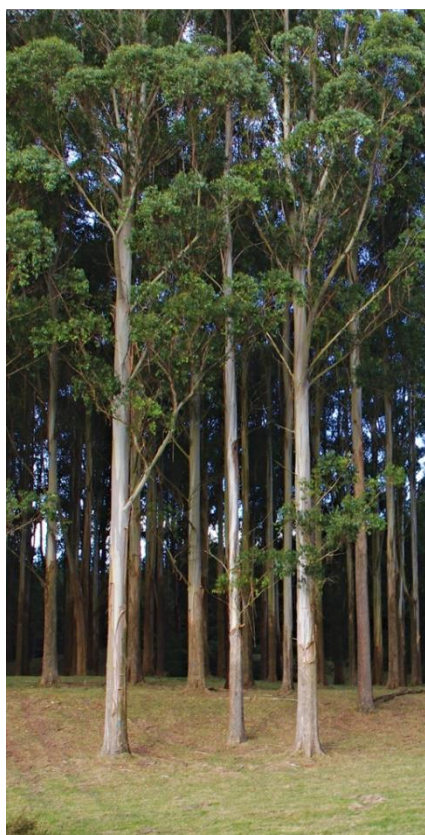


## Evaluation of genetic gain trials in Douglas-fir

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## Disclaimer

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# EXECUTIVE SUMMARY

The field experiments for the evaluation of realised genetic gain were established in 2012 and 2013 across New Zealand and measured for productivity and stem-form attributes in 2022. We have performed a statistical evaluation to compare the performance of seed sources that are commercially available in New Zealand. The experiments were designed to evaluate not only the differences in genetic quality of the seed lots but also the impact of silvicultural treatments in terms of initial stocking. The data exploration did not find any impact of silvicultural treatments on the investigated traits, most likely due to the young age of the trees. We would recommend re-evaluation of this experiment at a later age.

In terms of productivity, the seed sourced from the Fort Bragg provenance performed best in the North Island, while the California and Washington provenances performed poorly, presumably due to a short growth season in Washington or susceptibility to Swiss needle casting in the California provenance. On the other hand, seed sources from Fort Bragg provenances performed poorly in the south of the South Island, which might be attributed to a mismatch between phenology and climatic conditions, which may cause late frost damage. The seed sources based on selections from Oregon and Washington provenances showed superior performance in the south of the South Island, while seed sources based on selections from California and Washington provenances worked best in the north of the South Island. The material from the Washington seed stand performed the poorest.

In stem form traits, the seed sources based on selections from Ashley, Oregon, and Fort Bragg showed superior performance for stem form attributes in the North Island, while the seed sources based on selections from California showed the worst. Even in northern South Island (Blenheim), the seed sources based on Ashley provenance were excellent. Similar to productivity, seed sources based on selections from California provenances were superior in stem form attributes due to the lack of Swiss needle casting. The seed sources from Tyrell SO and Washington seed stands performed the worst in South Island stem form traits.

In terms of acceptability, the seed sources based on selections from Fort Bragg, Oregon, and Ashley provenances had the highest general acceptance on the North Island, while the selections from Tramway and Californian provenances had the lowest. In the South Island, the seed sources based on selections from Ashley, Fort Bragg, and California provenances had the highest acceptability in the north, and the seed sources based on selections from Fort Bragg and Washington provenances had the highest acceptability in the south. The seed sources from Washington Seed Stand and Tyrell SO had the lowest acceptability on the South Island.

# INTRODUCTION

Forest tree breeding involves continuously improving the features that are included in the breeding goals, and the effectiveness of breeding is often evaluated by the conduct of genetic experiments that are carried out in the field. Douglas-fir genetic gain trials were established on three sites in New Zealand (Figure 1) in 2012 FR510/1 (Kaingaroa) and FR510/2 (Dusky) and 2013 FR510/4 (Blenheim). Site FR510/3 established in 2012 failed early after planting due to animal browsing. The experiments were established at initial spacing of 3 x 3 m (1,111 stems per hectare) with additional alternative initial spacing of 3 x 4 m (883 stems per hectare) and 3 x 2 m (1,666 stems per hectare). and measurements were taken at the ages of 9 and 10 for diameter at breast height (DBH) in millimetres, tree height (HTM) in metres, stem straightness (STR) on a scale of 1 to 9, branching quality (BRH) on a scale of 1 to 9, malformation (MAL) on a scale of 1 to 9, and acceptability (ACC) on a scale of 0 to 1. The material that was evaluated at age of 9 – 10 comes from a variety of sources, including:

Proseed seed orchard:

- Californian provenances
- Oregon provenances
- Washington provenances
- Fort Bragg provenance
- Ashley provenance

Tyrell seed orchard (Wells Creek region - Oregon)

