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THE GF AND GF PLUS CERTIFICATION SCHEME



RPBC
Radiata Pine Breeding Co Ltd
BREEDING QUALITY



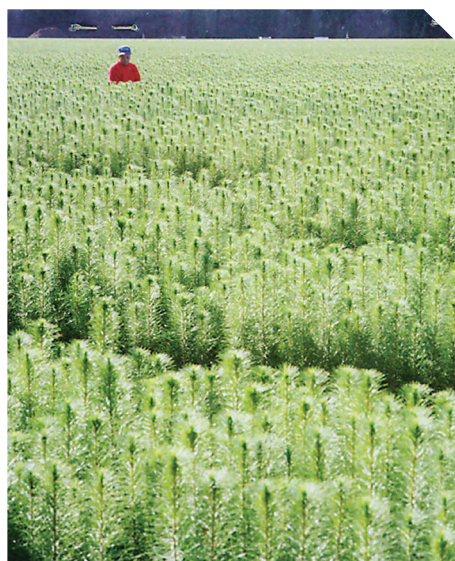
INTRODUCTION

The Radiata Pine Breeding Company Limited (RPBC), whose shareholders include major forest growing companies in New Zealand and Australia, has been working to improve the commercial value of radiata pine through breeding since the late 1980s. Although primarily aimed at providing improved germplasm to shareholders, RPBC also makes improved plants and trait rating information available to third parties on a commercial basis. Commercial seed and seedlings produced by open-pollination (OP) are sold under the **GF** trademark, and when produced by controlled pollination (CP) they are sold under the **GF Plus** trademark.

The genetic makeup of improved germplasm sold under the **GF** and **GF Plus** scheme (both **GF** and **GF Plus** are registered trademarks) and all information used in the testing and certification of improved seedlots is owned by the RPBC. Shareholders of RPBC have the right to use improved germplasm within their companies free of charge. In contrast, non-shareholding parties pay a royalty to RPBC at time of purchase of seed, seedlings, or cuttings, via the seed producer or nursery grower. These royalties are used to help fund on-going research into radiata pine genetic improvement.

HISTORY OF RATING GENETIC QUALITY

Initially, seed producers of radiata pine used terms such as select, seed orchard, elite and second generation to describe genetic improvement in their product.



By 1985 seed producers were selectively collecting from the better parents in seed orchards to increase genetic quality and produce seedlots for special-purpose end uses. As a result, the determination of comparative genetic quality became much more complex. In 1987 the New Zealand Forest Research Institute established the Seed Certification Service (SCS) and a

growth and form (GF) scale to rate seedlots. The **GF** rating worked on the basis that the higher the rating the greater the potential gains in growth and form (straightness) from genetic improvement.

The following years saw the **GF** system become widely accepted throughout the New Zealand forest industry. Over the same time period, there was a broadening of attention on developing and testing material for a number of specific tree growing and wood property traits in addition to growth and form. To make information on these traits available the **GF Plus** trait rating system was implemented in 1998.

THE GF AND GF Plus SCHEME

GF ratings, which relate only to OP seed, seedlings, and cuttings provide a single numerical value to describe increasing gains in stem diameter growth (volume) and form (straightness), with diameter growth weighted $\frac{2}{3}$ and form $\frac{1}{3}$. Thus GF7, GF14, and GF19 ascribed to different seedlots describe a series of increasing gain in these two combined traits.

The **GF Plus** scheme provides a rating for six different traits that is not confounded by any other trait. It provides the transparency required when

considering genetic options by giving the ability to examine trade-offs between traits. The six traits currently included within the **GF Plus** Scheme are listed below:

Growth - Diameter growth

Straightness - Stem straightness

Branching Habit - Branch incidence (uninodal to multinodal)

Wood Density - Average wood density

Spiral Grain - Incidence of significant spirality

Dothistroma resistance - Resistance to *Dothistroma* needle blight

Thus, the **GF Plus** scheme offers information on important additional wood property and disease resistance traits compared with only the growth and form rating of the earlier **GF** scheme. It is anticipated that other significant wood property traits will be introduced over time as more information becomes available. Corewood stiffness, on which a considerable body of information already exists, is most likely to be the next wood quality trait included.

