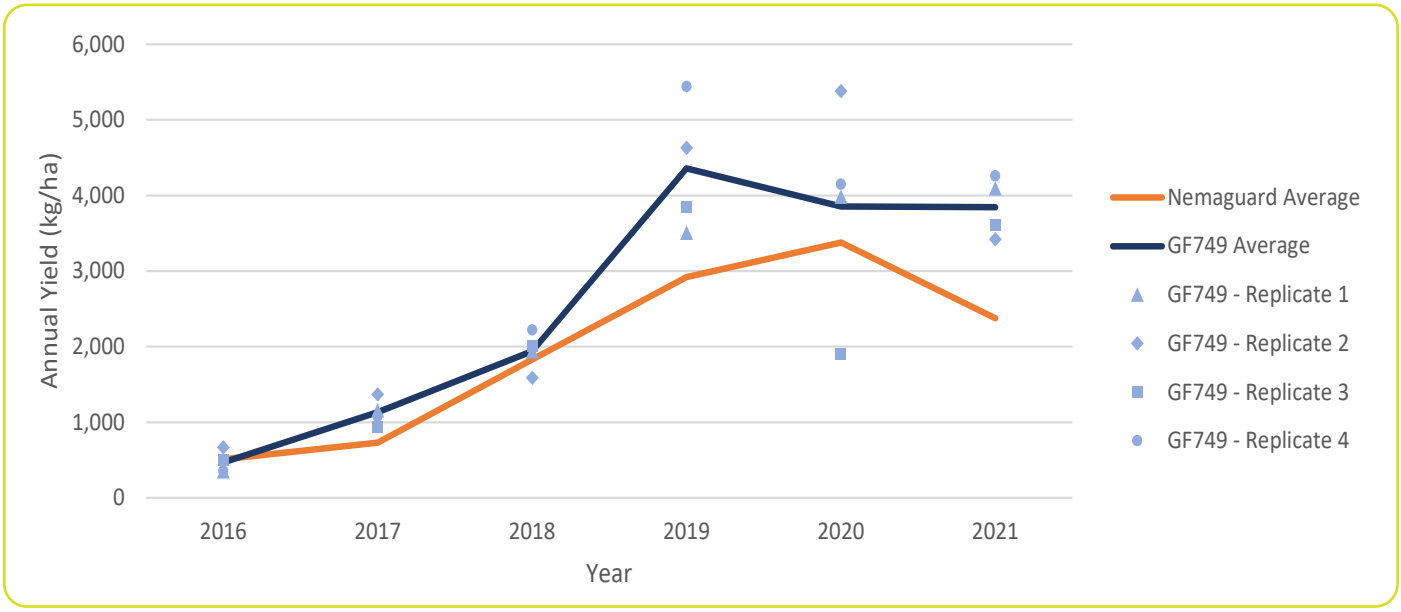


Figure 6. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Investigations into root-knot susceptibility for rootstocks in Australia indicate GF749 has medium to high susceptibility to Root-knot nematode and *M. javanica* and tolerance to *M. arenaria.* This rootstock should be avoided where high nematode pressures are expected. In 2021 (at 8th leaf) the rootstock evaluation trial plots indicated a moderate population of Root-knot nematode. Continued monitoring will help to determine any increase in nematode population and how this impacts yield.

GF749 brought forward the start of flowering by 2 days on average and reached full bloom earlier than Nemaguard.

GF749 had low levels of leaf sodium suggesting it has good salt tolerance excluding sodium and chloride from the soil.

Table 3. GF79 rootstock characteristics (Appendix 1).

Root-knot nematode	Lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Susceptible / Tolerant								High	Average

Figure 7. Juvenile tree - 2017.

Figure 8. Mature tree - 2021.

Figure 9. Graft union - 2021.

MONEGRO
PEACH X ALMOND

PERFORMANCE SUMMARY

Spanish bred Monegro (GN-9) was among the top seven highest performing rootstocks in terms of cumulative yield. Results are specific to the soil characteristics and management practices applied to this trial site. Monegro rootstock produced strong early growth with a higher canopy growing into the available space. Yields were higher than Nemaguard up to their 6th leaf. Some variability in seasonal yield was observed in their 7th leaf. Monegro is susceptible to Root-knot nematodes and should be avoided where high nematode populations are expected. Monegro had low levels of leaf sodium suggesting it has good salt tolerance.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Monegro had significantly higher average growth (608.75mm) compared with Nemaguard (550mm) in 2020 (Figure 10).

Monegro trees had strong early growth producing taller trees (4.54m) with the second widest canopy in 2017 (4.94m) and a slightly more spreading canopy. By 2021 the canopy filled the available space with tree height (4.88m) significantly higher than Nemaguard (4.65m) but similar to the spare Nemaguard height 4.83m (Figure 13).

PRODUCTION

Monegro produced consistently strong early yields (Table 4) across the four replicates with yields over 4 t/ha up to the 6th leaf in 2019 (Figure 11). In 2020 the average yield dropped due to lower yields in replicates 2 (2,423kg/ha) and 3 (1,897kg/ha).

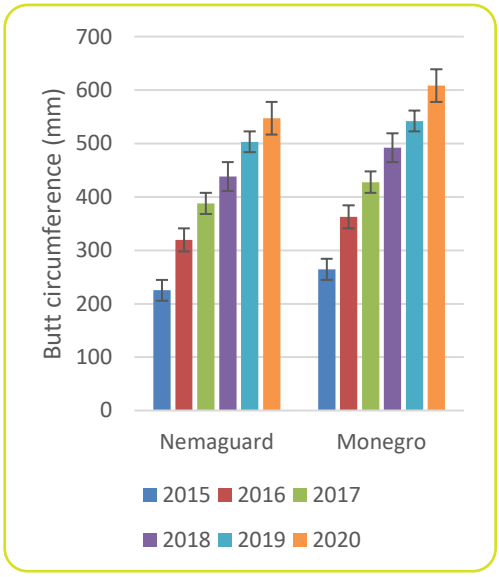


Figure 10. Average trunk circumference.

Table 4. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Monegro	468	1,308	2,010	4,446	3,265	3,872	15,369
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

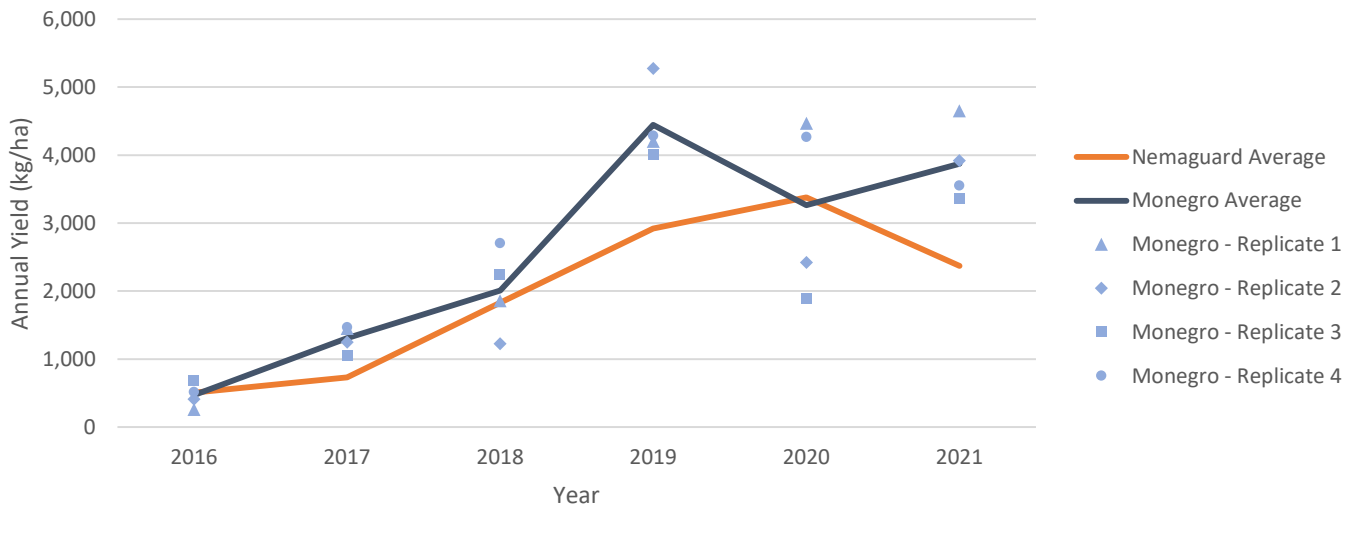


Figure 11. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Monegro has good vigour, ease of propagation and is well adapted to calcareous soils. Literature states that Monegro has strong drought tolerance mainly selected for non-irrigated conditions, which will be an important feature for industry to cope with predicted drier growing climates. Overseas literature states that Monegro has high resistance to Root-knot nematode. However, investigations into root-knot susceptibility for rootstocks in Australia showed Monegro had a medium to high susceptibility to Root-knot nematode *M. incognita*, *M. javanica* and Root-Root-lesion nematode *Pratylenchus vulnus* and should be avoided where high nematode pressures are expected. Monegro had low levels of leaf sodium suggesting it has good salt tolerance, able to exclude sodium and chloride from the soil.

Table 5. Monegro rootstock characteristics (Appendix 1).

Root-knot nematode	Lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Resistant/ Susceptible	Susceptible		Susceptible				Tolerant	High	Good

Figure 12. Juvenile tree - 2017.

Figure 13. Mature tree - 2021.

Figure 14. Graft union - 2021.