Tyrell seed orchard (Swisshome region - Oregon)

Bulk open-pollinated material from trees selected in progeny trial established in 1996

Washington seed stand – provenance Beaumont

Ernslaw One Etrick SO:

- selection from Tramway seed stand
- selection from Rankleburn
- selection from Kaingaroa compartment 657 (provenance Fort Bragg)

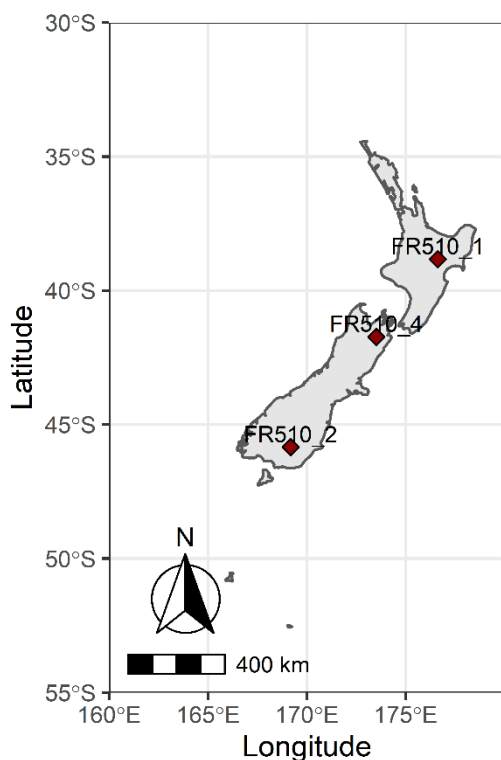


Figure 1: Distribution of genetic gain trials.

## METHODS

The analysis of genetic gain was performed through mixed linear models using breedR package as follows:

$$y = X\beta + Zu + e$$

where  $y$  is the vector of phenotypes,  $\beta$  is a vector of fixed effects (intercept, replication and provenance),  $u$  is a vector of random effects (block) and  $e$  is a vector of residuals.  $X$  and  $Z$  are incidence matrices assigning effect from  $\beta$  and  $u$  to vector of phenotypes. All data from marginal rows (1 and 10) and columns (1 and 6) of each block were removed from the analysis to eliminate the competition effect of neighbouring genetic entries. The seed source effects were extracted from the results and presented in interaction plots to investigate changes in the seed source ranking across tested environments.

# RESULTS

The visual exploration of the data was performed to investigate the impact of initial stocking on the studied traits. We did not find any discernible changes in the data across any of the characteristics or locations that were looked at (Figures 2–4). Because of this, the influence of the silviculture treatment (initial stocking) is not realised at this early age, and the assessment should be repeated at a later age when the canopy is closed and neighbouring trees compete for sunlight.

