

**GROWTH, STRAIGHTNESS and BRANCHING  
GFPLUS<sup>TM</sup> VALUES for SEEDLOTS  
in LARGE-BLOCK GENETIC GAIN TRIALS**

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This is an unpublished report and MUST NOT be cited as a literature  
reference.

## EXECUTIVE SUMMARY

The GF rating of a seedlot can be input into many of the New Zealand growth models in order to obtain predictions of growth for genetically improved seedlots. GF rating takes into consideration not only growth but also stem form, and separate genetic ratings for growth and form individually have been developed for use in the development of *GFPLUS<sup>TM</sup>* ratings. Use of a growth rating, rather than a GF rating, might improve predictions of increases in growth obtained from growth models.

This report documents the calculation of average individual trait breeding values for diameter, straightness and branching for the seedlots used in the genetic gain and silviculture/breed trials supported by the Stand Growth Modelling Cooperative (SGMC). The individual trait breeding values calculated for seedlots in the genetic gain trials have been converted to *GFPLUS<sup>TM</sup>* values and can be viewed as the best predictor of genetic worth at this particular point in time. Research is under way in the SGMC, to examine if use of these values as an alternative to GF ratings will improve predictions of growth of genetically improved seedlots.

This report is being used by both the SGMC and the New Zealand Radiata Pine Breeding Cooperative (NZRPBC). Both the individual trait breeding values and the *GFPLUS<sup>TM</sup>* values are reported to the NZRPBC, but only the *GFPLUS<sup>TM</sup>* values are reported to the SGMC.

## **INTRODUCTION:**

This report describes the calculation of average individual trait breeding values for diameter, straightness and branch cluster frequency for all seedlots used in the genetic gain and silviculture/breed trials supported by the SGMC.

GF rating can now be input into growth models, where genetic gain multipliers are altered to reflect a seedlot's growth potential (Carson et al. 1997). GF ratings are an indication of a seedlot's genetic potential for growth. GF, however, is calculated by taking into account not only growth potential, but also performance for stem form, with a weighting of two thirds for growth and one third for form. Growth potential is thus confounded with stem form performance in the GF rating.

Individual growth and form breeding values (BVs) have now been separated (Kumar et al. 1995, 1996, Turner et al. 1997a & b) and are expressed as a rating which is assigned to each parent. Ratings are being provided by the *Forest Research* Seed Certification Service, through the NZ Radiata Pine Breeding Cooperative *GFPLUS<sup>TM</sup>* scheme. These are in addition to the current GF ratings. Predictions from growth models may be better if a separate rating for growth is used as a 'cleaner' measure of a seedlot's growth potential. A seedlot rating for each trait; diameter (growth), straightness and branching, was obtained for all parents belonging to selection series '268', '850', '870', '875' and '880'.

## **DATA and METHODS:**

There are currently 45 trials (1269 plots) located throughout the country which are supported by the SGMC. The trials compare different seedlots (Appendix 1), silviculture and sites, and include a total of 50 different seedlots. More detailed parentage information for many of the seedlots are kept by the GTI section at *Forest Research*.

Individual trait BVs for seedlots of known parentage were calculated for diameter, straightness and branching as an average of parental BV, weighed by parental representation in a particular seedlot. Calculations of individual trait BVs were performed for each seedlot, unless specific parentage was not known (such as seedlots from open-pollinated seed orchards or of climbing select origin). In this case BV values calculated for control seedlots were used as representatives of the unknown pollen cloud, either as the actual value or as a component in the weighted average.

The control seedlot values are:

Control seedlot	GF	DBH	Straightness	Branching
Unimproved	2	-9.05	-1.62	-1.91
Climbing select	7	-2.97	-1.92	-1.69
OP seed orchard	14	-0.29	-0.22	-0.73

Seedlot breeding values ( $BV_s$ ) were calculated as follows:

$$BV_s = \frac{BV_m + BV_f}{2},$$

where

$$BV_m = \frac{\sum_i BV_{mi} w_{mi}}{\sum_i w_{mi}}$$

where  $BV_m$  is the weighted average of males,

$BV_{mi}$  is the breeding value of the  $i^{\text{th}}$  male parent,

$w_{mi}$  is the proportion of the pollen contributed by the  $i^{\text{th}}$  male, and

$$\sum_i w_{mi} = 1$$

$$BV_f = \frac{\sum_i BV_{fi} w_{fi}}{\sum_i w_{fi}}$$

where  $BV_f$  is the weighted average of females,

$BV_{fi}$  is the breeding value of the  $i^{\text{th}}$  female parent,

$w_{fi}$  is the proportion contributed by the  $i^{\text{th}}$  female, and

$$\sum_i w_{fi} = 1.$$

Breeding values for straightness and branching for long internode seedlot 9/0/83/99 could not be calculated because it is an '883' OP seedlot with parents which have not had BV calculated yet.

