Growth and Disease Tolerance in Selected Progenies of *Pinus radiata* (D. Don) in Kenya

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ABSTRACT

Five progeny trials of *Pinus radiata* were established at Timboroa, Nabkoi, Sabor and Kaptagat areas in the Rift Valley between 1985 and 1996. The objective of these trials was to determine the growth and disease tolerance levels among selected germplasm at different sites. One trial at Timboroa was 22 years and comprised 59 progenies introduced from Australia and one general collection seedlot. The trials at Sabor and Nabkoi were 17 years and comprised 38 progenies introduced from New Zealand and 6 progenies from local selections. The other trial at Timboroa was 16 years and comprised 24 progenies from New Zealand and one progeny from local selection. The 11 year old trial at Kaptagat comprised 12 locally selected progenies. In each of these trials, randomised block design was used with four blocks. Six trees from each progeny were planted per plot. Analysis of the data collected in 2007 show a significant variation in diameter at breast height (dbh), height and disease score in four out of five trials (p=0.5). Ranking of progeny performance was done on the basis of height growth. The best performing of the 22 year old Australian material at Timboroa was progeny number 9 with a mean height and dbh of 27.8 m and 31.6 cm respectively. Mean disease score on this progeny was 1.8 on a scale of 1-5 where 1 is least infected and 5 is most infected. The best result among the New Zealand material at 17 year was shown by progeny number 24 at Nabkoi where the mean height, dbh and disease score was 29 m, 31.6 cm and 1.3 respectively. The eleven year old trial at Kaptagat with local material did not show statistically significant difference among the progenies but the best performing group was progeny 7 with mean height, dbh, and disease score of 20.2 m, 19.4 cm and 1.8 respectively. Ranking of growth performance and disease tolerance levels of the progenies enabled the identification of the best performers at each site and recommendations made on their inclusion in further tree improvement programmes and germplasm/site matching to achieve maximum productivity of the species for supply of industrial wood.

Key words: Pinus radiata, growth, selection, disease tolerance, germplasm, progeny

INTRODUCTION

Pinus radiata (D. Don) is a fast growing high altitude plantation species which does well at altitudes between 1800 m to 2800 m above sea level and rainfall ranging from 1000 mm to 2200 mm per year. It can grow in a variety of soils but performance is best on deep volcanic soils (FAO, 1980). The tree attains a height of 30-50 m and diameter at breast height of 50 cm when grown to sawn timber rotation of 25-30 years in Kenya (Dyson, 1977). The main economic importance is production of timber, plywood, pulp and paper. It was first introduced in Kenya in 1927 (Dyson 1977) and became one of the major plantation species accounting for 25% of the total softwood plantations during the period 1942-1969. However, large scale planting of the species was suspended by the Forest Department in 1969 due to its high susceptibility to a needle blight disease caused by *Dothistroma pini* fungus (FD 1969). The fungi attacks pine needle foliage leading to reduction in growth and in severe cases death of the susceptible trees. The government ban on large scale planting of the species is still in force. The main concern on this species is the development of sustainable disease control strategies.

Early disease control measures tried in the 1970's involved aerial spraying of young trees with copper based fungicides. However, this method although successful in New Zealand, Australia, and other places (Carson 1989), was found to be unsustainable in Kenya due to high costs of the chemicals and environmental concerns arising from the effect of chemicals sprayed on large fields. A programme on developing disease resistant or tolerant genotypes of *P. radiata* was initiated as the best option for controlling the disease and thereafter reintroducing the planting of disease tolerant genotypes in appropriate sites on large scale. Under this programme new *P. radiata* germplasm was introduced in the country from Australia and New Zealand. They were planted at various trial sites alongside locally selected germplasm to determine growth and disease tolerance levels among them.

MATERIALS AND METHODS

Five progeny trials of *Pinus radiata* were established at Timboroa (2 sites), Nabkoi, Sabor and Kaptagat areas in the Rift Valley between 1985 and 1996. They comprised 59 progenies introduced from Australia, 38 from New Zealand and 12 selected locally from existing populations. Randomised block design was used with four blocks in each trial. Six trees from each progeny were planted per plot and replicated in each block per trial. The trees were spaced at 2.75x2.75m giving 1320 stems per ha. The plots were raised through shamba system and assessed for growth and disease severity annually until age 5 and every 5 years thereafter. Details of these trials are shown in Table 1.