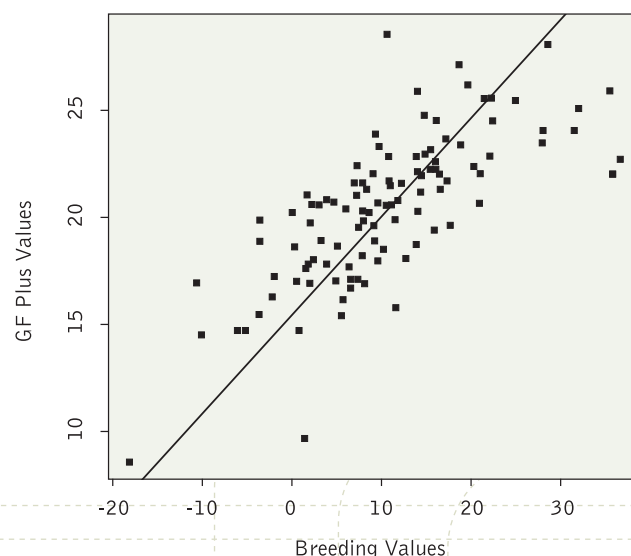
As stated, **GF Plus** ratings are currently provided only for CP seed, and seedlings or cuttings produced from CP seed. Increasing attention is now being given to the inclusion of Clones and OP seed into the **GF Plus** scheme.

HOW ARE GF Plus RATINGS DERIVED?

GF Plus values are based on Breeding Values (BVs) calculated according to audited procedures. Due to both the biological nature of the material and the addition of new data over time, the ranking of seed orchard parents can change over time. Moderate to large changes in BVs in any one ranking are carefully validated. Only the addition of data of appropriate quality is included in BV calculations.

Translation of BVs into **GF Plus** values has evolved over the last 20 years. During the early years of the **GF** scheme, ratings were regarded as somewhat qualitative. Since the introduction of the **GF Plus** scheme ratings are quantitatively based, although they are not intended to predict performance under any one site and regime combination. The Seed Certification System (SCS), which ascribes **GF Plus** values to seedlots, uses RPBC Breeding Values to calculate a **GF Plus** rating for an individual seedlot. Trait ratings are calculated using two major components:

1. Breeding value estimate for the trait
2. Proportional contribution of each parent to the seedlot



Example of conversion of Breeding Values to **GF Plus** values for growth

Estimates of Breeding Values are derived from RPBC progeny (performance) trials. Often the group of parents that make up a commercial seedlot have not all been tested in the same trial. In these instances, the Best Linear Unbiased Prediction (BLUP) technique adjusts the Breeding Value estimates and is a method for reducing the impact of variable age, site and unequal representation. **GF Plus** ratings for each parent are a linear transformation of the Breeding Values (see figure). The transformation allows **GF Plus** values to increase or decrease when new data is added. In those instances where information is insufficient to calculate a rating a hyphen (-) is shown on the **GF Plus** Seed Certificate.

GF and **GF Plus** ratings are derived differently. There is no direct correlation between a **GF** rating for a particular seedlot and its **GF Plus** growth and **GF Plus** straightness ratings. The **GF** rating is an amalgam of growth and form, while the traits are kept separate and ranked individually under **GF Plus**.

HOW DO THE RATING SCALES WORK?

The trait rating scale is open-ended. It was initially constrained to values between 1 to 30, but because of the need to add increasingly improved material the scale is now open ended and values can exceed 30 when Breeding Values are outstanding.

As tree breeding progresses and more advanced seedlots become available, higher trait ratings are achieved. Forest growers can use these **GF Plus** trait ratings to help them rank seedlots and determine the most suitable genetic material for their particular situation. For traits other than branching habit, higher ratings indicate better estimated performance of the trait. For example, a seedlot with a density rating of 23 will produce trees of higher density than a seedlot with a density rating of 18.

For branching habit, the higher the rating the more likely the seedlot will be multinodal. The **GF Plus** trait ratings for branching habit generally correlate well with internode index values used in silvicultural modelling software.

CAN RATINGS BE USED ACROSS ALL SITES?

GF ratings were initially national ratings applied to germplasm deployed throughout New Zealand, and in Australia. The performance of **GF** rated material across sites was initially validated using a national series of genetic gain trials which focused on broad-based seedlots. Results showed that for broad-based seedlots, such as GF 19, performance was stable over sites and **GF** ratings were a good predictor of performance.