The BVs (actual values only available to members of the Radiata Pine Breeding Cooperative) for the seedlots in the genetic gain trials were converted by the *Forest Research* Seed Certification Service to the *GFPLUS*<sup>TM</sup> values.

## RESULTS:

The average *GFPLUS*<sup>TM</sup> values for diameter for the seedlots (ranging from GF2 to GF25) ranged from 11 to 28 (Table 1), with the long internode seedlots occurring within this range (from 15-16). Straightness *GFPLUS*<sup>TM</sup> values ranged from 16-22. The long internode seedlots occur in the lower half of this range (from 16-18), tending to be less straight than the improved seedlots and having similar values to the unimproved and climbing select seedlots. Branching *GFPLUS*<sup>TM</sup> values ranged from 16 to 23, for multinodal seedlots. As expected the branching *GFPLUS*<sup>TM</sup> values were considerably lower for the long internode seedlots, which ranged from 1-7. Table 1 also includes the calculated BV's for each seedlot.

There was a good relationship between individual trait BV and GF rating (Figures 1-3). The relationship between GF rating and diameter BV ( $R^2=0.891$ ) was much closer than for straightness ( $R^2=0.717$ ) and branching ( $R^2=0.338$ ), which was expected because diameter is weighted by twice as much as stem form traits in the GF rating system. The BVs for branching were very highly correlated ( $R^2=0.861$ ) with GF rating when the long internode seedlots were excluded.

## DISCUSSION:

Since genetic improvement has had an effect on growth, taking an improvement rating into account in growth models leads to better predictions of yield (Carson et al. 1997). Separation of growth and form ratings has removed the confounding influence of the genetic potential for good form from the genetic potential for growth. Individual ratings for form traits are highly but not perfectly related to GF rating. The utility of the seedlot diameter rating in predicting growth from genetic improvement using growth models may lead to more accurate predictions, and this is being investigated.

The average individual trait *GFPLUS*<sup>TM</sup> values calculated for seedlots in the genetic gain trials can be viewed as the best predictor of genetic worth for individual traits at this particular point in time. As new information from progeny trials is regularly accumulated and incorporated into breeding value estimates (carried out by the NZRPBC), predictions must be expected to be modified in order to be improved.

Because genetic effects are very small when compared with non-genetic environmental variation, *GFPLUS*<sup>TM</sup> values will always be predictions of performance with a level of error attached. Prediction of genetic worth will always contain a measure of uncertainty for a number of reasons. These include error around the breeding value estimates used to calculate the individual trait ratings (which arise from sampling error in progeny trials, site variation, genotype by environment interaction), measurement and data analysis errors, and uncertainty about paternity of open-pollinated seedlots. These errors are probably relatively small when compared with non-genetic environmental variation which is unavoidable with low heritability traits like growth.

An important seedlot in the genetic gain trials is seedlot '850-55x850-96' (rated GF22<sup>1</sup>). This is the only seedlot from which current estimates of genetic gain multipliers for higher rated seedlots have been derived. This seedlot is more highly rated for growth, but lower for straightness and branching when compared with a number of seedlots with higher GF ratings (Table 1). The growth potential of this seedlot appears to be greater than for some seedlots with higher GF ratings, however, it fits the growth curve well (Figure 1a). Projections of growth for seedlots with higher GF ratings should take this into account.

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<sup>1</sup> GF ratings have less precision than breeding values, some GF ratings are only subjective estimates.

## REFERENCES:

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- Kumar, S.; Carson, S.D.; Gea, L.D.; Burger, F.C.; Jefferson, P.A 1995. Best linear prediction of breeding values for stem diameter in a *Pinus Radiata* improvement programme. FRI Project Record No. 4885. Stand Growth Modelling Cooperative Report No. 43.
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- Turner, J.A., Carson, S.D.; Manley, B.R 1997a. The relationship of mean internode length to breeding values for branch cluster frequency. In Burdon, R. (ed.) "The Genetics of Radiata Pine" Meeting IUFRO Working Party, S2.02.19 (*Pinus radiata*, provenances and breeding). Conference 1-4 December 1997, New Zealand Forest Research Institute Ltd, Rotorua, New Zealand.
- Turner, J.A.; Carson, S.D.; Gea, L.D.; Grace, J.C.; Kumar, S 1997b. Transformation of breeding values for branch cluster frequency to enable comparison of internode length across selection groups. NZ Radiata Pine Breeding Cooperative Report No. 59.

