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ABSTRACT*

Four mature stocking trials in Kaingaroa Forest were compared, by assessing selected treatments with MARVL. This technique avoids many of the uncertainties involved in predictive models such as STANDPAK. The treatments selected were those that most closely resembled a modern "direct" regime – early thinning to final stockings, and pruning to 6 m.

There was a significant height reduction (of up to 3 m) at stockings below about 350 stems/ha. Lower stockings resulted in reduced total volume and volume of small-branched logs, but increased volume of large branched logs. Pruned volume was largely unaffected by stocking (except at very low stockings), with higher stockings having more pruned logs and a smaller piece size.

The mean diameter of the fattest 100 stems/ha was clearly influenced by stocking, the trend being apparent at all stocking levels from 100 stems/ha to 700 stems/ha.

Due to lack of within-trial replication, it was not possible to identify the stocking that yields the greatest profit to the grower or the greatest revenue at harvest.

A COMPARISON OF FINAL CROP STOCKINGS IN MATURE STANDS AT KAINGAROA FOREST

Piers Maclaren
Exotic Forest Management

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INTRODUCTION

The concept of "optimum final crop stocking" is meaningful for direct regimes, but less so for regimes that incorporate one or more commercial thinnings. The "optimum" stocking can be defined as that which gives the greatest expected benefit to the grower on a single hectare basis. Naturally, other factors (eg estate considerations, market risk, understorey effects, etc) may override this optimum. Neither will the optimum be the same for different growers - differing sites, costs, price estimates, discount rates, etc, will result in different optima. Nevertheless, an examination of biological data may enable one to narrow down the range of stockings under consideration.

There have been several attempts to calculate "optimum" final crop stocking (eg Fenton and Sutton, 1968; Maclaren, 1989) but these have relied largely or partly on the use of predictive models. With such models, there is always the suspicion of bias, whereby one stocking extreme is unduly favoured. This distrust of predictive models is reinforced in situations where the output of one prediction is the input of another. For example, in STANDPAK the volume per hectare of a given log grade will depend on branch index predictions, which currently rely on basal area at age 20. This is predicted by growth models, which are dependent on estimates of site index... .

MARVL inventory of mature stands obviates the need for prediction. The Method for the Assessment of Recoverable Volume by Log Types is described by Deadman and Goulding (1978), and shown to be capable of providing "good estimates of total recoverable volume and volume by different log sorts" (Manley et al, 1987).

It is apparent that MARVL will be used increasingly for a direct comparison of treatments in regime trials, whenever these trials reach maturity.

BACKGROUND

Four trials were selected to fulfil the following criteria:

1) Maturity. The trials were 28-30 years old, thus avoiding the need to predict absolute and relative changes in quantitative and qualitative parameters.
2) Time of thinning. In order to most closely resemble a modern "direct" regime, treatments were selected that involved an early thinning to final stockings.
3) Pruned height. All trees were pruned to approximately 6 m (still a common practice), with the exception of very high stockings, where a few followers remained.
4) Stocking range. Stockings from 100 stems/ha to over 700 stems/ha were included.

A number of other suitable trials exist, and it is to be hoped that they will be given a MARVL inventory before clearfelling. These are listed in Appendix A.

Table 1 summarises the data base that was used for this study.

TABLE 1

THE DATABASE USED

Trial no. and location	Plot no.	Nominal stockings	No.trees per rep.	Age of stand	Time of final thinning
RO 680	37-40	370	60	29	Age 7
Cmpt 1119	13-16	200	24	29	Age 9
	21-24	100	16	29	Age 9
RO 488	1	534	100	30	< Age 10
Cmpt 158	2	361	67	30	< Age 10
	3	200	38	30	< Age 10
RO 911/2	1 & 2	350	79	28	Age 8 ?
/1	1,3,4	200	120	28	Age 7-9
RO 681	37-40	741	112	28	Age 8
Cmpt 48	41-44	543	86	28	Age 8
	53-56	444	72	28	Age 8
	33-36	370	59	28	Age 8
	45-48	300	48	28	Age 8
	49-52	200	32	28	Age 8

Unfortunately, except for R911 the trials did not contain adequate replication. R680 and R681 contain four "plots" per treatment, but these are not true replicates and the data for each treatment was pooled.

If resources had been available, four more sets of plots could have been included, which could have increased precision:

RO 680 :	Plots 1-4	370 stems/ha	
RO 681 :	Plots 1-4	200	
	9-12	370	
	21-24	543	

METHODS

30 trees per treatment were measured for height, except in the two cases where there were fewer than 30 trees present. Height trees were chosen that would systematically sample the range of diameters present, with a slight emphasis on the larger (and more economically important) trees.

As the trials were approximately the same age and height, it was decided to compare results directly, with no growth adjustment.