Table 1. Particulars of *P. radiata* experiments assessed

P. radiata trial number	Code	Experiment site	Age (yrs) in 2007	No. and source of germplasm
Kefri EP145-1985	Aus. Timb. 1985	Timboroa	22	59 Australia, 1 local
Kefri/PRP/1/1990	NZ. Sabor 1990	Sabor	17	38 New Zealand, 6 local
Kefri/PRP/2/1991	NZ. Nabkoi 1991	Nabkoi	16	38 New Zealand, 6 local
Kefri/PRP/3/1991	NZ. Timb. 1991	Timboroa	16	25 New Zealand
Kefri/PRP/4/1996	Local. Kapt. 1996	Kaptagat	11	12 Local selection

Assessments carried out in 2007

All the five experiments were assessed in 2007 for height (ht) using a suunto clinometer, stem diameter at breast height (dbh) using a diameter measuring tape, *Dothistroma* needle blight disease severity assessment was based on visual examination of brownness of the crown foliage and assigning an appropriate score on a scale 1 to 5 with the corresponding infection levels as shown in table 2.

Table 2. Criteria of Scoring for *Dothistroma* disease severity in *P. radiata*

Disease severity score	Level (%) of browning of foliage/tree
1	0-25
2	25-50
3	50-75
4	75-100
5	Tree dead

Data Analysis

Analysis of variance was done on the data collected in 2007 for each experiment separately and ranking of progeny performance on the basis of height was done. In order to have a measure that combines both dbh and ht, it was necessary to compute mean volumes of the progenies using the model;

$V=0.01722+0.0001937d^2+0.00005069dh+0.00002296d^2h$ which was developed by Wanene and Wachiuri, 1975. V=tree volume (m^3), d=stem diameter at breast height (cm), h= tree height (m).

Growth rates in terms of mean annual increment (MAI) and projected annual productivity per hector were calculated.

RESULTS

Growth characteristics and disease severity levels

The means of parameters assessed in all the five experiments were ranked on the basis of progeny mean height in a descending order of performance in each experiment (Tables 3-7).

Experiment, Kefri/EP145-1985, at Timboroa with Australian germplasm

For 22 year old Australian germplasm at Timboroa, (Table 3), progeny 9 had the best result with means of 27.8 m, 31.6 cm and 1.8 for height, dbh and disease severity score respectively. The poorest performing was progeny 39 with ht, dbh, and disease score of 18.9 m, 14.3 cm and 2.0 respectively. The mean ht, dbh, and disease score for all the progenies in the experiment were 22.9 m, 25.3 cm, and 2.2 score respectively. Analysis of variance showed a significant difference in all the three parameters (p=0.05).

Table 3. The best ten and worst three progenies in terms of mean heights of 22 year old Australian germplasm at Timboroa

Rank of progeny based on height	Progeny	Height (m)	Dbh (cm)	Disease score
1	9	27.8	31.6	1.8
2	3	27.3	39.8	1.5
3	37	26.8	31.2	1.8
4	58	25.3	27.3	1.7
5	19	25.2	34.0	2.8
6	50	25.0	27.8	1.8
7	4	24.9	28.2	2,1
8	26	24.7	29.7	1.8
9	57	24.5	27.5	2.0
10	14	24.4	29.6	2.0
57	59	19.0	18.0	3.0
58	56	19.0	17.0	3.0
59	39	18.3	14.3	2.0
	Mean	22.9	25.3	2.2

Std deviation	5.3	9.4	0.9
Variance	28.1	88.4	0.8

Experiment, Kefri/PRP/1/1990, at Sabor with New Zealand germplasm

The best performing progeny in this trial at age 17 was number 49 with mean ht, dbh, and disease score of 25.0 m, 35.0 cm, 2.0 score respectively (Table 4.). The worst performing progeny was 17 with ht, dbh, and disease score of 13.0 m, 10.4 cm, 4.0 respectively. Overall performance showed means as follows: ht, 17.4 m; dbh of 19.5 cm and disease score 2.7. Analysis of variance showed a significant difference in the three characteristics at p=0.05.

Table 4. The best 10 and worst three progenies by ht of the 17 year old New Zealand germplasm at Sabor

Rank of progenies based on by height	Progeny	Ht (m)	Dbh (cm)	Dis. sco
1	49	25.0	35.0	2.0
2	20	21.0	26.3	3.3
3	28	20.6	23.6	2.6
4	42	20.5	25.3	1.8
5	45	20.2	26.4	2.1
6	6	19.2	19.3	2.0
7	38	19.1	24.5	2.0
8	39	19.0	31.6	2.1
9	14	19.0	22.3	2.3
10	46	18.7	25.0	2.3
38	12	14.0	7.7	3.8
39	33	13.3	11.5	3.0
40	17	13.0	10.4	4.0
Total	Mean	17.4	19.5	2.7
	Std Deviation	5.2	13.1	1.1
	Variance	27.0	171.1	1.2

Experiment, Kefri/PRP/2/1991 at Nabkoi, with germplasm from New Zealand

The best result in the 16 year old trial was progeny 24 with ht, dbh, and disease score of 29.0 m, 31.7 cm, and 1.3 respetively (Table 5). Progeny 22 was worst performing with ht, dbh, and disease score of 17.1 m, 18.2 cm, and 2.6 respectively. The overall mean performance of this plot across the progenies was 21.2 m height, 21.2 dbh and 2.7 disease score. Anova showed a significant difference between progenies in Dbh and ht but an insignificant difference in disease score(p=0.05).