FELINEM
PEACH X ALMOND

PERFORMANCE SUMMARY

Spanish bred Felinem (GN-22) was among the top seven highest performing rootstocks in terms of cumulative yield. Results are specific to the soil characteristics and management practices applied to this trial site. Felinem produced a tree with higher growth characteristics including trunk circumference and canopy size than Nemguard. Further monitoring will be needed to determine the effect of canopy growth on light interception and tree yield. Felinem delayed all stages of flowering start, full bloom and end of flowering compared with Nemaguard.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Felinem had one of the larger trunk circumference (605mm) which was significantly higher than Nemaguard and spare Nemaguard (Figure 15).

In 2020 Nonpareil trees grown on Felinem were among the largest trees in the trial for width (6.42m) and height (4.93m) readily occupying the available growing space (Figure 18).

PRODUCTION

Some variability within replicates was observed for seasonal yields and some decline in yield noted in the 8th leaf. Ongoing monitoring of seasonal yields will help establish any tendency towards biennial bearing.

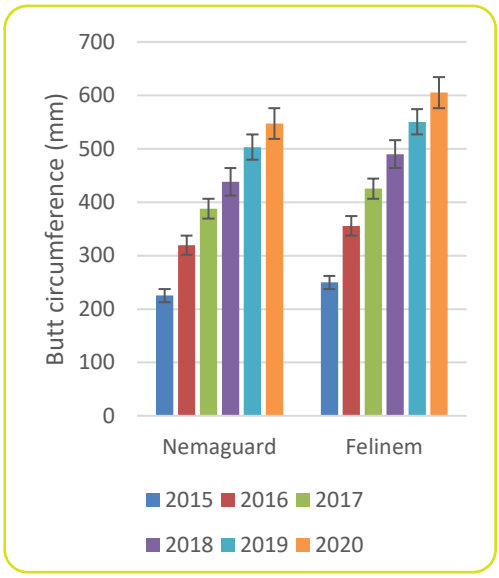


Figure 15. Average trunk circumference.

Table 6. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Felinem	415	1,127	1,962	4,009	4,445	3,211	15,169
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

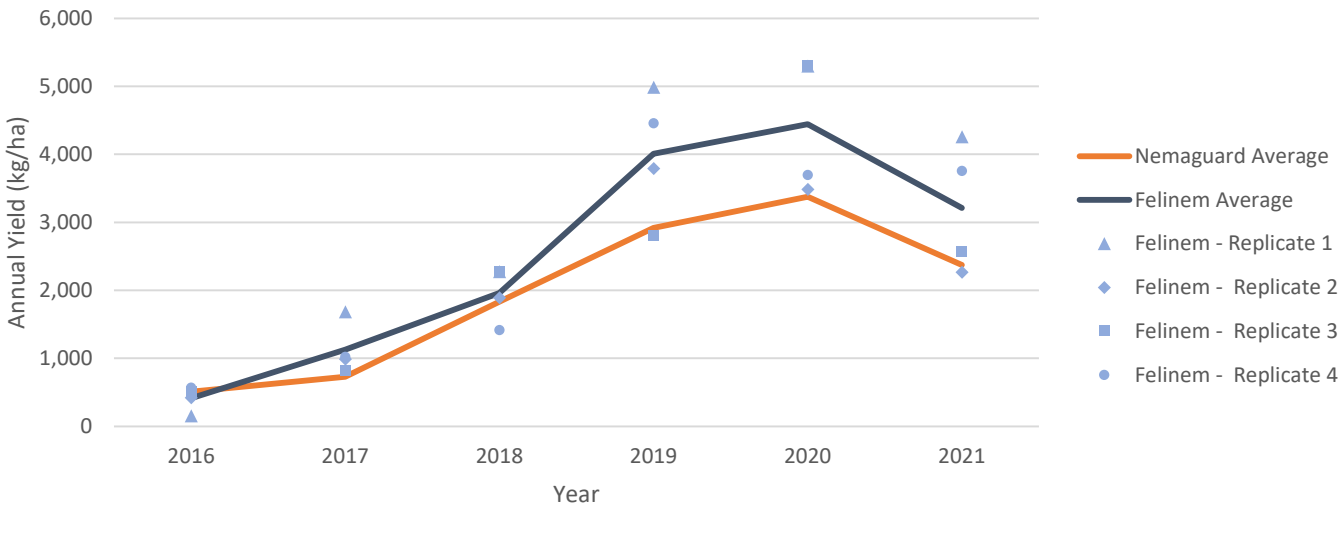


Figure 16. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Felinem has good vigour, ease of propagation, and is well adapted to water stress, calcareous and poorer soils if well drained. Felinem is resistant to Root-knot nematode *M.arenaria* and *M.incognita* and trials in Australia found it tolerant to *M.javanica* while overseas research found it resistant. It has moderate susceptibility to Root-Root-lesion nematode. On average Felinem delayed the start of flowering by 1.5 days. Full bloom and end of flowering were also later than Nemaguard (Figure 2).

Table 7. Felinem rootstock characteristics (Appendix 1).

Root-knot nematode	Lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Resistant	Moderate	Unknown	Susceptible			Unknown	Tolerant	High	Good

Figure 17. Juvenile tree - 2017.

Figure 18. Mature tree - 2021.

Figure 19. Graft union - 2021.

PERFORMANCE SUMMARY

Spanish bred Garnem (GN-15) was among the top seven highest performing rootstocks in terms of cumulative yield. Results are specific to the soil characteristics and management practices applied to this trial site. Garnem resulted in vigorous trees with a spreading habit that were significantly higher than Nemguard. Of the top seven rootstocks Garnem rootstock is commercially available as a grafted tree in Australia.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Garnem (572mm) were not significantly different from Nemaguard (550mm) or spare Nemaguard (556mm) (Figure 20). Statistical analysis undertaken in years 2016, 2018 and 2020 applied some adjustment to account for a tree death in Replicate 3.

Garnem produced the largest trees in the trial significantly higher (4.98m) than Nemaguard (4.65m) but not significantly different from spare Nemaguard (4.83m). The trees had a spreading canopy that readily filled the available canopy space by 8th leaf.

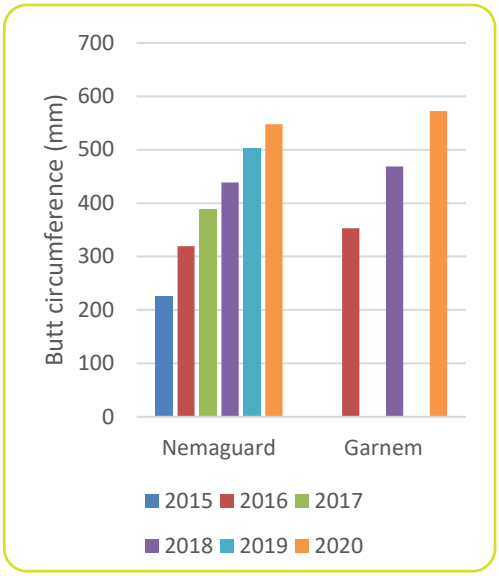


Figure 20. Statistically adjusted trunk circumference.

PRODUCTION

Seasonal yields for Garnem had little variability each year, except in 2020 where some variability was observed between replicates (Figure 21). Average seasonal yields followed a similar trend to Nemguard with a slight decline in 8th leaf.

Table 8. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Garnem	365	1,301	1,936	3,859	4,038	3,378	14,877
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

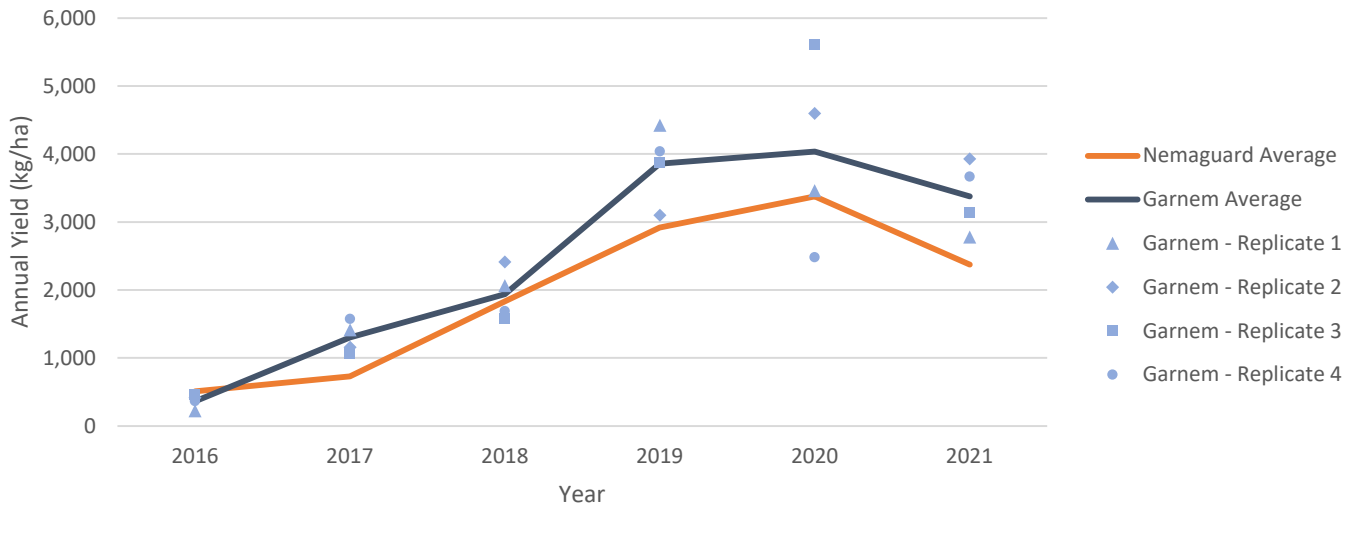


Figure 21. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Garnem has good vigour, ease of propagation and is well adapted to calcareous and poorer soils if well drained. Overseas literature states Garnem is resistant to Root-knot nematode and when tested in Australia Garnem showed good tolerance to *M.incognita* and *M.javanica* and resistance to *M.arenaria*. No root-knot or root-Root-lesion nematodes were observed in the rootstock evaluation trial. While susceptible to root-Root-lesion nematode, only low populations of Ring nematode were recorded in this trial and their impact on Garnem is unknown.