**Table 1. Breeding values and *GFPLUS*<sup>TM</sup> values for growth, straightness and branching for seedlots in large-block genetic gain trials supported by the SGMC**

Seedlot	GF	DBH GF+	GF	STR GF+	GF	BRN GF+
88/101	2	9.6	2	17	2	16
R67/795	3	9.6	3	17	3	16
R74/1027	2	9.6	2	17	2	16
CY/C/75/51	8	14.2	8	16	8	17
88/102	6	14.2	6	16	6	17
CY/C/75/40	7	14.2	7	16	7	17
FRI79/2320	7	14.2	7	16	7	17
NN/C/75/2	7	14.2	7	16	7	17
RO/C/76/1	7	14.2	7	16	7	17
SD/C/75/27	7	14.2	7	16	7	17
SD/C/76/2	7	14.2	7	16	7	17
WN75/15	5	14.2	5	16	5	17
88/105	14	16.5	14	17	14	19
FRI78/2299	14	17.4	14	18	14	21
3/3/80/2	14	17.5	14	19	14	21
3/3/83/2	14	17.5	14	19	14	21
3/3/85/1	14	17.5	14	19	14	21
3/3/87/1	14	17.5	14	19	14	21
WN76/2	14	17.5	14	19	14	21
WN68/A1	13	17.7	13	18	13	21
2/3/87/34	16	18.3	16	17	16	21
'850' polycross	14	18.5	14	20	14	19
2/6/86/27	16	18.7	16	17	16	21
2/6/86/29	19	18.8	19	18	19	21
88/6	16	18.8	16	18	16	22
88/201	16	18.9	16	17	16	21
9/4/80/11	17	19.0	17	19	17	22
2/6/87/35	19	19.0	19	18	19	21
9/0/83/96	17	19.3	17	21	17	23
2/3/84/53	17	19.4	17	18	17	22
9/0/83/91	16	19.5	16	19	16	23
FRI78/2300	18~	20.7	18~	20	18~	23
6/6/87/21	22	21.1	22	21	22	23

\* Implies that less confidence should be placed on the GF rating, due to the fact that only a small number of parents have contributed to the seedlot mix.

~ This seedlot has been considered to be equivalent to a GF14 for previous growth modelling (see SGMC Report No. 35)



**Table 1. Cont.**

<b>Seedlot</b>	<b>GF</b>	<b>DBH GF+</b>	<b>GF</b>	<b>STR GF+</b>	<b>GF</b>	<b>BRN GF+</b>
6/3/86/46	21	21.2	21	21	21	23
89/708	25	21.3	25	22	25	23
NZFP 268	21	21.4	21	21	21	23
90/294	25	21.8	25	21	25	23
88/1	25	21.9	25	21	25	23
88/2	23	22.0	23	20	23	23
88/7	18*	24.7	18*	18	18*	21
850-55x850-96	22*	25.5	22*	19	22*	22
6/6/87/20	25	27.1	25	21	25	23
88/4	25	27.5	25	21	25	23
<u>Long internode seedlots</u>						
88/868	6(LI27)*	14.5	6(LI27)*	16	6(LI27)*	6
3/3/87/3	7(LI20)	14.5	7(LI20)	16	7(LI20)	6
9/0/83/95	10(LI20)	14.7	10(LI20)	16	10(LI20)	6
9/3/86/170	9(LI23)	15.3	9(LI23)	16	9(LI23)	5
9/0/83/99	11(LI25)	15.5	11(LI25)	na	11(LI25)	na
FRI78/2301	8(LI19)	16.4	8(LI19)	18	8(LI19)	7
9/3/86/166	13(LI28)	17.7	13(LI28)	18	13(LI28)	1
89/15	13(LI25)	18.7	13(LI25)	16	13(LI25)	5

\* Implies that less confidence should be placed on the GF rating, due to the fact that only a small number of parents have contributed to the seedlot mix.