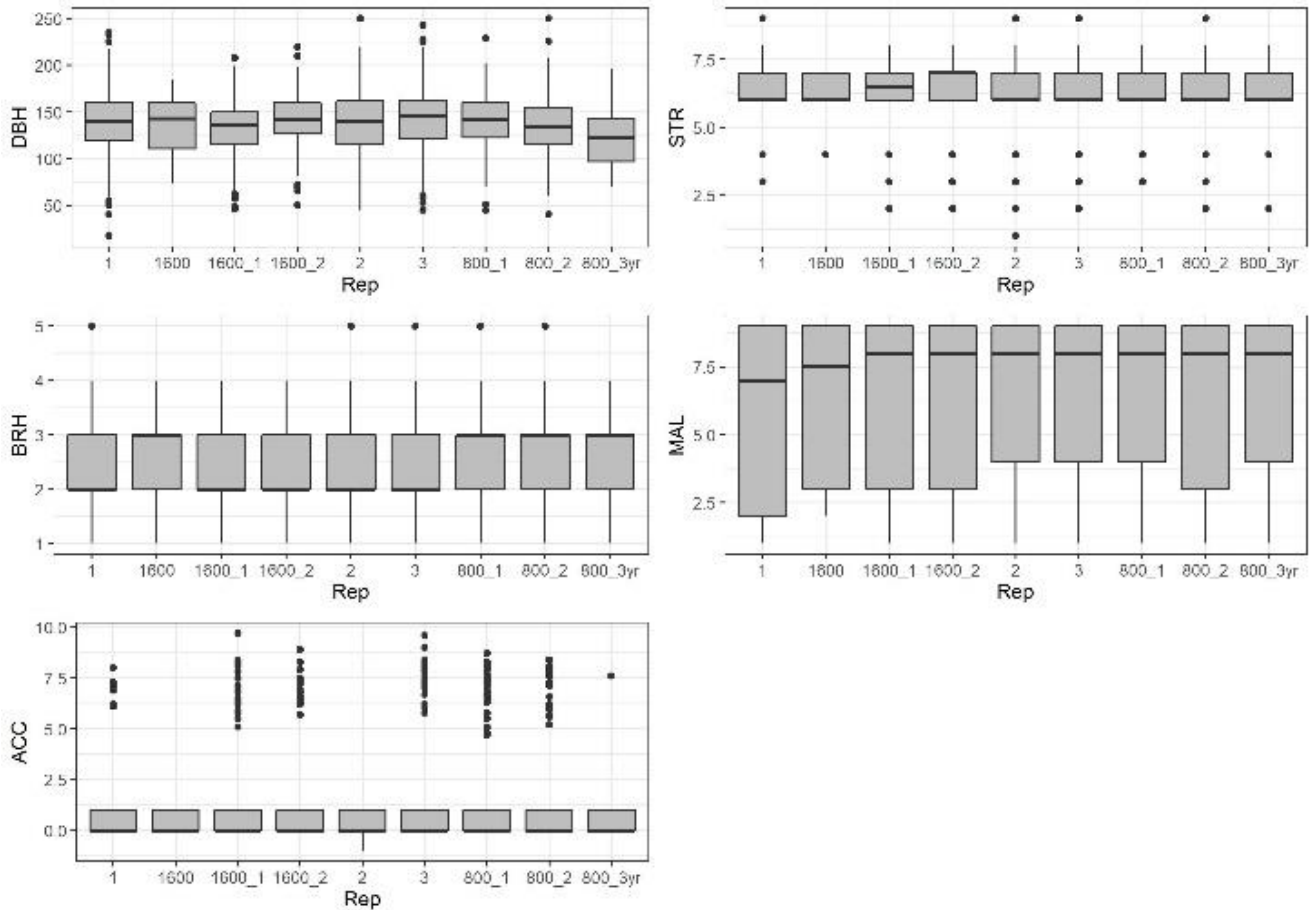


Figure 2: Distribution of attributes within each treatment at FR510/1



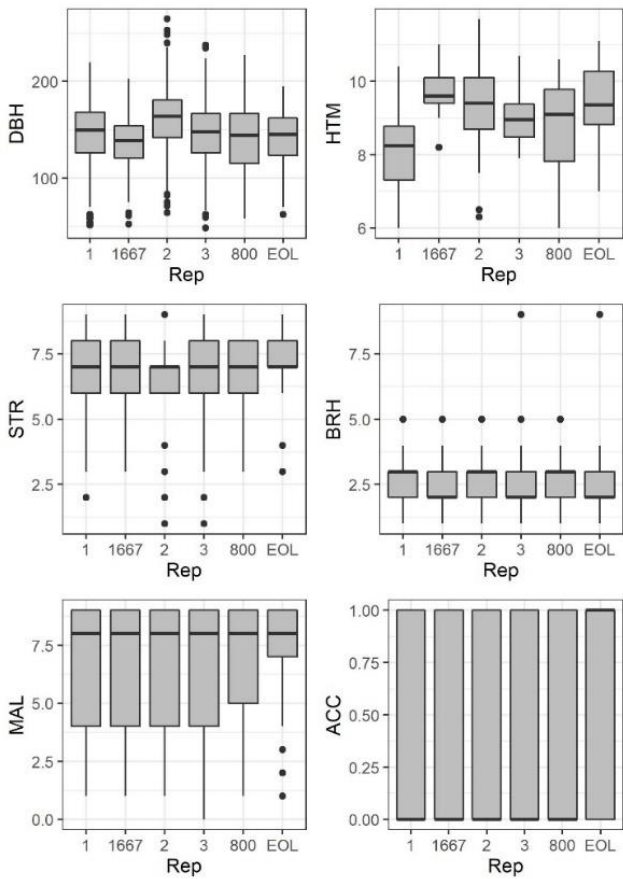


Figure 3: Distribution of attributes within each treatment at FR510/2

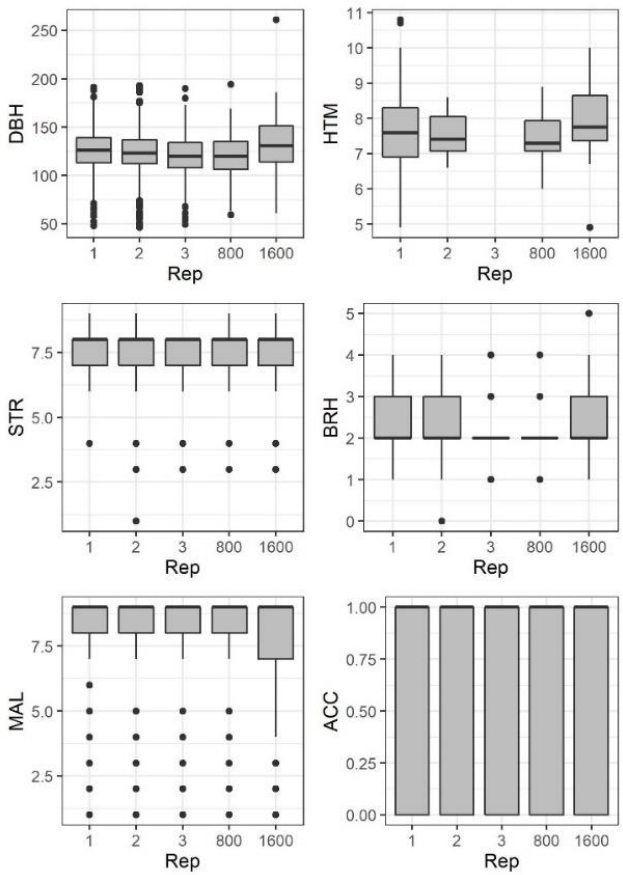


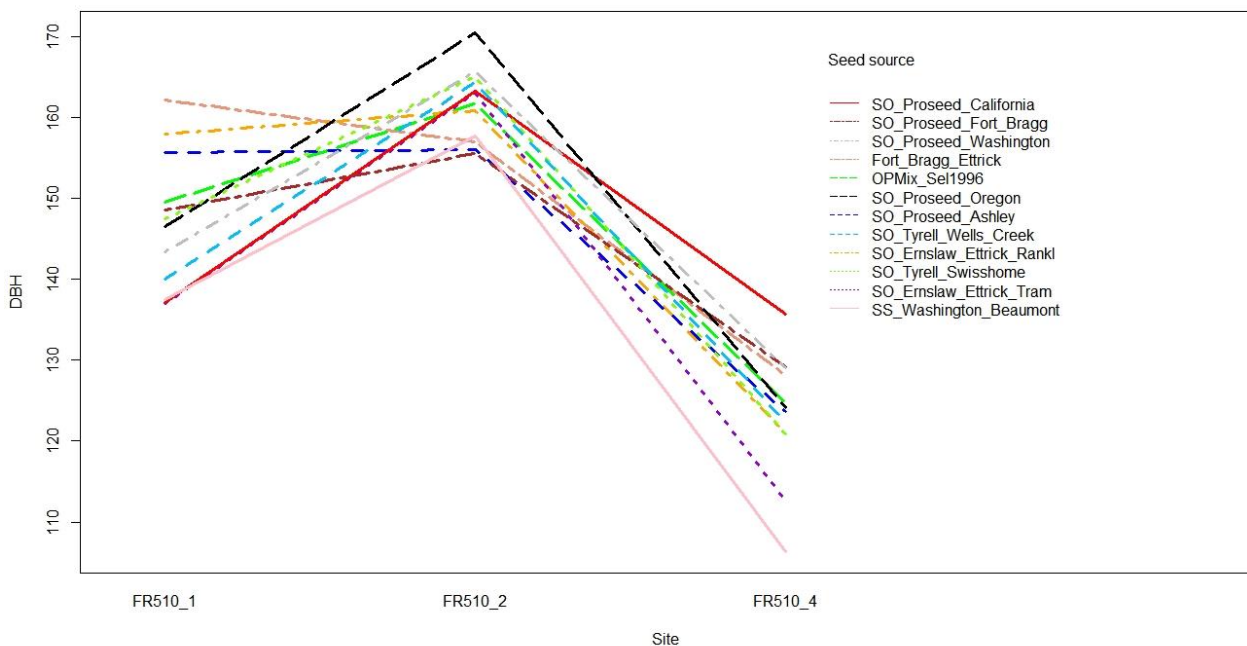
Figure 4: Distribution of attributes within each treatment at FR510/4

## Diameter at breast height (DBH)

At the Kaingaroa site, the seed source from Ernslaw One SO (Fort Bragg provenance) showed the highest realised genetic gain, while the seed source also from Ernslaw One SO (selection from Tramway) showed the lowest, with a difference of 25 millimetres between the two. In addition, the seed sources from Washington and California provenances produced the poorest results at this location. The shorter growing season of Washington provenances is likely to be responsible, while increased susceptibility to Swiss needle cast was the primary factor in California's provenances.

At the Blenheim site, the seed sources from Proseed SO (selections from California and Washington provenances) performed the best, probably due to a Swiss needle cast-free environment and selection for adaptability to New Zealand conditions. The lowest realised genetic gain was observed in seed sources from Ernslaw One SO and Tyrell SO, as well as a seed stand in Washington. The diameter at breast height difference between the best seed sources and the poorest seed sources was around 29 millimetres.