Table 9. Garnem rootstock characteristics (Appendix 1).

Root-knot nematode	Lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Resistant / Tolerant	Medium / Susceptible	Unknown	Susceptible	Unknown	Susceptible	Excluder	Tolerant	High	Good

Figure 22. Juvenile tree - 2017.

Figure 23. Mature tree - 2021.

Figure 24. Graft union - 2021.

HANSEN 536
PEACH X ALMOND

PERFORMANCE SUMMARY

Hansen 536 was among the top seven highest performing rootstocks in terms of cumulative yield. Results are specific to the soil characteristics and management practices applied to this trial site. Hansen 536 produced trees with the largest trunk circumference and one of the larger tree canopies in the trial. Average annual yields followed a similar trend as Nemaguard. Hansen 536 had significantly higher leaf calcium (Ca) and magnesium (Mg) levels which correlated with other rootstocks with higher yields. Earlier start of flowering by 0.75 days was observed for Hansen 536 compared to Nemaguard.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Hansen (619.6mm) were significantly larger than Nemaguard (549.8mm) in 2020 (Figure 25) and significantly larger than all other rootstocks (Table 1).

Hansen produced one of the larger canopies, 5.83m wide and 4.9m high, significantly higher than Nemaguard (4.65m) but not significantly higher than spare Nemaguard (4.83m). Early canopy areas and light interception were higher for Hansen 536 than Krymsk 86 but not significantly different than other rootstocks. These differences were lost by 2021.

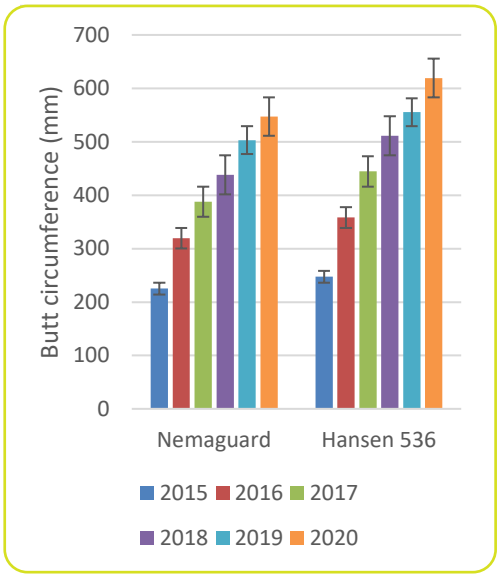


Figure 25. Average trunk circumference.

PRODUCTION

Hansen 536 larger canopy growth has assisted in producing average seasonal yields slightly higher than Nemaguard each year resulting in a cumulative yield significantly higher than Nemaguard. As seen in Figure 26 average seasonal yields follow a similar trend to that of Nemaguard.

Strong early growth meant Hansen 536 had a low production efficiency not significantly different from the production efficiency for Nemaguard. These differences in production efficiency were no longer observed in 2020 (Table 1).

Table 10. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Hansen 536	401	1,062	1,940	3,618	4,151	3,104	14,276
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

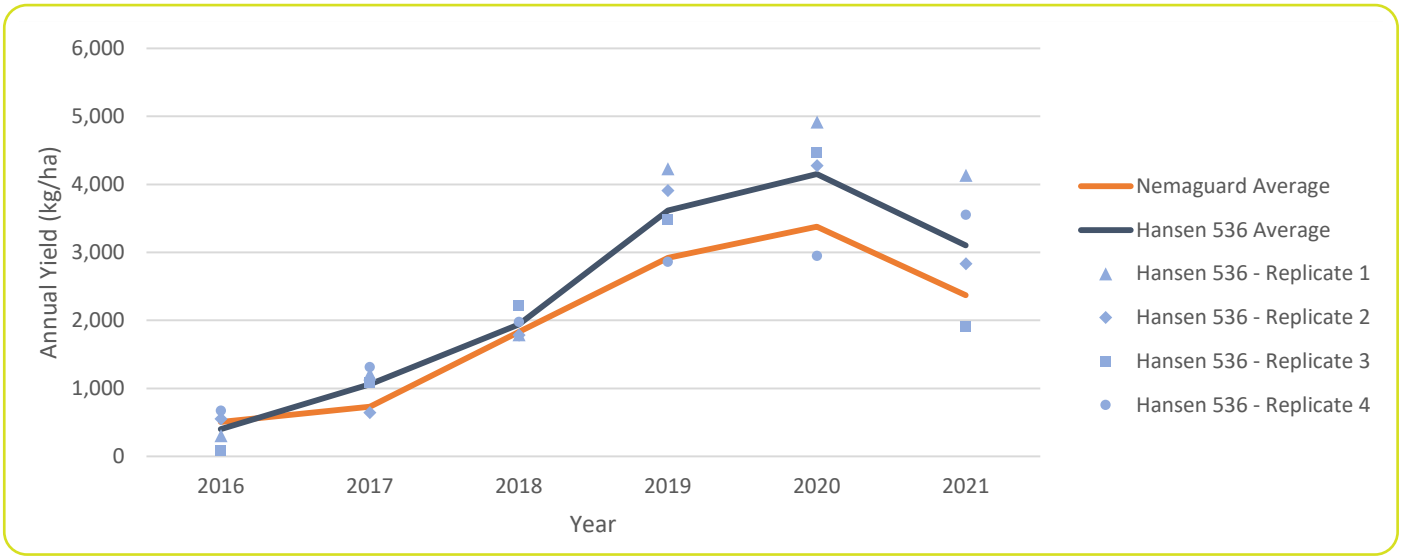


Figure 26. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Leaf analyses indicated a highly significant correlation between yield and leaf calcium (Ca) and magnesium (Mg) levels with Hansen 536 having the highest uptake of both Ca and Mg. Hansen 536 is resistant to Root-knot nematode and no nematodes were observed in the rootstock evaluation trial. On average Hansen 536 delayed the start of flowering by 0.75 days with full bloom and end of flowering also slightly later than Nemaguard (Figure 2).

Table 11. Hansen 536 rootstock characteristics (Appendix 1).

Root-knot nematode	Lesion Nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Resistant	More tolerant than Nemaguard	Susceptible	Susceptible	Susceptible	Susceptible	Resistant/ Excluder	Tolerant	High	Poor

Figure 27. Juvenile tree - 2017.

Figure 28. Mature tree - 2021.

Figure 29. Graft union - 2021.

GF677
PEACH X ALMOND

PERFORMANCE SUMMARY

GF677 was among the top seven highest performing rootstocks in terms of cumulative yield. Results are specific to the soil characteristics and management practices applied to this trial site. GF677 produced trees with similar trunk circumferences to Nemaguard and tree canopies were upright with open upper canopies. GF677 is susceptible to Root-knot nematode and low levels detected in the trial will need to be monitored to determine if these populations increase and what effect (if any) they have on future yields. Of the top seven rootstocks GF677 rootstock is commercially available as a grafted tree in Australia.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on GF677 (570mm) were not significantly larger than Nemaguard (549.8mm) in 2020.

In 2020, GF677 produced upright tree canopies (Figure 33) that were narrower (4.72m) than their height (4.93m) and significantly higher than Nemaguard (4.65m) but not significantly higher than the spare Nemaguard (4.83m). The upper part of the canopy is slightly less dense than the lower parts, leaving room for more growth in the future years.

Early canopy areas and light interception (canopy densities) were higher for GF677 than Krymsk 86 but not significantly different than other rootstocks. These differences were lost by 8th leaf.

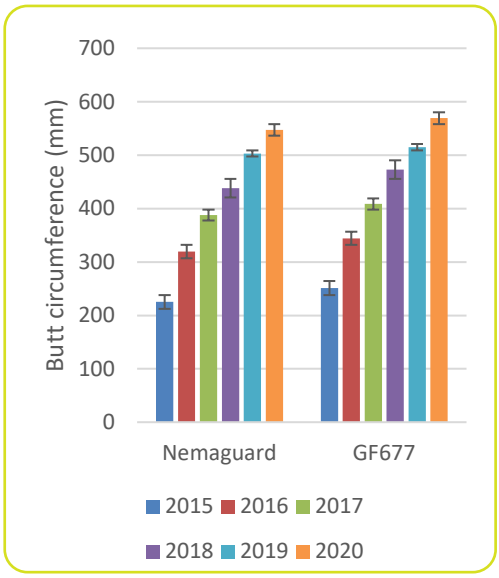


Figure 30. Average trunk circumference.

PRODUCTION

GF667 produced seasonal yields that were similar and slightly higher than Nemaguard each year resulting in a cumulative yield significantly higher than Nemaguard but similar to spare Nemaguard (Table 1), achieving over 3 tonnes per hectare by 2019. In 2020 an outlying yield was observed in Replicate 4 reducing the average annual yield harvested in that year.