**Special Purpose Breeds Trials Seedlots – DBH GFplus values only**

<b>Seedlot</b>	<b>GF</b>	<b>DBH GF+</b>
91/523	18	3.3
870 cross	18	3.4
875/268 mix	18	3.9
875/268 mix	25	8.5
91/296,297 mix	27	11.8
91/294	28	13.3
850x268	30	15.1

## Appendix 1.

### Seedlots in large-block genetic gain trials supported by the Stand Growth Modelling Cooperative

Seedlot	GF	Trials	Seedlot composition
2/3/84/53	17	FR 57	Kaingaroa (Top 25 "268" )
2/6/86/27	16	FR 10	Kaingaroa ("268")
2/6/86/29	19	FR 7	Kaingaroa (Top 16 "268")
2/3/87/34	16	FR 55	Kaingaroa ("268")
2/6/87/35	19	FR 57	Kaingaroa (Top 16 "268")
3/3/80/2	14	FR 58	Gwavas ("850" 25 clone)
3/3/83/2	14	RO 1897	Gwavas ("850" 25 clone)
3/3/85/1	14	FR 7,8,9,10,11,12	Gwavas ("850")
3/3/87/1	14	FR 54,56	Gwavas ("850")
3/3/87/3	7	FR 57	Tikokino "870", LI20
6/3/86/46	21	FR 7,8,9,10,11,12	Amberley (CP "268" best clones)
6/6/87/20	25	FR 85	Amberley (CP 850.55 x Top16)
6/6/87/21	22	FR 54,55,56,85	Amberley (CP "268" x Top16)
850-55x850-96	22*	AK 1058, CY 421 NN 530/2 RO 2103/1,2 SD 564, WN 377	850.55 x 850.96 (40%) + 850.55 x average top 25 850's (50%) + average top 25 850's (10%)
88/1	25	FR 84	Amberley ("268" 7 of Top 16 x Top 16) - seedlings
88/1 RC	25	FR 77,78	Amberley ("268" 7 of Top 16 x Top 16) - root trainer cuttings
88/1 RS	25	FR 77	Amberley ("268" 7 of Top 16 x Top 16) - root trainer seedlings
88/101	2	FR 77,78,84,85,86	Ngaumu Bulk
88/102	6	FR 121/8-13	Kaingaroa & Rotoehu - 5 unimproved seedlots
88/105	14	FR 121/1-13	Gwavas, Kaingaroa & Waimahia - 9 "850" OP seedlots
88/2	23	FR 85,86	Amberley B+C "268" x Top 16
88/2 OC	23	FR 77,78	Amberley B+C "268" x Top 16 - open grown cuttings
88/201	16	FR 121/1-13	Brightwater "268" (Baigents)
88/4	25	FR 85	Amberley 850.55 x Top 16 "268" - low wood density
88/6	16	FR 84,85,86	Gwavas + Kaingaroa "850"+"268"+"875"
88/6 OS	16	FR 77,78	Gwavas + Kaingaroa "850"+"268"+"875"- open grown seedlings
88/7	18*	FR 85	Kaingaroa 850.55 OP - low wood density
88/868	6*	FR 86	Tikokino 4 of "870" OP, LI27
89/15	13	FR 121/1,2,3,5,6 FR 121/8-13	Tikokino 7 of "870", LI25
89/708	25	FR 121/1-7	Amberley "268" 8 of Top 16 x Top 16
90/294	25	FR 121/8-13	Amberley "268" 12 of Top 16 x Top 16
9/0/83/91	16	RO 1897	Bulked "268" crosses - FRI seed
9/0/83/95	10	RO 1897	Tikokino "870" OP (best 20 clones)

\* Implies that less confidence should be placed on the GF rating, due to the fact that only a small number of parents have contributed to the seedlot mix