As CP seed became available, more questions were raised over the stability of performance between sites. At the same time, additional traits were being introduced as the **GF Plus** scheme became established. Potentially, some of these traits could be less stable between sites than diameter and straightness. This concern was largely answered by ensuring that seedlots were comprised of at least six parents, such that combined performance over a range of site types was moderated to provide stability in performance.

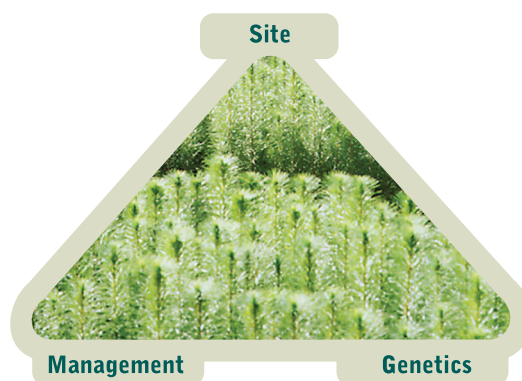
Although the trial base of the RPBC is expanding rapidly, there is always a concern as to how material will perform on sites that are outside the range of test sites from which Breeding Values are derived. In Australia, the performance of RPBC **GF**-rated OP seed has proved good for growth and superior to local seed sources for form. The RPBC has continued to expand its trial base over the last 5 years, and this will soon provide the opportunity for regionally-based Breeding Values and **GF Plus** values for both Australian and New Zealand members. An international demonstration trial series, testing the performance of the range of available **GF Plus** germplasm, was established between 2001 and 2003. This will test the performance and stability of RPBC

germplasm over a wide range of sites in most countries in which radiata pine is grown.

Forest growers are aware that the expression of different traits in radiata pine can vary greatly across forest sites independently of **GF Plus** ratings. For example, average tree wood density can vary by as much as 80 – 100kg/m³ between forest sites in Northland and Southland, New Zealand. These site-related effects provide the environmental background against which seedlots of different **GF Plus** rating will perform, and should be taken into account when seed and plant purchasing decisions are made.

HOW RELIABLE ARE TRAIT RATINGS?

As noted above, seedlots of six parents or more are likely to be relatively stable between sites. To refine deployment even further for single crosses and clones, Breeding Values (from which the ratings are derived) need to include site effects and reach a minimum level of reliability (a measure between 0 and 1). RPBC members now have access to Breeding Values and reliability estimates for progeny-tested parents and cross-tabs of progeny numbers in the trials where the parents are tested. During the last 5 years, a network of trials has been established on RPBC shareholder's estates which will provide reliable regional breeding value estimates. Stability of stock performance between forests within regions is considered to be the responsibility of the individual members.



From a commercial perspective, **GF Plus** trait ratings are for the seedlot described by the seed producer at time of application, using the parental proportions provided. They are an average for the seedlot as a whole and will not necessarily apply to part of the seedlot or each individual tree within the seedlot. The trait rating will also be compromised if parental proportions are changed (for example, through differential propagation from cutting stool beds or irregular germination). Ratings are based on forest trials, and trait performance does not necessarily become apparent in the nursery bed or in the first few years of forest growth. As a rule of thumb, trait ratings will generally begin to become apparent by age 5–6 in the forest. Genetics alone should not be considered as the key to successful forest growing, with site and stand management having a significant impact on actual results achieved. The use of the **GF Plus** scheme, through its ranking of genetic quality does, however, assist the forest grower in making informed decisions as to the most suitable planting stock for any particular situation.

DO GF Plus RATINGS CHANGE OVER TIME?

The basic data from which **GF Plus** ratings are derived are taken from forest trials spread throughout Australasia. This is an ongoing programme, with information continually being added to the database. Breeding Values are calculated each year in an externally audited process.

Breeding Values, from which the **GF Plus** values are derived, can change over time, due to both changes in the method of Breeding Value calculation and the addition of new data. Methodologies will also change over the next few years as regional effects are included in the breeding value calculations. Although either factor may cause rank changes, it is the policy of the RPBC to provide the most up to date information to users of the **GF Plus** scheme.



Controlled pollination

The RPBC thus has an expanding data set on which **GF Plus** values are based. The number of breeding parents (see table) and the data from progeny tested germplasm doubled between 1997 and 2006. In addition, within the next 8 years regional breeding values will be available for introduction into the **GF Plus** scheme.