Table 12. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
GF677	549	1,010	1,829	3,803	3,433	3,464	14,089
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

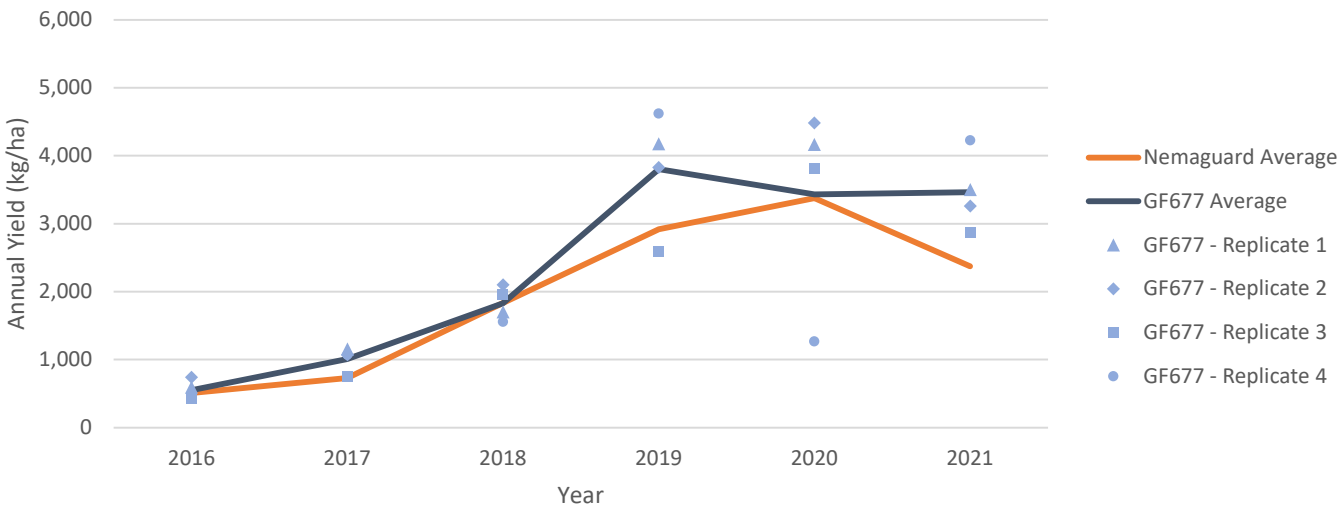


Figure 31. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Root-knot nematode was observed in the soil at low levels for GF677 and Root-Root-lesion nematode at moderate levels. GF677 is susceptible to Root-knot nematode, *M.javanica*, *M.incognita,* root-Root-lesion nematode and should be avoided where high nematode pressures are expected. Continued monitoring will determine if the nematode populations increase around this rootstock and what impact this has on future yields for trees planted on GF677.

Table 13. GF677 rootstock characteristics (Appendix 1).

Root-knot nematode	Lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Susceptible / Tolerant	Susceptible	Susceptible	Susceptible		Susceptible	Excluder	Tolerant	High	Poor

Figure 32. Juvenile tree - 2017.

Figure 33. Mature tree - 2021.

Figure 34. Graft union - 2021.

BRIGHTS HYBRID

PEACH X ALMOND

PERFORMANCE SUMMARY

Bright's Hybrid was among the top seven highest performing rootstocks in terms of cumulative yield. Results are specific to the soil characteristics and management practices applied to this trial site. Early canopy growth produced yields that were similar to Nemaguard and steadily increased each year. Bright's Hybrid had a significant delay in nut maturity where only 53% of nuts had reached stage 3 hull split by 25th January 2021 where all other rootstocks had reached 100% by the same day. Of the top seven rootstocks Brights Hybrid is one that is commercially available as a grafted tree in Australia.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Brights Hybrid (560.4mm) were not significantly larger than Nemaguard (549.8mm) in 2020.

In 2020, Brights Hybrid produced tree canopies that were 5.74m wide and 4.93m tall, and significantly higher than Nemaguard (4.65m) but not significantly higher than the spare Nemaguard (4.83m).

Canopy areas and light interception were higher for Brights Hybrid than Krymsk 86 but not significantly different than other rootstocks. These differences were lost by 8th leaf.

The lower canopy had quite dense growth with sparse limb growth into the upper canopy (Figure 38).

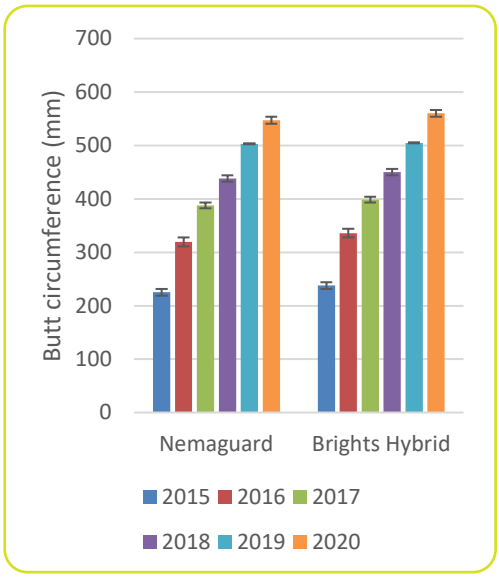


Figure 35. Average trunk circumference.

PRODUCTION

Brights Hybrid showed a steady increase in average seasonal yield over time unlike many other rootstocks where the average annual yield in 2020 and / or 2021 declined below 2019 levels.

Table 14. Average annual yields (kg/ha)

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Bright's Hybrid	469	1,156	1,826	2,840	3,314	3,914	13,519
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

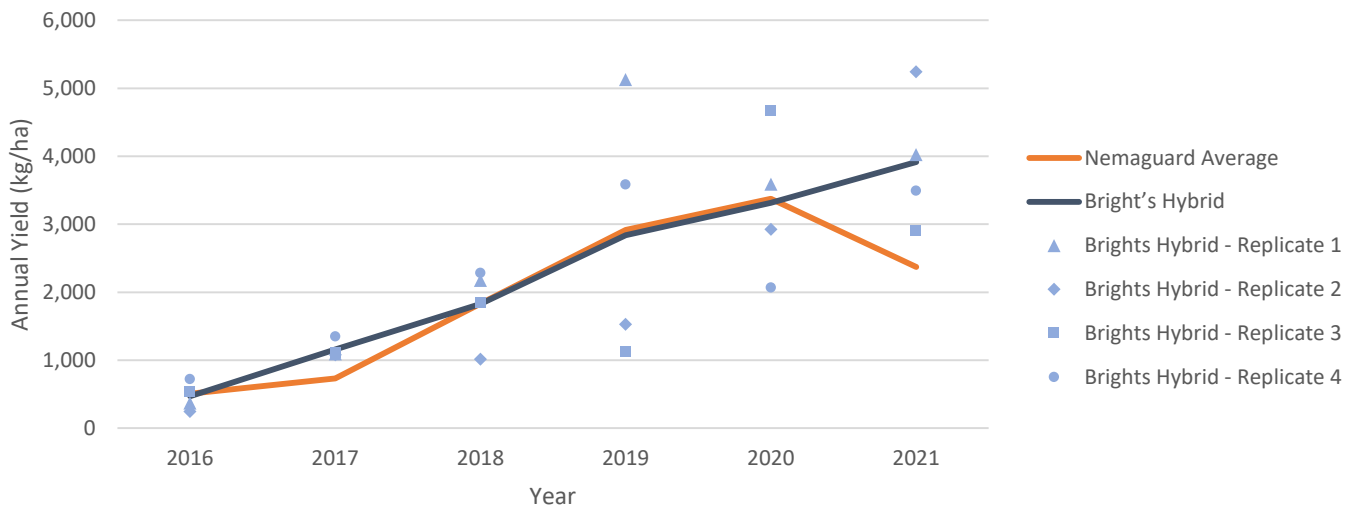


Figure 36. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Bright's Hybrid is susceptible to Root-knot nematode *M. incognita* but resistant to *M. javanica* and *M. arenaria*. While no Root-knot nematode was observed for Bright's Hybrid, there were very low levels of Root-lesion and Ring-nematode. Continued monitoring will be required as Bright's Hybrid is susceptible to Ring-nematode. Bright's Hybrid had a significant delay in nut maturity where only 53% of nuts had reached stage 3 hull split by 25th January 2021 where all other rootstocks had reached 100% by the same day. This delay was not evident in progressing to stage 6 hull split where all rootstocks had reached 100% by 18th February.

Table 15. Bright's Hybrid rootstock characteristics (Appendix 1).

Root-knot nematode	Root-lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Resistant/ Susceptible	More Tolerant than Nemaguard	Susceptible	Susceptible	Susceptible	Susceptible	Tolerant/ Excluder	Tolerant	High	Poor

Figure 37. Juvtenile tree - 2017.

Figure 38. Mature tree - 2021.

Figure 39. Graft union - 2021.

PERFORMANCE SUMMARY

Nemaguard was not among the top seven highest performing rootstocks in terms of cumulative yield but had similar yields to Brights Hybrid, Adafuel, Cornerstone (planted one year later) and GF557. Cumulative yield was significantly higher for Nemaguard than Krymsk 86 for this trial site and management practices. Leaf analysis showed low levels of Ca and Mg and high levels of leaf sodium may have contributed to low yield performance.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Nemaguard (549.8mm) were similar to Spare Nemaguard (556.25mm) in 2020 and were significantly smaller than Adafuel (600.2mm), Monegro (608.8mm), Felinem (605.4mm) and Hansen 536 (619.6mm) but not other rootstocks.

In 2020, Nemaguard produced smaller tree canopies with heights of 4.65m (4.78m wide) and together with spare Nemaguard, of similar height 4.83m (4.9m wide), ranked in the bottom four tree heights. Visually the rootstock promoted strong light interception through the spacing of the canopy (Figure 43).

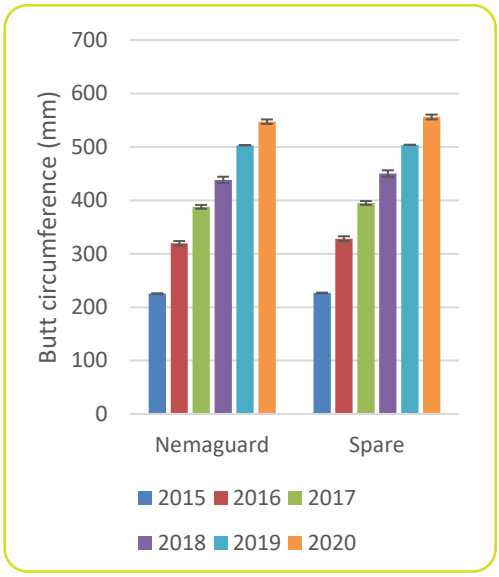


Figure 40. Average trunk circumference.