Seedlot	GF	Trials	Seedlot composition
9/0/83/96	17	FR 54,55,56 RO 1897	Kaingaroa "268" bulked OP seed (best 25 clones)
9/0/83/99 #	11	RO 1897	Bulked "883" OP seed - 2nd generation long internode
9/3/86/166	13	FR 7,8,9,10,11,12	Control pollinated "870" long internode (best 5 clones) LI28
9/3/86/170	9	FR 54,56	Open pollinated "870" long internode (best 5 clones) LI23
9/4/80/11	17	RO 1897	GTI 268x875 ESSO Trial - cuttings
CY/C/75/40	7	CY 421	Balmoral climbing select
CY/C/75/51	8	SD 682	"850" Canterbury clones
FRI78/2299 *	14	NN 530/1, SD 682 RO 2103/3	"875" Diallel crosses
FRI78/2300 ~	18	NN 530/1, SD 682 RO 2103/3	"268" Polycross
FRI78/2301	8	NN 530/1, SD 682 RO 2103/3	"870" Polycross , LI19
FRI79/2320	7	FR 7,8,9,10,11,12 FR 121/1,2,3,4,6,7 RO 1897	Kaingaroa climbing select
NN/C/75/2	7	NN 530/2	Golden Downs climbing select
NZFP 268	21	FR 8	"268" Top 16 NZFP
R67/795	3	RO 972	Kaingaroa Felling Select
R74/1027	2	AK 1058, CY 421 NN 530/2 RO 2103/1,2 SD 564, WN 377	Kaingaroa Bulk
RO/C/76/1	7	AK 1058 NN 530/1 RO 2103/1,2,3	Kaingaroa Climbing Select
SD/C/75/27	7	SD 564	Rankleburn Climbing select
SD/C/76/2	7	SD 682	Rankleburn Climbing select
WN75/15	5	WN 377	Ngaumu Climbing select
WN68/A1	13	RO 972	Gwavas ("850" 14 clone)
WN76/2	14	AK 1058, CY 421 NN 530/2 RO 2103/1,2 SD 564, WN 377	Gwavas ("850" 14 + 25 clone)
'850' polycross	14	AK 1056, CY 597 NN 529, RO 2098	"850" Polycross - seedlot number yet to be assigned Average of all '850' clones for mother 10 individual '850' pollen parents

# no breeding values available for the '883' long internode series

\* this seedlot is inbred and has not been used to calculate the genetic gain multipliers

~ this seedlot has been considered to be equivalent to a GF14 for previous growth modelling ( see SGMC Report No. 35)

Figure 1a.