Values / Traits	Diameter	Straightness	Branching Habit	Dothistroma Resistance	Wood Density	Spiral Grain
1997 BV's	1077	1077	1077	384	273	185
2006 BV's	2348	2348	2348	973	629	490
2016 BV's	3000	3000	3000	2000	1400	500

The top 600 breeding and the production population parents will have regional breeding values which will be integrated into the **GF Plus** scheme.

HOW DOES GF Plus WORK?

Seed producers apply to the SCS to have their seedlots rated. A **GF Plus** Seed Certificate rating the genetic potential of each trait is issued to the seed producer or clonal provider, along with a unique seedlot number. The seed producer then sells its seed and collects a royalty at time of sale from the purchaser. The spurchaser, usually a nursery grower or clonal provider, produces planting stock for deployment in the forest. Where the purchaser produces cuttings material, a Propagation Licence issued by the RPBC is required. The purchaser collects a royalty, equivalent to that paid on seed, when the cuttings are sold. When purchasing **GF Plus** planting stock the forest owner is entitled to a copy of the **GF Plus** Seed Certificate relating to the trees purchased. This certificate shows the individual trait ratings and other information as shown in the example.

A **GF Plus** Seed Certificate showing trait rating information is available from the nursery grower for each control-pollinated (CP) seedlot purchased. CP seedlots can be certified and rated under **GF Plus** as both the improved male and female parents used to produce the seedlot can be identified. In the case of open-pollinated (OP) seedlots, a **GF Plus** Seed Certificate is issued without trait information as only the improved female parent can be identified with certainty. A **GF** rating is still available for OP seedlots. In recognition of this, the royalty paid on OP plants is currently less than that paid on CP plants

GF Plus™ SEED CERTIFICATE

SEED PRODUCER:

DATE:

ORCHARD:

YEAR OF COLLECTION:

NUMBER OF PARENTS:

SEEDLOT NUMBER:

POLLINATION METHOD: CP

NUMBER OF CROSSES

Relying on the information provided by the seed producer this seedlot is rated as:

Pinus radiata

and individual trait ratings are:

GROWTH	STRAIGHTNESS	BRANCHING	DOTHISTROMA	WOOD DENSITY	SPIRAL GRAIN
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Proportion of seedlot rated:

Special Comments:

Manager:

Date:

An indication of the estimated ratings for an average unimproved seedlot is:

GROWTH	STRAIGHTNESS	BRANCHING	DOTHISTROMA	WOOD DENSITY	SPIRAL GRAIN
11	17	17	15	18	18

Ratings allocated are estimates of the seedlot average. They are developed from data that has differing levels of confidence, thus the more parents involved in a seedlot, the higher the confidence level of the rating. An asterisk(*) after a GF rating infers a less than average confidence level, and a hyphen (-) means that there was insufficient data available to estimate a rating.

When different seedlots are compared strictly under the same conditions the following will usually apply:
the higher the rating, the:
Better the expected average growth (diameter).
Better the expected average stem straightness.
More multinode branching habit of the seedlot.
Greater the resistance to Dothistroma.
Higher average wood density (juvenile wood).
Lower the average incidence of spiral grain.

IMPORTANT

The GF Plus™ trade mark, copyright in this GF Plus™ Seed Certificate and all other intellectual property used in the testing and certification of the seedlot described above ("Seed") and in the creation of, or pertaining to, this GF Plus™ Seed Certificate ("Intellectual Property") belong exclusively to the Radiata Pine Breeding Company ("RPBC"). Without limiting the terms of any terms of supply or licence between you and RPBC, you may not use the GF Plus™ trade mark, copy this GF Plus™ Seed Certificate or otherwise use the Intellectual Property to promote, advertise, distribute or sell any plants propagated by or for you from plants grown or derived from any of the Seed ("Plants") unless you have signed a licence to do so from RPBC. For purposes of clarification, propagated means the propagation of any plant by vegetative means (including, without limitation, tissue culture) for the purpose of producing multiple plants from a single plant.

If you wish to sell Plants, please contact the GF Plus™ Scheme Administrator on 0800 00 GFPLUS

See reverse for further information.

The Radiata Pine Breeding Company Ltd (RPBC) has 17 shareholding companies from Australia and New Zealand. RPBC is currently operated as a Consortium between shareholders and the Foundation for Research, Science and Technology. Shareholders have free access to all RPBC information, Breeding Values, and use of the GF and GF Plus Trademarks. Shareholders pay no royalties for deployment of RPBC germplasm on their own land for their own purposes.



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