PRODUCTION

Seasonal yields on Nemaguard were typically mid-range with some rootstocks achieving higher yields e.g. GF749, Monegro, Felinem, Hansen 536, Garnem, GF677, and others lower yields e.g. Krymsk 86, and GF557. While earlier yields for Adafuel and Brights Hybrid were similar to Nemaguard they may surpass Nemaguard in future years if their upward trajectory continues.

Figure 41 shows the variability that makes up the average yields for Nemaguard and spare Nemaguard.

Table 16. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Spare Nemaguard	482	893	2,144	3,486	3,502	2,736	13,243
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

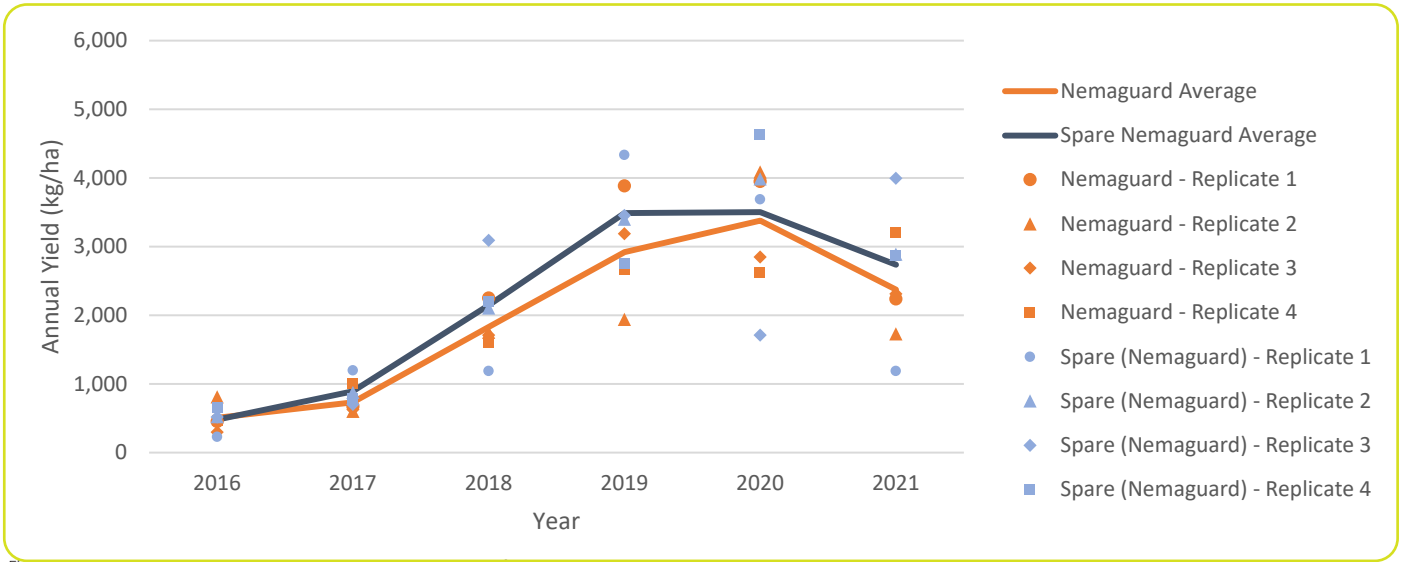


Figure 41. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Table 17. Nemaguard rootstock characteristics (Appendix 1).

Root-knot nematode	Lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Tolerant / Resistant	Medium	Medium	Medium	Susceptible	Medium	Sensitive	Suscepti-ble	Medium	NA

Nemaguard is vigorous and performs well in sandy loam and loam soils. Literature states Nemaguard is resistant to Root-knot nematode species *M. incognita* and *M. arenaria*, with variable resistance to *M. javanica*. When tested in Australia Nemaguard typically had low levels of gall growth for each species suggesting good tolerance to *M. incognita* and M. arenaria, and resistance to *M. javanica* except for one isolate from an almond property. No Root-knot nematodes were detected in the rootstock evaluation trial however very low levels of root-lesion and Ring nematode were detected for which Nemaguard has medium resistance. Susceptible to ring and Root-lesion nematode, bacterial canker, phytophthora and crown gall. It is also sensitive to high soil pH, high lime and high salt and water logging. In 2021 leaf analysis indicated a significant correlation between yield and leaf Ca and Mg levels with the two Nemaguard rootstocks having the lowest leaf Ca and Mg levels. Similarly, there was a significant correlation between yield and leaf sodium with high sodium levels correlating with low yields. The highest levels were observed in Krymsk and Nemaguard. Both Krymsk and Nemaguard have been found to be poor excluders of sodium and chloride and may have contributed to low yield performance even though soil salinities were below the level considered to affect yield (1.5dS/m).

Figure 42. Juvenile tree - 2017.

Figure 43. Mature tree - 2021.

Figure 44. Graft union - 2021.

ADAFUEL
PEACH X ALMOND

PERFORMANCE SUMMARY

While Adafuel produced larger trees and high production efficiencies early (2017) this did not translate into cumulative yields that were significantly higher than Nemaguard, potentially due to variability within the trial. Root-knot nematode was detected on Adafuel rootstock in moderate levels and Adafuel is reported to have low to medium susceptibility. Adafuel brought forward flowering start dates and flowering duration compared to Nemaguard.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Adafuel (600.2mm) were significantly larger than Nemaguard (549.8mm) and had similar circumferences as high performing rootstocks Monegro (608.8mm), Felinem (605.4mm) and Hansen 536 (619.6mm).

In 2020, Adafuel produced strong semi upright canopy growth of 4.56m wide with heights (4.93m) significantly higher than Nemaguard (4.65m) but not significantly higher than the spare Nemaguard (4.83m). Most growth was in the lower part of the canopy with some limbs extending apically in the upper canopy.

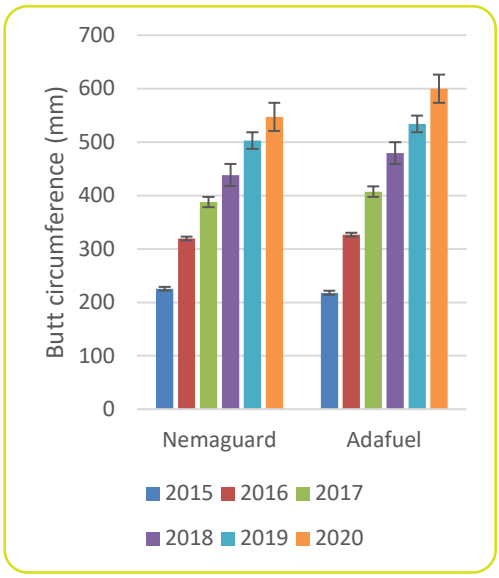


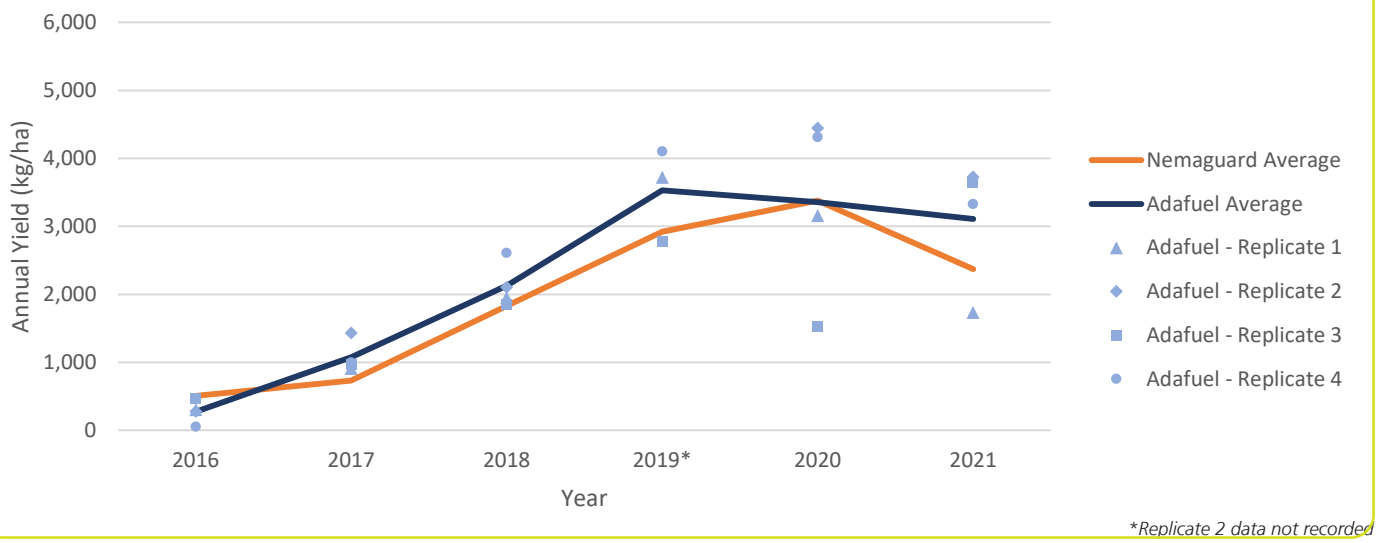
Figure 45. Average trunk circumference.