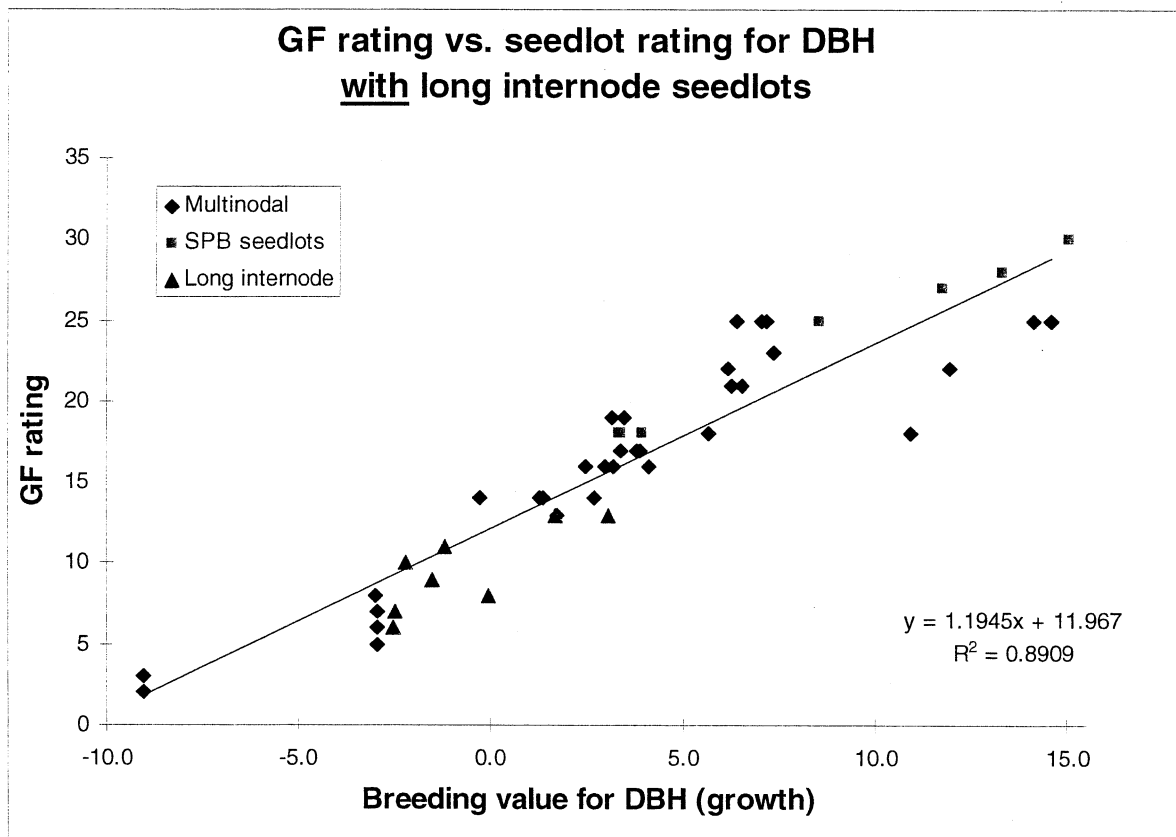


Figure 1b.

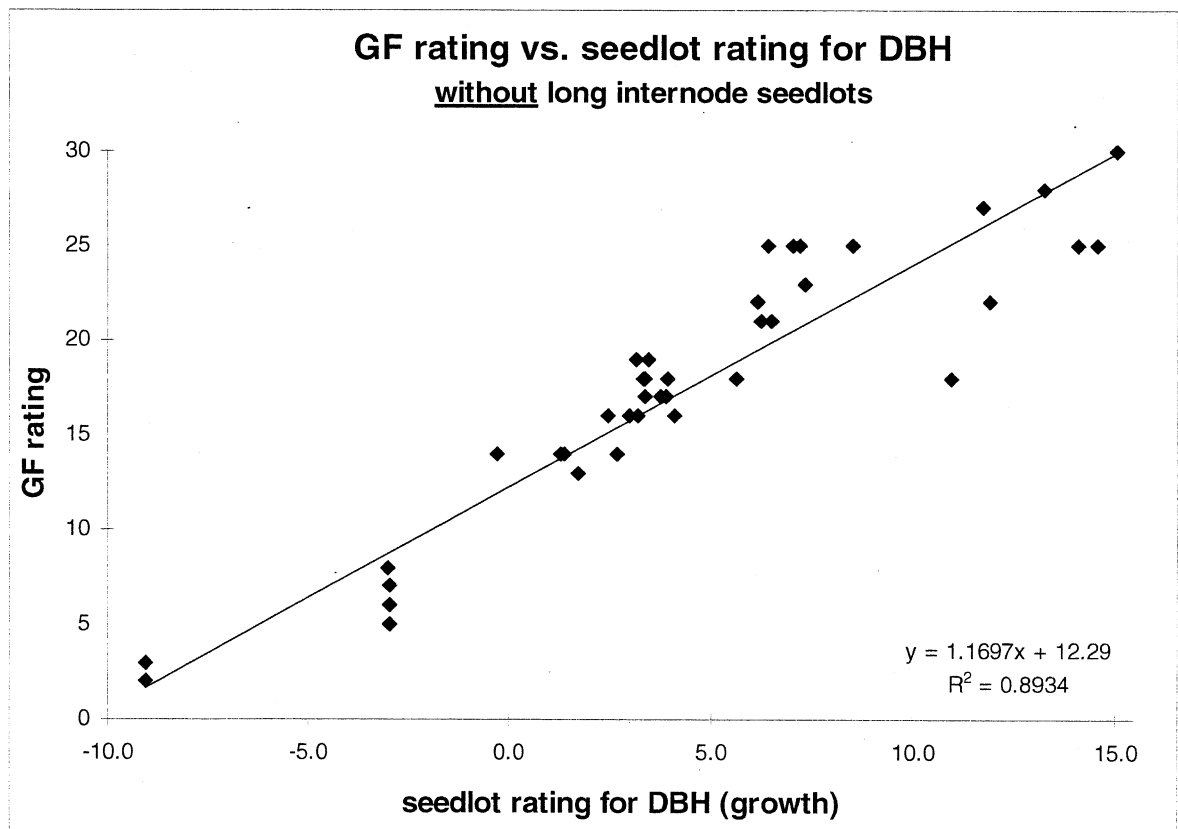


Figure 2a.