Table 5. The best ten and worst three progenies according to ht of 17 year old New Zealand germplasm at Nabkoi

Rank of progenies based on height	Progeny	Ht (m)	Dbh (cm)	Dis. sco
1	24	29.0	31.7	1.3
2	48	26.2	29.4	2.0
3	19	23.9	25.3	2.4
4	46	23.7	22.7	2.5
5	11	23.5	25.4	1.5
6	2	23.3	24.0	2.9
7	4	23.0	33.8	1.6
8	50	22.9	27.8	2.3
9	21	22.6	23.5	2.7
10	27	22.5	23.3	2.7
42	26	17.9	18.3	2.7
43	34	17.4	18.3	3.1
44	22	17.1	18.2	2.6
Total	Mean	21.2	21.2	2.7
	Std. Deviation	6.0	10.4	1.1
	Variance	36	108.6	1.2

Experiment, Kefri/PRP/3/1991 at Timboroa, with germplasm from New Zealand

The 16 year old trial showed progeny 9 to be the best performing with ht, dbh, and disease score of 21.7 m, 19.9 cm, and 2.5 respectively (Table 6). Worst performer was progeny 4 with ht, dbh, and disease score of 14.4 m, 10.9 cm and 3.2 respectively. Mean performance for the plot were dbh 18.7 m ht, 18.6 cm dbh and 2.7 disease score. Anova showed a significant difference between the progenies for all the traits at p=0.05.

Table 6. The best 10 and worst three progenies ranked on basis of height of 16 year old New Zealand germplasm at Timoroa

Rank of progenies based on height	Progeny	Ht (m)	Dbh (cm)	Dis. Sco
1	9	21.7	19.9	2.5
2	34	21.3	22.0	3.4
3	25	21.1	24.1	2.3
4	26	20.4	21.9	3.0
5	21	19.9	19.2	2.5
6	13	19.9	18.7	2.5
7	30	19.9	17.8	2.6
8	24	19.8	21.3	1.5
9	10	19.7	19.9	2.9
10	18	19.6	20.2	2.7

	23	20	16.1	18.0	3.2
	24	11	15.9	18.9	3.1
	25	4	14.4	10.9	3.2
Total		Mean	18.7	18.6	2.7
		Std. Deviation	6.7	9.7	1.3
		Variance	44.9	94.1	1.7

Experiment, Kefri/PRP/4/1996, at Kaptagat with locally selected germplasm

The 11 year old trial with locally selected germplasm had progeny number 7 being the leading in performance with mean ht, dbh and disease of 20.2 m, 19.4 cm and 1.8 score respectively. Progeny 12 was the worst performer with ht of 14.3 m,, and dbh of 12.1 cm, and disease score of 3. The mean performance of the plot was 17.8 m, 15.6 cm, and 2.5 score for ht, dbh, and disease severity respectively. Anova showed no significant difference between the progenies at p=0.05.

Table 7. Ranking of progeny means according to height of 11 year old trial at Kaptagat composed of local material

Rank of progenies based on height		Progeny	Ht. (m)	Dbh(cm)	Dis. score
1		7	20.2	19.4	1.8
2		6	19.6	17.2	1.9
3		1	19.3	19.7	1.7
4		2	18.8	17.1	2.5
5		8	18.6	16.6	2.4
6		10	18.1	17.3	2.8
7		4	18.0	16.3	2.4
8		11	17.2	13.1	2.8
9		5	17.0	13.3	2.9
10		9	16.8	13.1	2.9
11		3	15.0	12.7	3.2
12		12	14.3	12.1	3.0
Total	Mean		17.8	15.6	2.5
	Std. Deviation		5.4	7.8	1.1
	Variance		29.2	60.8	1.2