PRODUCTION

Seasonal yields on Adafuel were similar to Nemaguard (Table 18). Early high production efficiency seen in 2017 did not translate into significantly higher cumulative yield than Nemaguard potentially due to the variability within the trial. In 2019, Replicate 2 did not have harvest data therefore the average annual yield was based on 3 data sets. An outlying low yield in Replicate 3 in 2020 combined with a declining trend in Replicate 1 meant the cumulative yield by 2021 was not significantly higher than Nemaguard.

Table 18. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Adafuel	274	1,074	2,127	2,648	3,357	3,106	12,588
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738



**Replicate 2 data not recorded*

Figure 46. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Root-knot nematode was detected on Adafuel rootstock in moderate levels is reported to have tolerance to *M.incognita* and *M.javanica* but resistant to *M.arenaria*. On average Adafuel brought forward the start of flowering two days earlier than Nemaguard with a shorter flowering period from 26 days to 24.75 days (Figure 2).

Table 19. Adafuel rootstock characteristics (Appendix 1).

Root-knot nematode	Root-lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Resistant/ Tolerant							Tolerant	High	Medium

Figure 47. Juvenile tree - 2017.

Figure 48. Mature tree - 2021.

Figure 49. Graft union - 2021.

PERFORMANCE SUMMARY

Cornerstone was planted one year later in this trial making it difficult to compare with other rootstocks. The delayed planting was further complicated in that they received the same fertilizer and irrigation amounts as the trees 12 months older enabling growth and yields to catch up to that of other rootstocks. By 3rd leaf Cornerstone's average annual yield was higher than Nemaguard and after 7 years growth produced a similar cumulative yield to Nemaguard that had 8 years growth.

KEY OBSERVATIONS

TREE HABIT

Despite being planted one year later, Nonpareil trees grown on Cornerstone had strong growth and by 2020 (540.4mm) had similar trunk circumferences as Nemaguard (549.8mm).

In 2020, Cornerstone had one of the smaller canopies with heights (4.78m) similar to Nemaguard (4.65m) but not significantly smaller than the spare Nemaguard (4.83m).

PRODUCTION

In 2017 Cornerstone had significantly higher production efficiency (0.095kg/cm2) than Nemaguard (0.057kg/cm2) the significance between rootstocks was lost after 2017.

Despite being planted 12 months later Cornerstone produced annual average yields higher than Nemaguard in all years except for 2016 and 2020. After seven years growth Cornerstone achieved a similar cumulative yield to Nemaguard that had eight years growth.

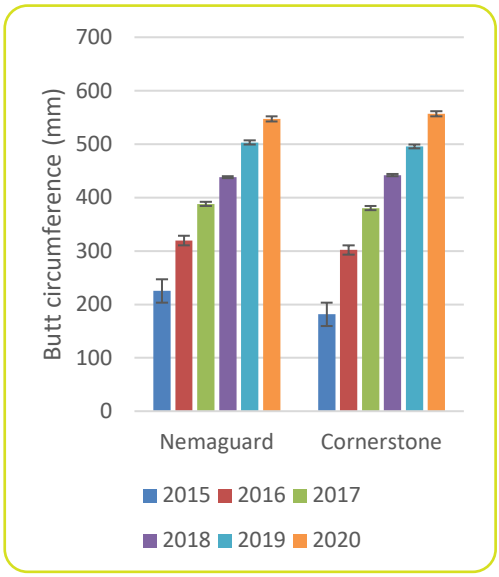


Figure 50. Average trunk circumference.

Table 20. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Cornerstone*	123	1,132	1,931	3,309	2,669	2,824	11,987
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

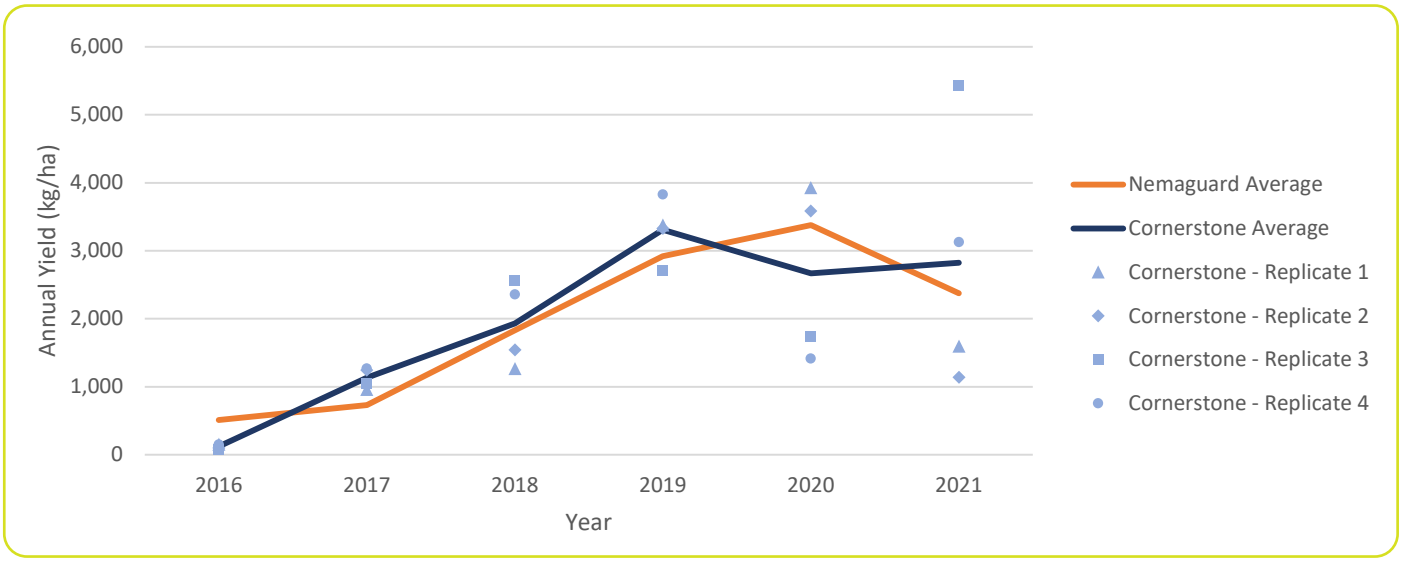


Figure 51. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Cornerstone is tolerant to Root-knot nematode with very low levels of *M.javanica* and *M.incognita;* and is resistant *to M.arenaria.* No Root-knot nematodes were detected during the rootstock evaluation and only very low levels of Ring nematode which will require ongoing monitoring. Flowering time for Cornerstone was similar to Nemaguard (Figure 2).

Table 21. Cornerstone rootstock characteristics (Appendix 1).

Root-knot nematode	Root-lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Tolerant / Resistant	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible	Excluder	Tolerant	High	Good

Figure 52. Juvenile tree - 2017.

Figure 53. Mature tree - 2021.

Figuret 54. Graft union - 2021.

GF557
PEACH X ALMOND

PERFORMANCE SUMMARY

GF557 produced trees that were similar to Nemaguard in terms of canopy size, seasonal yields and cumulative yield. Root-knot nematode was detected in soils at low levels and will require monitoring to determine any yield impacts given GF557 is susceptible to Root-knot nematode. GF557 had low levels of leaf sodium suggesting it has good salt tolerance. GF557 brought forward the start of flowering by one day and shortened the flowering period to 24.75 days compared to Nemaguard (26 days).

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on GF557 (564.6mm) were similar in size as Nemaguard (549.8mm) and spare Nemaguard (556.3mm).

By 2020, trees grown on GF557 (4.88m) were significantly higher than Nemaguard (4.65m) but not significantly higher than spare Nemaguard (4.83m). Canopy growth was evenly distributed in the upper and lower canopy without apically dominant limbs (Figure 58).

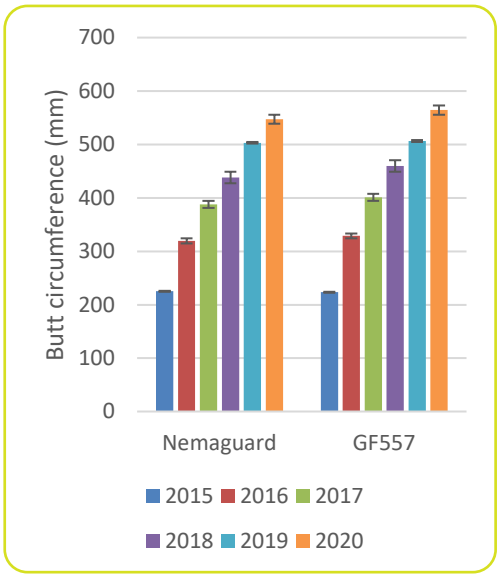


Figure 55. Average trunk circumference.

PRODUCTION

GF557 had similar average annual yield and cumulative yield as Nemaguard (Table 22).