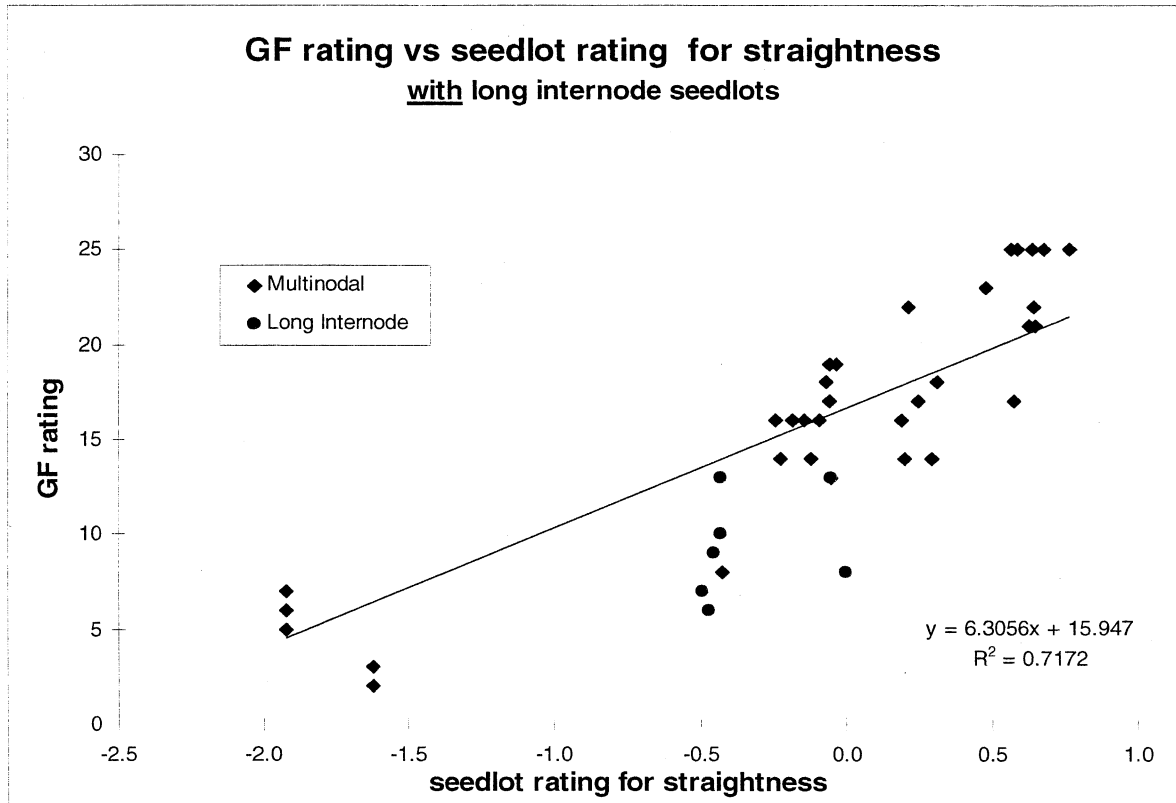


Figure 2b.