A standard quality code dictionary was used (Manley et al, 1987). This is given in Appendix B. The first approach was to use a cutting strategy (Appendix C) that would split the resource into broad log categories - pruned logs, large branched logs, small branched logs and pulp. This would demonstrate in a crude way the trade-offs that exist when final crop stocking is varied.

The second approach was to use a "realistic" cutting strategy (Appendix D), in order to generate the volumes of standard FRI log grades that would actually occur if trees were bucked in the most profitable manner. Market information on log stumpages is hard to obtain, and no doubt there will be differences of opinion on the prices used. But stumpage relativities would have to vary substantially before there was a noticeable shift in the grade outturn.

As market information is particularly lacking for pruned logs, a 'residual value' approach using SAWMOD (I.Whiteside, pers.comm.) provided the prices of 10 classes of pruned logs, defined by small end diameter. (Table 2). Sweep, ovality, and log length will also affect the value of pruned material but these appear to be of lesser importance. Moreover, they are unlikely to vary much between stockings. The classes used were consistent with the output files of MARVL, and defect core was assumed to be a constant 240 mm regardless of stocking or DBH.

The four scenarios for pruned log prices are:

Scenario A. "Pessimistic" - a base price of $87 (at Sawmill door), and a gradual (almost linear) increase with s.e.d.

Scenario B. "Current domestic" - a base price of $105 and a steeper increase.

Scenario C. "Current export" - a base price of $118 and a increase steeper still.

Scenario D. "Optimistic" - $141 base price, and a very steep increase.

Sawmill door prices were converted to stumpages by subtracting the national average of $26/m^3 for logging and transport (G.Horgan 1989, unpublished report).

Some of the stumpage prices may seem unbelievably high, and it is true that such figures have not yet been obtained. It can be argued that this is because high-quality pruned material has not been on the market for long enough to realise its potential value.

It must be appreciated that "maximising revenue" is not the same as "maximising profit". Profit must include the compounded growing costs, and these will vary with stocking. In addition, harvesting costs vary with piece size (which is stocking-dependent).

TABLE 2

STUMPAGE PRICES FOR PRUNED LOG CLASSES ($\$/m^3$)

SED class (cm)	Scenario A	Scenario B	Scenario C	Scenario D
28+	46.50	57.00	61.50	76.50
32+	55.00	69.50	79.00	98.50
36+	63.00	82.00	96.50	120.50
40+	72.00	96.50	115.00	144.50
46+	80.00	111.00	135.00	171.00
48+	89.00	123.50	153.00	194.50
52+	97.00	137.50	171.00	217.00
56+	105.00	149.00	186.00	236.00
60+	113.50	162.00	201.00	254.50
64+	121.50	175.00	216.50	269.00

RESULTS

Table 3 is a summary of the results of the first cutting strategy. Figs 1-8 are graphs showing trends derived from Table 3.

Table 3
Summary of MARVL results using Cutting strategy 1

Data	source	SPH	MTH	MTD	Median SED of P	Vol P	Vol S	Vol L	Vol Pulp	Total vol
R680	/1	337	40.7	55.1	32+	228	294	61	24	608
	/2	198	39.3	61.0	40+	226	137	176	11	550
	/3	99	38.1	68.2	48+	169	49	184	3	405
R488	/1	494	43.4	54.0	32+	254	438	84	20	796
	/2	326	44.7	56.5	36+	287	369	111	8	774
	/3	188	42.2	64.7	44+	239	145	231	3	684
R911	/1	345	45.7	57.8	36+	274	289	204	34	801
	/2	199	43.6	67.4	44+	267	31	424	5	728
R681	/1	691	44.2	51.4	32+	257	660	28	45	990
	/2	525	44.1	51.4	32+	267	654	3	14	938
	/3	444	44.2	52.7	36+	258	502	41	22	822
	/4	364	44.1	54.1	36+	257	463	13	11	744
	/5	296	43.5	56.2	36+	259	303	152	10	724
	/6	198	42.2	57.6	40+	218	261	91	8	578

Fig 1 compares the Mean Top Height across sites and stockings. There is a statistically significant loss of 2-3 m in height for stockings below about 400 stems/ha. This trend is not confirmed by all other trials (for example, R589) and may be due to early differences arising from pruning/thinning/stocking interactions, or may be due to the method of height measurement. R589, for example, has a Mean Top Height that is derived by regression from Predominant Mean Height. PMH involves the measurement of the tallest tree per 0.1 ha, (in R589, 6 trees per plot). Whereas, as mentioned above, in this study 30 trees spread across the diameter range were used to derive a Petterson Curve for estimating Mean Top Height.

Fig 2 demonstrates a trend well known to foresters: larger diameters occur with lower stockings. This trend also occurs with the fattest 100 trees per hectare ("Mean Top Diameter"). The interesting observation is that diameters show no sign of "tailing off" at the lowest stockings. This is also confirmed by Maclaren (paper in prep) in which stockings as low as 50 stems/ha were examined.