Table 22. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
GF557	379	871	1,884	3,013	3,219	2,520	11,886
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

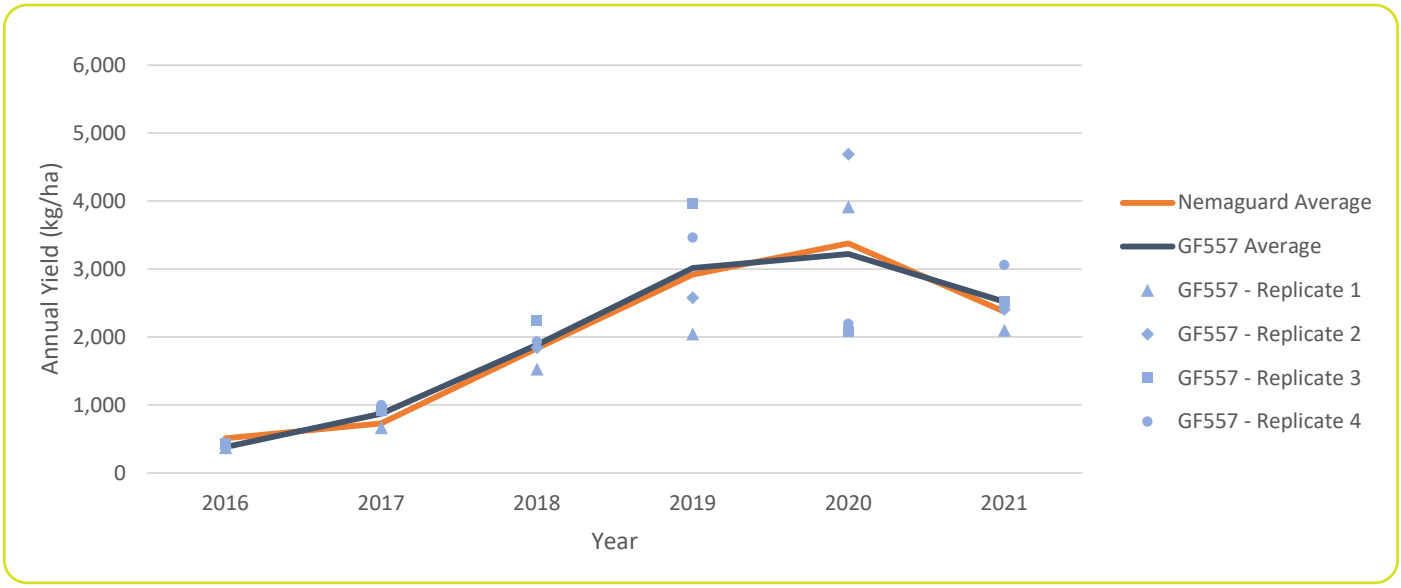


Figure 56. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Root-knot nematode was detected in soils at low levels. Given GF557 is susceptible to Root-knot nematode M.javanica and M.incognita but resistant to M.arenaria continued monitoring will determine if populations increase and their impact on yield. GF557 had low levels of leaf sodium suggesting it has good salt tolerance, able to exclude sodium and chloride from the soil. GF557 brought forward the start of flowering by one day and shortened the flowering period to 24.75 days compared to Nemaguard (26 days).

Table 23. GF557 rootstock characteristics (Appendix 1).

Root-knot nematode	Root-lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytophthora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Susceptible / Resistant								High	Good

Figure 57. Juvenile tree - 2017.

Figure 58. Mature tree - 2021.

Figure 59. Graft union - 2021.

KRYMSK 86
PEACH X PLUM

PERFORMANCE SUMMARY

Krymsk 86 was the lowest performing rootstocks within the trial producing trees with similar trunk circumference, height and canopy area to Nemaguard however yields were significantly lower than Nemaguard and all other rootstocks. These results are specific to the soil characteristics and management practices applied to this trial site. Leaf analysis showed low levels of Ca and Mg and high levels of leaf sodium may have contributed to low yield performance. Krysmk 86 brought forward the start of flowering (0.5 days) and reduced flowering periods by 3.5 days compared to Nemaguard. Fruit on Krymsk 86 reached stage 3 hull split earlier than Nemaguard.

KEY OBSERVATIONS

TREE HABIT

Using trunk circumference as an indicator of tree growth, Nonpareil trees grown on Krymsk 86 (568.8mm) had similar growth compared to Nemaguard (549.8mm) and spare Nemaguard (556.3mm) but was significantly smaller than Hansen 536 (619.6mm).

In 2020, Krymsk 86 produced small trees with height (4.87m) similar to Nemaguard (4.65m) and Cornerstone (12 months younger) and significantly smaller than all other rootstocks.

Canopy area measures in 2018 indicated that Krymsk 86 had a significantly smaller canopy area than most rootstocks but not significantly different from Nemaguard, GF557 and Felinem. Strong apical limb growth was observed for some limbs with much of the available space between trees remaining in 2021 (Figure 63).

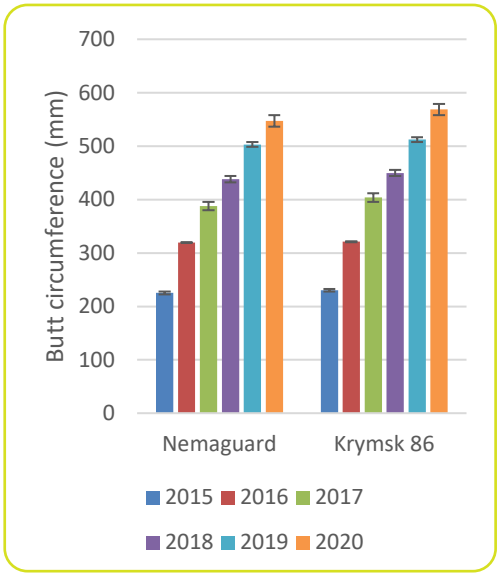


Figure 60. Average trunk circumference.

PRODUCTION

Average annual yields for Krymsk 86 were consistently less than Nemaguard resulting in a cumulative yield significantly lower than Nemaguard and all other rootstocks (Table 24).

Table 24. Average annual yields (kg/ha).

Rootstock	2016	2017	2018	2019	2020	2021	Cumulative
Krymsk 86	370	651	1,299	2,403	2,392	2,089	9,204
Nemaguard	508	731	1,831	2,919	3,377	2,373	11,738

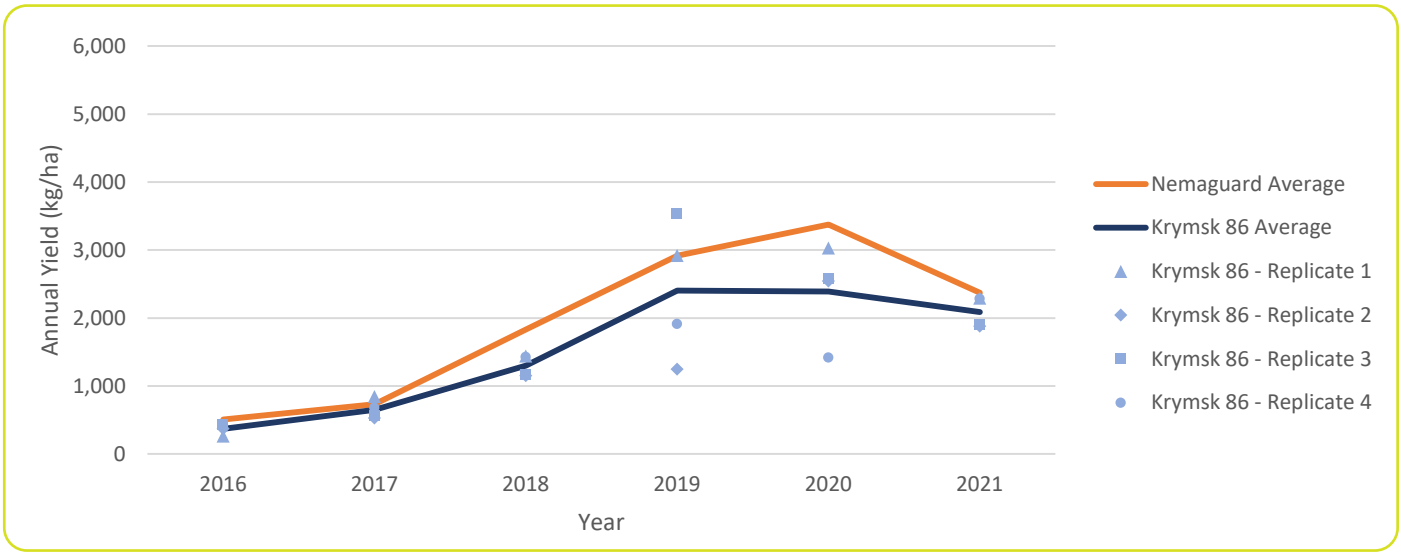


Figure 61. Average annual yields 2016 to 2021 (3rd to 8th leaf).

ROOTSTOCK CHARACTERISTICS

Table 25. Krymsk 86 rootstock characteristics (Appendix 1)

Root-knot nematode	Lesion nematode	Ring nematode	Crown Gall	Armillaria	Phytoph-thora	Salt exclusion	Chlorosis	Vigour	Propagation by cuttings
Susceptible / Tolerant	Medium	Susceptible	Medium	High	Tolerant	Sensitive	Medium	Medium	Good

In 2021 leaf analysis indicated a significant correlation between yield and leaf Ca and Mg levels with trees grown on Krymsk 86 and Nemaguard having the lowest leaf Ca and Mg levels. Similarly, there was a significant correlation between yield and leaf sodium with high sodium levels correlating with low yields. The highest levels were observed in Krymsk 86 and Nemaguard. Both Krymsk 86 and Nemaguard have been found to be poor excluders of sodium and chloride and may have contributed to low yield performance even when soil salinities were below the level considered to affect yield (1.5dS/m).

Trials in Australia found Krymsk 86 to be susceptible to M.javanica, and tolerant to M.arenaria and M.incognita however no Root-knot nematode was detected in the rootstock evaluation trial. Moderate levels of Ring nematode were observed in the soil around Krymsk 86. Krymsk 86 is susceptible to Ring nematode which is known to Ring nematode is known to increase the susceptibility to bacterial cankers and will require monitoring to determine if the nematode population increases and its effect on tree growth and yield.

Fruit on Krymsk 86 reached stage 3 hull split earlier than Nemaguard with 98% of the fruit reaching stage 3 by January 18 compared to Nemaguard having only 74% of fruit reaching stage 3 on the same date.

Krymsk brought flowering forward by half a day and reduced the flowering period to 22.5 days compared with Nemaguard's average flowering period of 26 days.