At the Dusky site, the seed sources from Proseed SO (selections from Oregon and Washington provenances) as well as Tyrell SO showed superior performance, while the seed sources from Proseed SO and Ernslaw One SO with Californian origin performed the poorest. However, there is only a 15 mm difference in DBH between the best seed sources and the poorest seed sources (Figure 5).



**Figure 5:** Ranking of seed source across sites for DBH



## Stem straightness (STR)

At the Kaingaroa site, the seed sources from Proseed SO (selections from Ashley and Oregon provenance) and Ernslaw One SO (selections from Fort Bragg provenance) showed the most realised genetic gain, while the open-pollinated mix from the 1996 progeny test showed the least. In addition, the seed sources from Tyrell SO were also ranked lower at this location.

At the Blenheim site, the seed sources from Proseed SO (selections from Ashley and California provenances) showed superior performance, while the seed sources from an open-pollinated mix from the 1996 progeny test and Tyrell SO showed the poorest performance in STR.

At the Dusky site, the seed sources from selections in Fort Bragg provenance coming from both seed orchards (Proseed SO and Ernslaw One SO) showed the highest realised genetic gain, while the open-pollinated mix from the 1996 progeny test and Tyrell SO performed poorly.

The Blenheim location had the highest STR score, indicating the overall best performance in stem straightness (Figure 6).

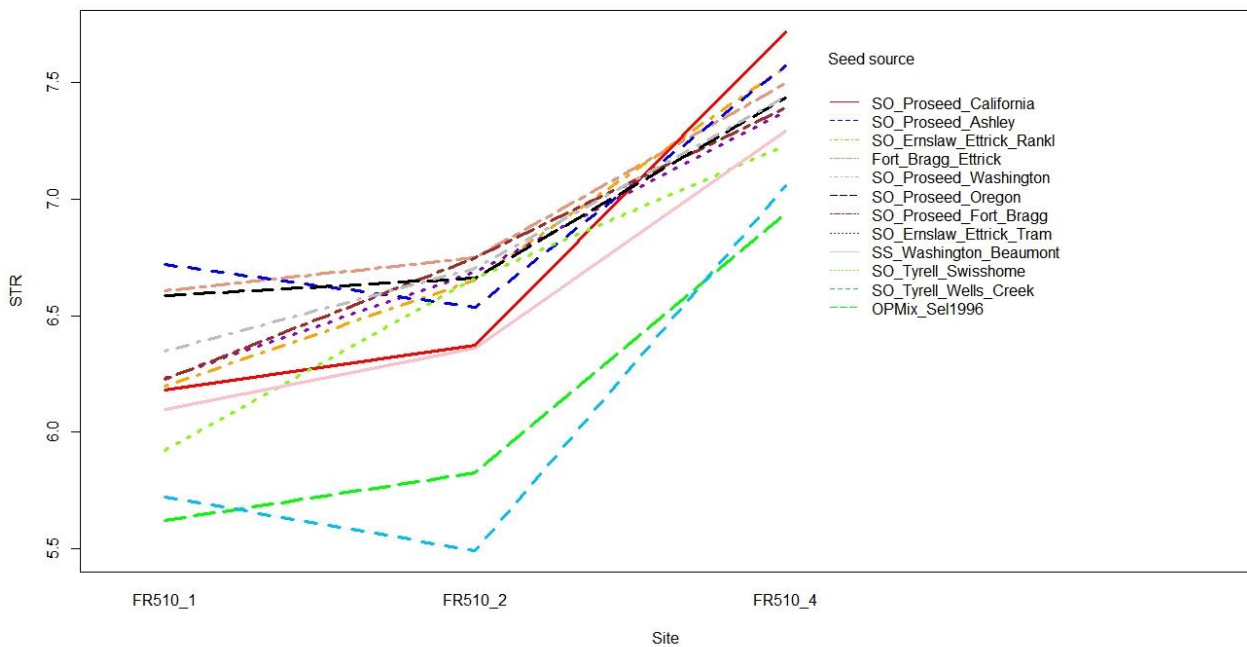


Figure 6: Ranking of seed source across sites for STR

## Branching quality (BRH)

At the Kaingaroa site, the seed sources from Proseed SO (selections from Fort Bragg provenance) and Ernslaw One SO (selections from Fort Bragg provenance) showed the highest realised genetic gain, whereas the seed sources from Proseed SO (selections from California provenance) showed the lowest realised genetic gain. In addition, the seed sources from Tyrell SO (Wells Creek) and the Washington seed stand showed the lowest genetic gain at this location.

At the Blenheim site, the seed sources from Proseed SO (selections from California, Fort Bragg, and Oregon provenances) showed the highest realised genetic gain, while the seed sources from Ernslaw One SO (selections from Tramway progeny test) and Washington seed stands showed the lowest realised genetic gain at this location.