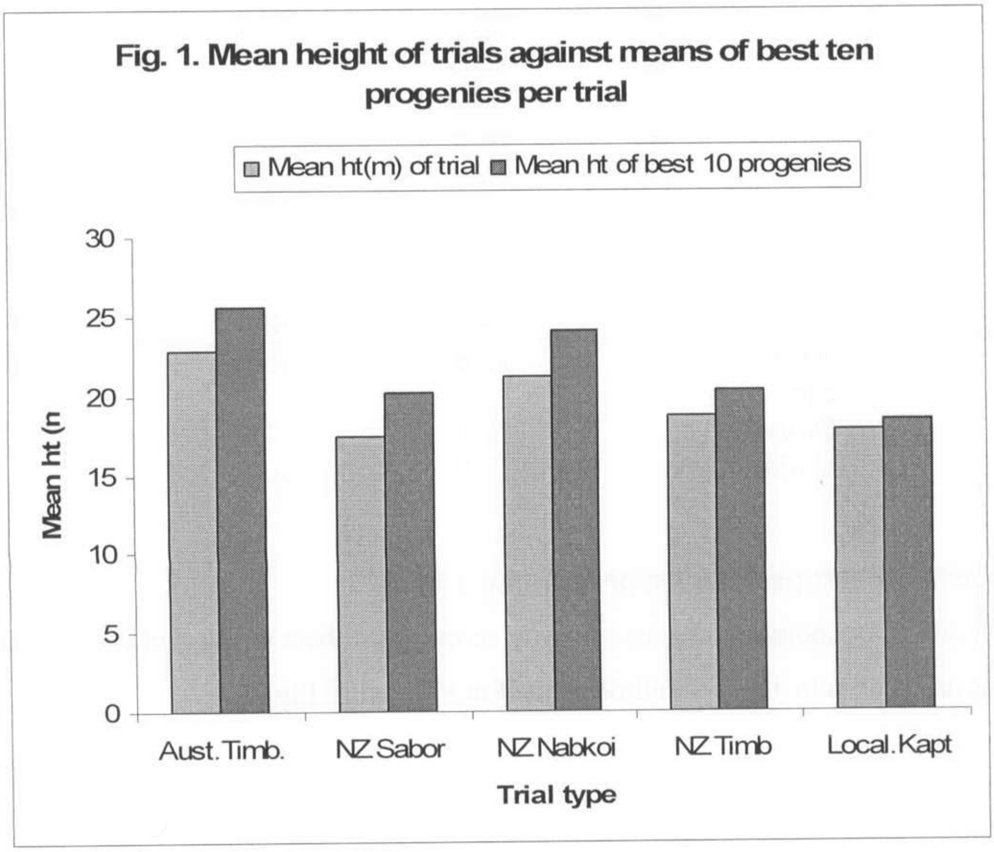
Mean height growth of best performing progenies per trial

The mean height and corresponding disease severity score of the best ten progenies compared to the trial means are shown in Table 8 and illustrated in Fig. 1 and Fig. 2.

Table 8. Mean height growth and disease levels of the progenies in each trial and the means of the best ten progenies at each trial (in brackets)

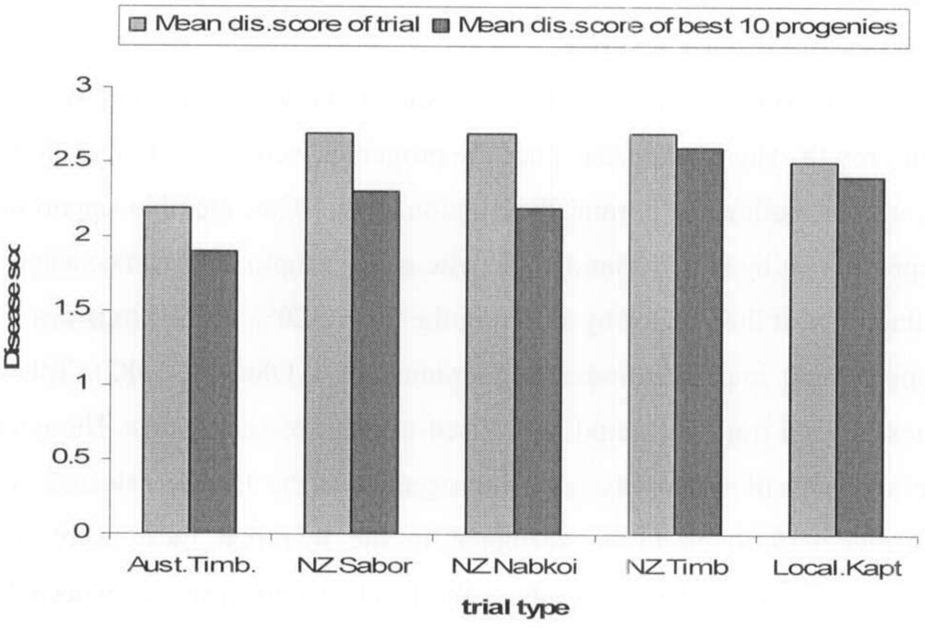
Trial No.	Age	Mean ht (m) of trial; (mean of best10 in brackets)	Mean disease score of the trial; (mean of best 10 in brackets)
Australian Timboroa 1985	22	22.9 (25.6)	2.2 (1.90
New Zealand Sabor 1990	17	17.4 (20.2)	2.7 (2.3)
New Zealand Nabkoi 1991	16	21.2 (24.1)	2.7 (2.2)
New Zealand Timboroa 1991	16	18.7 (20.3)	2.7 (2.6)
Local Kaptagat 1996	11	17.8 (18.4)	2.5 (2.4)