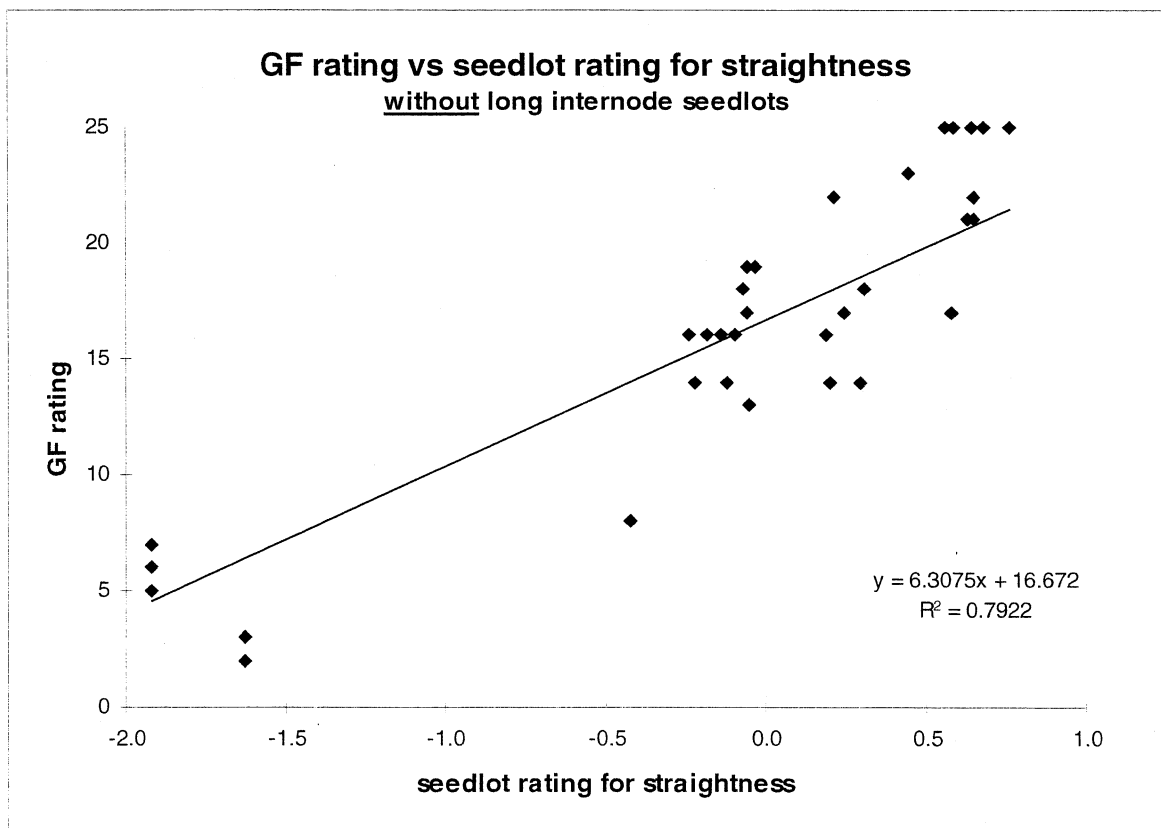


Figure 3a.

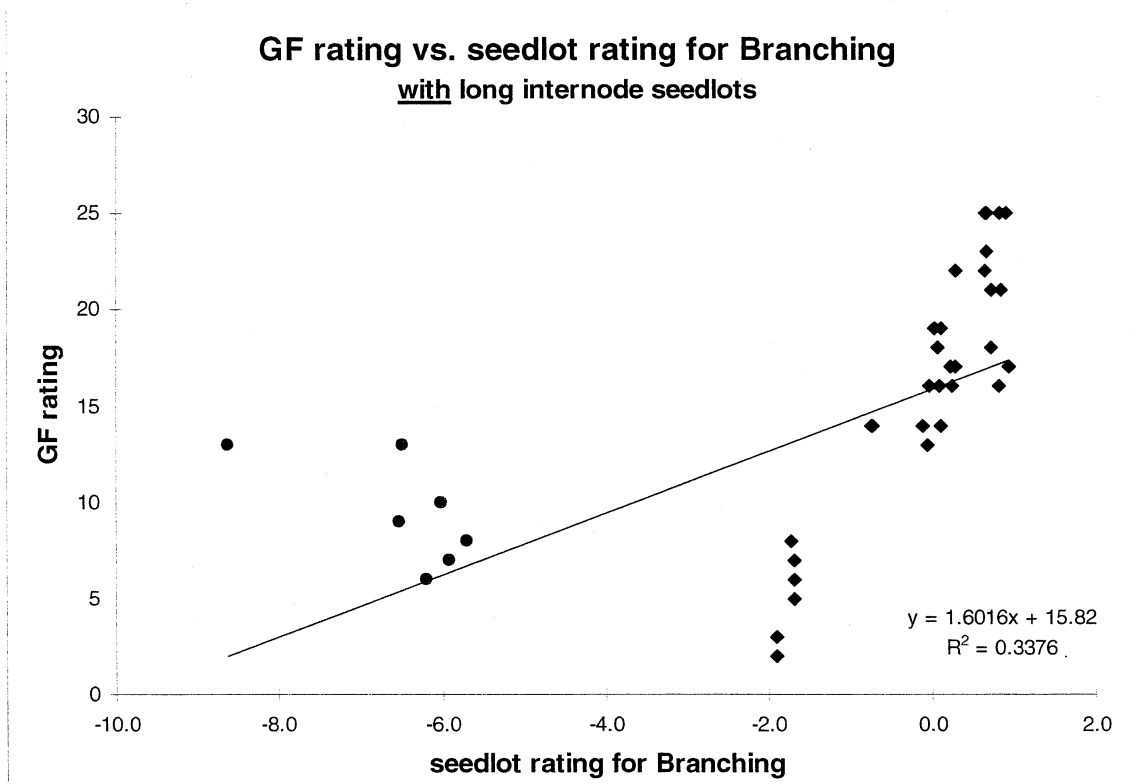


Figure 3b.