At the Dusky site, the seed sources from Proseed SO (selections from Oregon, California, and Washington provenances) showed the highest realised genetic gain, while the seed sources from Tyrell SO (Swisshome area) and Proseed SO (selection from Ashley provenance) performed poorly.

The Blenheim location showed the lowest score from the BRH for its overall performance in this trait (Figure 7).

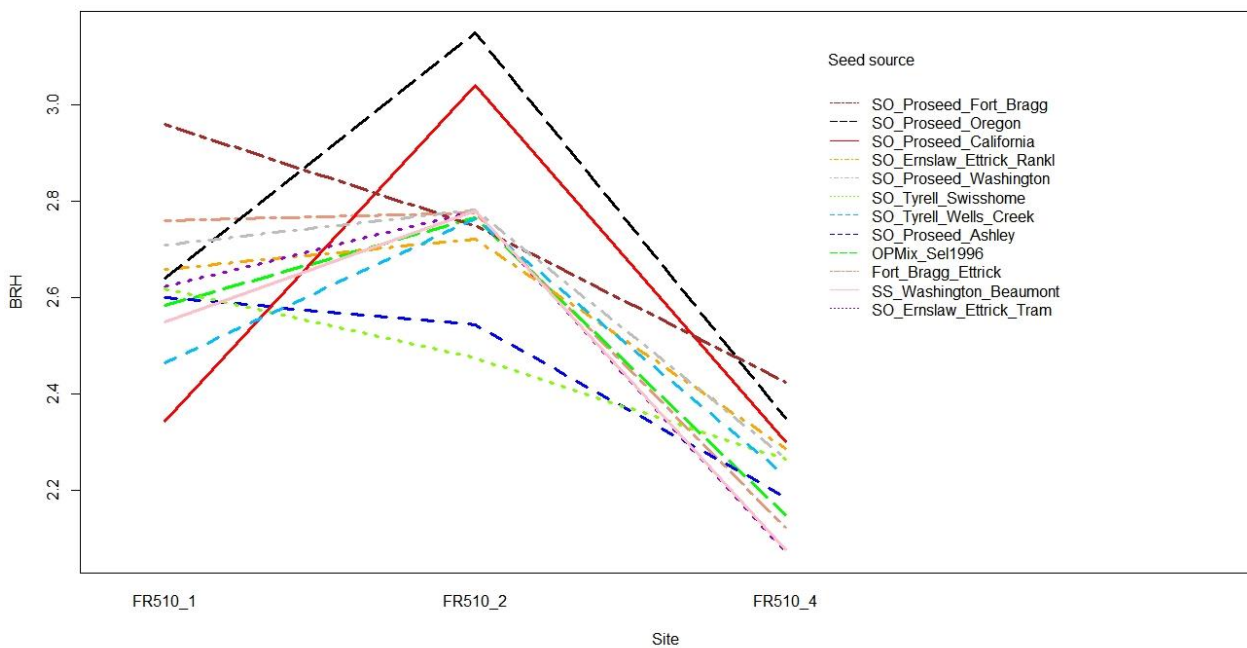


Figure 7: Ranking of seed source across sites for BRH

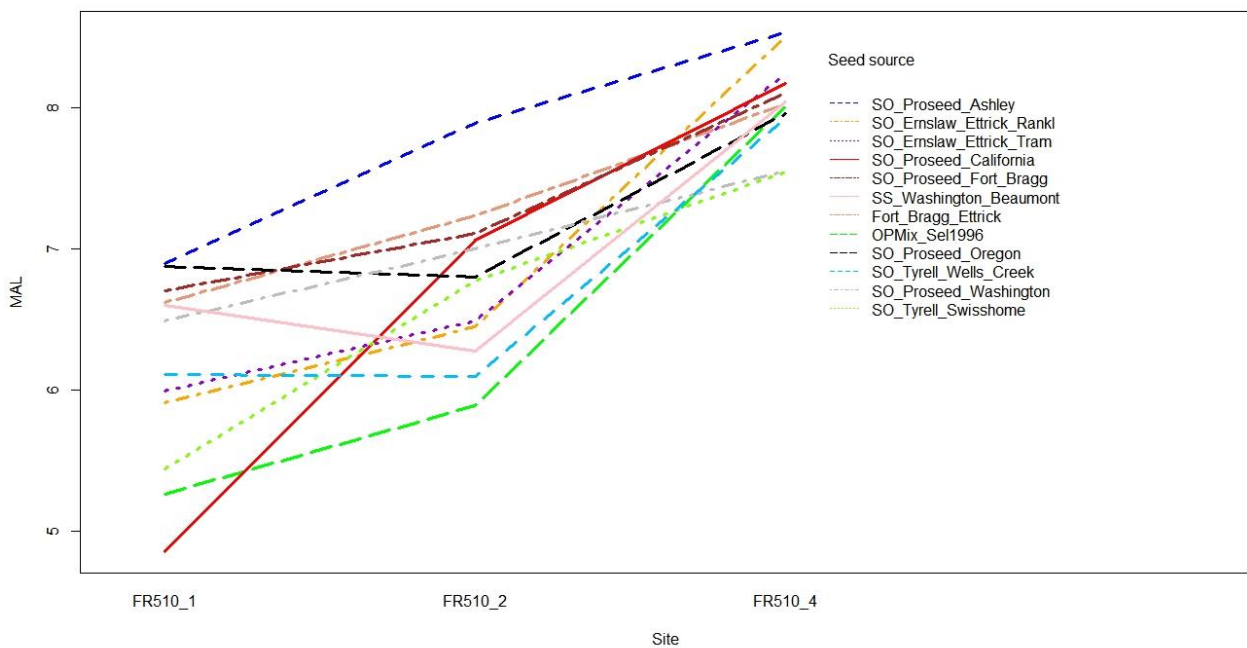
## Stem malformation

At the Kaingaroa site, the seed sources from Proseed SO (selections from Ashley, Oregon, and Fort Bragg provenances) showed the highest realised genetic gain, whereas the seed sources from Proseed SO (selections from California provenances) and open-pollinated mix from the 1996 progeny test showed the lowest.

At the Blenheim site, the seed sources from Proseed SO (selection from Ashley provenance) and Ernslaw One SO (selection from Rankleburn and Tramway) were found to have the greatest realised genetic gain. Seed sources from Tyrell SO (Swisshome) and Proseed SO (selections from Washington provenance) demonstrated the lowest realised genetic increase at this location.

At the Dusky site, the seed sources from Proseed SO (selections from Ashley provenance) and Ernslaw One SO (selection from Fort Bragg provenance) performed exceptionally well, while seed sources from open-pollinated seed from the 1996 progeny test and Tyrell SO (Wells Creek) performed poorly.

The MAL score indicates that the Blenheim location had the best performance overall. Additionally, the seed source from Proseed SO (selections from Ashley provenance) performed the best across all tested sites (Figure 8).



**Figure 8:** Ranking of seed source across sites for MAL

## Acceptability

At the Kaingaroa site, the seed sources originating from Proseed SO (selections from Oregon provenances) and Ernslaw One SO (selections from Fort Bragg provenance) had the highest realised genetic gain, while the seed sources originating from Ernslaw One SO (selections from Tramway) and Proseed SO (selections from California provenances) had the lowest realised genetic gain in ACC.

At the Blenheim site, the seed sources from Proseed SO (selections from Ashley provenance) and Ernslaw One SO (selections from Fort Bragg provenance) had the largest realised genetic gain, while the seed sources from Washington seed stands and Tyrell SO showed the lowest realised genetic gain at this location.

At the Dusky site, the seed sources from Proseed SO (selections from Fort Bragg provenance) and Ernslaw One SO (selections from Tramway) had the largest realised genetic gain, while the open-pollinated mix from the 1996 progeny test and Tyrell SO (Wells Creek) performed poorly.

The Dusky location had the lowest total ACC score since it had the poorest performance overall (Figure 9).