A comparison of the mean height of the best ten progenies relative the mean of the whole trial is as shown in Fig 1. below.



The mean disease scores for the ten most tolerant progenies against the mean of the rest of the trial is illustrated in Fig. 2.

Fig. 2. Mean disease score of trials against mean disease score of ten best progenies



Productivity of the best material in the trials

The overall projected productivity of the top 20% of the germplasm in the five trials is as shown in Table 9. On average, the New Zealand progenies at Nabkoi have the potential to achieve a mean annual increment (MAI) of 0.0407 m^3/tree/year followed by Australian progenies which can achieve 0.0378 m^3/tree/year. The best progenies from the local material can achieve 0.0238 m^3/tree/year.

Table 9. Average potential productivity of the best 20% of the progenies in the five trials

Trial	Germplasm source	MAI (m^3/tree/year)
Aus.Timb.1985	Australia	0.0378
NZ.Sabor.1990	New Zealand	0.0278
NZ.Nabkoi.1991	New Zealand	0.0407
NZ.Timb.1991	New Zealand	0.0225
Local.Kapt.1996	Local	0.0238

DISCUSSION AND CONCLUSION

Growth characteristics and disease severity

The progenies introduced from Australia and New zealand show a significant variation in diameter and height growth. This is expected since the progenies were half-sib open pollinated germplasm whose output assumes a normal distribution curve. Considerable opportunity is offered for tree improvement by such variation. Genetic gains of upto 20% can be achieved in improving the productivity of the species by selecting the top 10-20% of the progenies in such a trial and developing them into seed orchards (Burdon, 2001; Olembo, 1982). Tables 3-7 identifies progenies in each trial that could be utilised to achieve such gains. The relatively good performance and lack of variability among progenies in the locally selected material (experiment; Kefri/PRP/4/1996) could be attributed to the fact that these were superior material from already selected mother trees where the level of uniformity is expected to be high. Mbinga (2002), Burdon et al. 1992, and Bail and Pederick (1989) found similar results when working with different pines of selected stock. Diameter and height growth were negatively correlated with disease severity as demonstrated by the lower disease scores in progenies that show bigger height and diameter measurements. This too is consistent with Mbinga (2002) findings on a different *P. radiata* experiment in Timboroa. Site too plays an important part in growth and disease reaction as shown by different ranking of the same progenies from New Zealand at three different sites of Sabor, Nabkoi and Timboroa. The performance at Nabkoi site is better than the rest. However, the growth of *P. radiata* in these trials was found to be lower than the growth of selected *Cupressus lusitanica* (Miller) and *Pinus patula* , the dominant plantation species in Kenya. The mean height and dbh of selected *C. Lusitanica* is 25.1 m, and 36.7 cm respectively while selected *P. patula* has mean height and diameter of 25.7 m and 40.7 cm respectively when the trees are between the ages of 15 and 23 years (Mbinga 2006). By contrast, selected best performing *P. radiata* progenies between age 16 and 22 have a mean height and dbh of 22.5 m and 26 cm respectively.

Productivity of *P. radiata*

Hoef (2003), reported that the average productivity of *radiata* pine in Victoria, Australia was 18 m^3/ha/year, with more than 30 m^3/ha/year achievable on good sites. The author also reports that in New Zealand growth rates of over 50 m^3/ha/year have been recorded. A selection of the best 20% of the progenies in the five trials in this paper show potential growth rates which achieve productivity ranging from 30 m^3/ha/year to 54 m^3/ha/year. This result is therefore comparable to, and in some cases higher than the growth rate of *P. radiata* obtained in those two leading *P. radiata* growing countries. In conclusion, these series of experiments has shown that the trials contain both new germplasm and local selections which have acceptable growth rates and sufficient level of tolerance to *Dothistroma* disease. Those high performing progenies have been identified and should be included in seed development programmes.

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