Figure 62. Juvenile tree - 2017.

Figure 63. Mature tree - 2021.

Figure 64. Graft union - 2021.

APPENDIX 1: SUMMARY OF INTELLECTUAL PROPERTY AND PROPAGATION METHODS FOR KEY ROOTSTOCKS IN AUSTRALIA

Rootstock	Origin	Breeder	Source/ Australian Agent	Major Propagator	Intellectual Property			Method of Propagation (**Bold** = most common in Australia *Italic* = most common Internationally)			Commercially available in Australia as a grafted tree
					Status	Date of Grant	Right Expires	Seedling	Cuttings	Micropropagation	
Nemaguard	Georgia, USA	USDA	Ausbuds	Ausbuds	Public			***Yes***	No	No	Yes
Barrier 1 (Empyrean 1)	Firenze, Italy	National Research Council of Italy Trees and Timber Institute	ANFIC	Olea & Little Tree Company				No	**Yes**		Yes
Cadaman (Avimag)	Bordeaux, France	INRA	GF	GF, Olea & Little Tree Company	Granted	28 Mar 2002	28 Mar 2027	No	**Yes**	*Yes*	No
Adafuel	Zaragoza, Spain	CSIC	ABA	Ausbuds	Public			No	**Yes**	*Yes*	
Bright's Hybrid	California, USA	Brights Nursery	Ausbuds	Ausbuds	Public			No	**Yes**	*Yes*	Yes
Cornerstone	California, USA	Burchell Nursery	Mossmont Nurseries	Ausbuds	Granted	26 Feb 2014	26 Feb 2039	No	***Yes***	*Yes*	Yes
Felinem	Zaragoza, Spain	CITA	ABA	Ausbuds	Granted	13 Feb 2014	13 Feb 2039	No	**Yes**	*Yes*	No
Garnem	Zaragoza, Spain	CITA	ABA	Ausbuds	Granted	13 Feb 2014	13 Feb 2039	No	**Yes**	*Yes*	Yes
Monegro	Zaragoza, Spain	CITA	ABA	Ausbuds	Granted	13 Feb 2014	13 Feb 2039	No	**Yes**	*Yes*	No
GF557	Bordeaux, France	INRA	ABA	Ausbuds	Public			No	**Yes**	***Yes***	
GF677 (Paramount)	Bordeaux, France	INRA	ABA	Ausbuds & Boulevarde	Public			No	**Yes**	***Yes***	Yes
GF749	Bordeaux, France	INRA	ABA		Public						
Hansen 536	California, USA	UC Davis	Ausbuds	Ausbuds	Public			No	**Yes**	*Yes*	
Krymsk (Kuban) 86	Krasnodar, Russia	Krymsk Breeding & Research Station	ANFIC	Olea & Little Tree Company	Granted	17 Nov 2010	17 Nov 2035	No	**Yes**	*Yes*	Yes
Nickels	California, USA	UC Davis	Mossmont Nurseries	Ausbuds	Withdrawn			No	**Yes**	*Yes*	No
Atlas	California, USA	Zaiger Genetics	GF	GF	Granted	14 June 2000	14 June 2025	No	**Yes**	Yes	Yes
Viking	California, USA	Zaiger Genetics	GF	GF	Granted	3 June 2003	3 June 2028	No	**Yes**	Yes	Yes

Legend
ABA – Almond Board of Australia Inc
ANFIC – Australian Nurseryman's Fruit Improvement Company Ltd
CITA – Centro de Investigacion y Tecnologia Agroalimentaria de Aragon
CSIC - Consejo Superior de Investigaciones Científicas
USDA – United States Department of Agriculture
UC Davis – University of California, Davis Campus
*date of Grant unknown

SUMMARY CHARACTERISTICS FOR KEY ROOTSTOCKS IN AUSTRALIA

Rootstock	Parentage	Pathogen Resistance								Soil Adaptation		Effects on the Variety		
		Root Knot Nematode Variation in resistance / susceptibility of species and isolates when tested in Australia[1]			Lesion Nematode	Ring Nematode/ Bacterial Canker	Crown Gall	Armillaria	Phytophthora	Salt Exclusion[1]	Chlorosis	Compatibility	Vigour	Propagation by Cuttings
		M.javanica	*M.arenaria*	*M.incognita*										
Nemaguard	Wild Peach x Peach	Tolerant[1]	Tolerant[1]	Tolerant[1]	Medium	Medium	Medium	Susceptible	Medium	Sensitive[1]	Susceptible	Good	Medium	NA
Barrier 1 (Empyrean 1)	Wild Peach x Peach	Susceptible[1]		Resistant							Tolerant	Good	High	
Cadaman (Avimag)	Wild Peach x Peach	Resistant[1,2]	Resistant[1]	Resistant[1]	Susceptible	Unknown	Susceptible	Susceptible	Unknown	Moderate[1]	Medium	Good	High	Poor
Adafuel	Peach x Almond	Tolerant[1]	Resistant[1]	Tolerant[1]							Tolerant[3]	Good	High	Medium
Bright's Hybrid	Peach x Almond	Resistant[1]	Resistant[1]	Susceptible[1]	More Tolerant than Nemaguard	Susceptible	Susceptible	Susceptible	Susceptible	Tolerant[1]/ Excluder	Tolerant	Good	High	Poor
Cornerstone	Peach x Almond	Tolerant[1]	Resistant[1]	Tolerant[1]	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible	Excluder[1]	Tolerant	Good	High	Good
Felinem	Peach x Almond	Tolerant[1]	Resistant[1,3]	Resistant[1,3]	Moderate[2,3]	Unknown	Susceptible[3]				Tolerant[2]	Good[3]	High[3]	Good[3]
Garnem	Peach x Almond	Tolerant[1] Resistant[3]	Resistant[1,3]	Tolerant[1] Resistant[3]	Medium / Susceptible[2,3]	Unknown	Susceptible[3]	Unknown	Susceptible	Excluder[1]	Tolerant[3]	Good[3]	High[3]	Good[3]
Monegro	Peach x Almond	Tolerant[1] Resistant[3]	Resistant[1,3]	Susceptible[1] Resistant[3]	Susceptible[2,3]	Unknown	Susceptible[3]				Tolerant[3]	Good[3]	High[3]	Good[3]
GF557	Peach x Almond	Susceptible[1]	Resistant[1]	Susceptible[1]								Good	High[3]	Good
GF677	Peach x Almond	Susceptible[1]	Tolerant[1]	Susceptible[1]	Susceptible	Susceptible	Susceptible		Susceptible	Tolerant / Excluder[1]	Tolerant[3]	Good	High	Poor
GF749	Peach x Almond	Susceptible[1]	Tolerant[1]	Susceptible[1]								Good	High	Average

[1]Walker, A.R., Smith, M.H., McDavid, D., Goonetilleke, S., Hassan, M., 2017. Resilience traits for almond rootstocks. Final report for IRSPR2-004. CSIRO Agriculture and Food, Urbrae, pp 61.

[2]Pinochet, J., Calvet, C., Hernández-Dorrego, A., Bonet, A., Felipe, A., and Moreno, M. 1999. Resistance of Peach and Plum Rootstocks from Spain, France, and Italy to Root-knot Nematode *Meloidogyne javanica*. HORTSCIENCE 34(7):1259–1262.

[3]Felipe, A.J., 2009. Felinem', 'Garnem', and 'Monegro' Almond · Peach Hybrid Rootstocks. HORTSCIENCE 44(1):196–197.

Rootstock	Parentage	Pathogen Resistance								Soil Adaption		Effects on the Variety		
		Root knot Nematode Variation in resistance / susceptibility of species and isolates when tested in Australia[1]			Lesion Nematode	Ring Nematode/ Bacterial Canker	Crown Gall	Armillaria	Phytophthora	Salt exclusion[1]	Chlorosis	Compatibility	Vigour	Propagation by Cuttings
		M.javanica	*M.arenaria*	*M.incognita*										
Hansen 536	Peach x Almond	Resistant[1]	Resistant[1]	Resistant[1]	More Tolerant than Nemaguard	Susceptible	Susceptible	Susceptible	Susceptible	Resistant[1]/ Excluder	Tolerant	Good	High	Poor
Nickels	Peach x Almond	Susceptible[1]	Tolerant[1]	Susceptible[1]	More Tolerant than Nemaguard	Susceptible	Susceptible	Susceptible	Susceptible	Moderate[1]	Tolerant	Good	High	Poor
Krymsk (Kuban) 86	Peach x Plum	Susceptible[1]	Tolerant[1]	Tolerant[1]	Medium	Susceptible	Medium	High	Tolerant	Sensitive[1]	Medium	Good	Medium	Good
Atlas	Peach x Almond x Apricot x Plum	Susceptible[1]	Resistant[1]	Resistant[1]	Medium	Susceptible	Medium	Susceptible	Medium	Sensitive[1]	Tolerant	Good	High	Poor
Viking	Peach x Almond x Apricot x Plum	Susceptible[1]	Resistant[1]	Resistant[1]	Medium	High	Medium	Susceptible	Medium	Moderate[1]	Tolerant	Good	High	Good
Rootpac 20		High[1]								Moderately tolerant[1]				
Rootpac 40		High[1]								Moderately tolerant[1]				
Rootpac R										Sensitive[1]				

[1]Walker, A.R., Smith, M.H., McDavid, D., Goonetilleke, S., Hassan, M., 2017. Resilience traits for almond rootstocks. Final report for IRSPR2-004. CSIRO Agriculture and Food, Urbrae, pp 61.

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[3]Felipe, A.J., 2009. Felinem', 'Garnem', and 'Monegro' Almond · Peach Hybrid Rootstocks. HORTSCIENCE 44(1):196–197.

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ALMOND BOARD OF AUSTRALIA