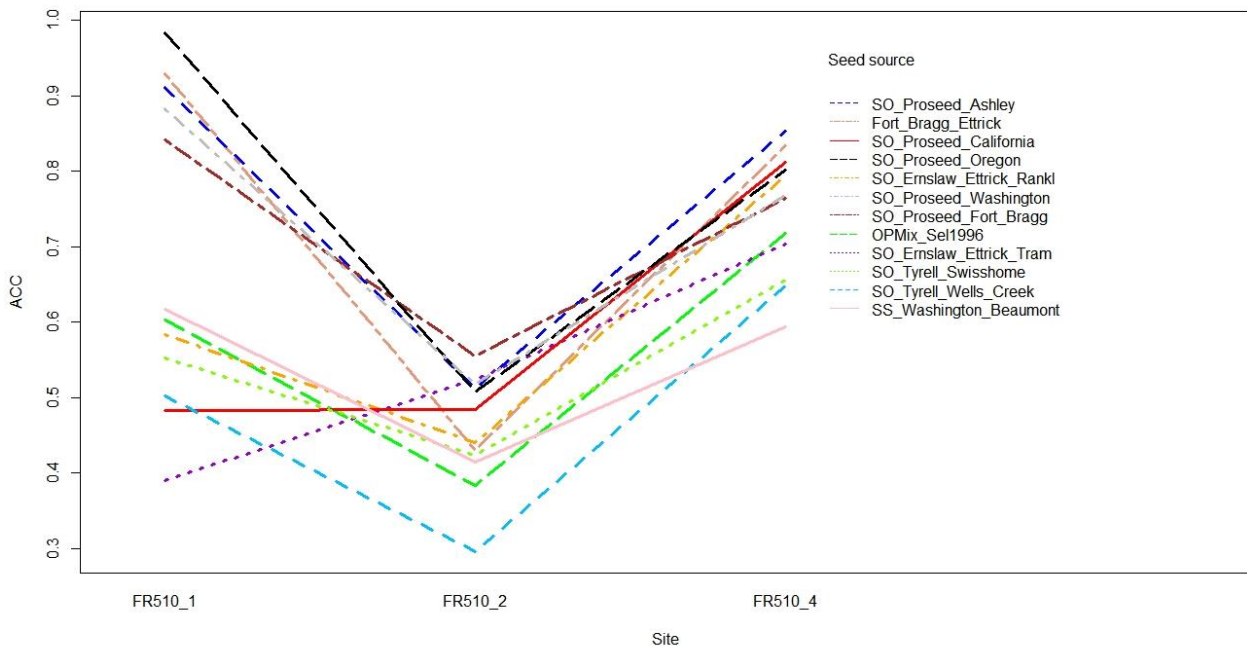


Figure 9: Ranking of seed source across sites for ACC

## CONCLUSION

The field experiments established within this genetic gain trial were designed to test not only genetic differences between seed sources but also the impact of silvicultural treatments in terms of initial stocking. The exploration of the data did not find any significant difference between the treatments at the ages of 9 and 10 years. As a result, the tests should be re-evaluated at a more advanced age when there will be more competition.

Regarding the productivity (DBH), the seed sources from Proseed and Ernslaw One seed orchards (selection from Fort Bragg provenance) showed the highest genetic gain on the North Island (Kaingaroa site), while the selections from California and Washington provenances resulted in the poorest performers. This was most likely due to a lack of growth time in Washington or sensitivity to a Swiss needle cast in California. Both of these factors may have contributed to the poor performance.

Seed sources from Proseed SO (selections from California and Washington provenances) showed superior performance in the northern part of the South Island (Blenheim site), along with seed sources from selections from the Fort Bragg provenance. Although seed sources from the Fort Bragg provenance outperformed in the Blenheim site, they performed the worst in the southern part of the island (Dusky site). This could be because of a mismatch between the phenology of the trees and the environmental conditions, which could have caused the trees to be damaged by late frost. The seed sources from the Washington seed stand material performed the worst at this location.

In the southern part of the island (Dusky site), the best seed sources were Proseed SO selections from Oregon and Washington provenances.

Regarding the stem form traits, the seed sources from Proseed SO (selections from Ashley, Oregon, California, and Fort Bragg provenances) and Ernslaw One SO (selections from California and Fort Bragg provenances) in the North Island showed the best performance in the North Island (Kaingaroa site), while the seed sources from Proseed SO (selections from California provenances) and the open-pollinated mix from the 1996 progeny test showed the poorest performance.

The seed sourced from Proseed SO (selection from Ashley provenance) demonstrated superiority in stem form traits in the northern part of the South Island (Blenheim site). Additionally, the seed sources from California provenances also showed superior performance at this site. The lack of a Swiss needle cast is most likely the reason for this achievement. At this location (the Blenheim site), the seed sources from Tyrell SO and Washington seed stands showed poor performance in terms of their stem form attributes.

Surprisingly, the seed sources from the Fort Bragg provenance supplied by both Proseed SO and Ernslaw One SO exhibited remarkable performance in stem form at the southern end of South Island (Dusky site), despite the fact that they had done badly in terms of productivity (DBH) at this site. The seed sources that originated from the open-pollinated mix from the 1996 progeny test, the Tyrell SO (Wells Creek) and Washington seed stands, had the weakest performance in terms of form attributes.

Regarding acceptability, the seed sources from Proseed SO (selections from Ashley, Oregon, and Fort Bragg provenances) showed high levels of acceptability in North Island (Kaingaroa site), whereas the seed sources from Ernslaw One SO (selections from Tramway) and Proseed SO (selections from California provenances) had the lowest.

In the South Island, the seed sources from Proseed SO (selections from Ashley, Fort Bragg, and California provenances) showed the best performance in the northern region (Blenheim site), as well as the seed sources from Proseed SO (selections from Fort Bragg, Washington provenances), and Ernslaw One SO (selections from Tramway) in the southern region (Dusky site). The seed sources from Washington Seed Stand and Tyrell SO performed the worst on the South Island.

## **ACKNOWLEDGEMENTS**

We would like to thank to Specialty Wood Partnership program for financial support of this study.



## **APPENDICES**

Appendix 1: Table of genetic gain realized by each tested seed source for each trait and site.

Please contact FGR for a copy of “Appendix 1 - Estimated breeding values.xls”