There appear to be those who still believe that the fattest 100 stems/ha grow at the same rate regardless of the presence or absence of other trees on that hectare. In case it is argued that MTDs are derived from a Petterson Curve and may disguise the real situation, the actual fattest 100 stems/ha have been identified and the mean of their diameters calculated. The results of this calculation appear in Table 4.

TABLE 4
Fattest 100 stems/ha

Trial no. and location	Nominal stockings	Petterson derived MTD	Actual top 100 DBH
RO 680	370	55.1	55.3
Cmpt 1119	200	61.0	61.2
	100	68.2	67.7
RO 488	534	54.0	53.9
Cmpt 158	361	56.5	56.5
	200	64.7	64.1
RO 911/2	350	57.8	57.8
/1	200	68.1	67.4
RO 681	741	51.4	50.1
Cmpt 48	543	51.4	50.8
	444	52.7	53.0
	370	54.1	54.7
	300	56.2	56.2
	200	57.6	58.6

Fig 3 also confirms our knowledge: there is a marked decline in total recoverable volume as stocking is reduced. The effect is repeated in Fig 4, where only S logs are considered, and again in Figure 5 for pulp logs.

L logs show the opposite trend, as evidenced in Fig 6, though the effect is not so clear. There may be a "threshhold" at 300-400 stems/ha, above which L logs are not produced at all.

The effect on pruned volume is demonstrated in Fig 7. Pruned volume may be relatively constant unless very low stockings are used.

Fig 8 shows the increase in small end diameter of the pruned logs as stocking is reduced. This is a vital factor in any economic study: s.e.d. is important in sawn conversion and in the proportion of higher value clear boards obtained.

Table 5 gives the MARVL results using a more realistic cutting strategy, and Figs 9-11 are derived from it.

Fig 9 demonstrates the importance of separating total pruned volume according to piece size. Volumes of P1 logs increase as stocking is decreased, at least down to 200 stems/ha. Fig 10 shows the opposite trend for P2 volumes.

The revenue per hectare listed in Table 5 shows no clear trend against stocking. This revenue has been obtained by using a fixed price for P1 logs ($86) and for P2 logs ($58).

Table 6 gives the revenue obtained using the 10 price classes for pruned logs listed in Table 2. Again, there is no clear trend due to stocking.

TABLE 5 - MARVL results using "realistic" cutting strategy

Data source	SPH	$/ha	MTH (m)	MTD (cm)	P1 (m^3)	P2 (m^3)	S1 (m^3)	S2 (m^3)	S3 (m^3)	S4 (m^3)	I (m^3)	L1 (m^3)	L2 (m^3)	L3 (m^3)	L4 (m^3)	Pulp (m^3)	Total vol.
R680/1	337	25983	40.7	55.1	127	76	35	111	127	21	4	6	39	6	3	27	585
/2	198	28054	39.3	61.0	187	16	37	48	31	7	0	76	83	30	4	17	535
/3	99	22374	38.1	68.2	152	0	24	4	7	0	0	115	58	19	2	10	396
R488/1	496	29860	43.4	54.0	113	105	28	135	216	56	21	4	46	26	3	11	762
/2	326	36300	44.7	56.5	181	70	40	192	123	19	36	16	52	18	2	6	755
/3	188	31744	42.2	64.7	196	14	49	58	23	5	14	90	100	41	3	12	606
R911/1	345	36610	45.7	57.8	184	65	43	112	107	16	12	70	114	51	4	37	816
/2	199	36928	43.6	67.4	234	6	8	9	4	2	5	215	146	59	8	14	710
R681/1	691	33421	46.2	51.4	113	79	25	258	324	64	13	0	13	20	3	31	944
/2	525	34568	44.1	51.4	83	128	31	265	293	54	40	0	3	2	0	5	905
/3	444	32305	44.2	52.7	115	101	27	219	213	35	29	0	21	12	3	17	791
/4	364	31847	44.1	54.1	125	98	54	221	166	33	8	0	0	8	0	7	720
/5	296	32353	43.5	56.2	158	68	34	157	96	18	4	36	85	36	4	10	705
/6	198	28741	42.2	57.6	172	18	57	111	62	9	15	26	59	20	4	9	565

TABLE 6 - Value of strata using pruned log classes ($/ha stumpage)

Data source		REVENUE FROM PRUNED LOGS				Plus revenue from other logs	TOTAL REVENUE			
		Price scenario					Price scenario			
		A	B	C	D		A	B	C	D
R680/1	337	13943	18583	22068	27757	10665	24607	29248	32733	38422
/2	198	14068	19341	23567	29825	11049	25117	30390	34616	60874
/3	99	14832	20907	25857	32692	9034	29941	34891	34891	41726
R488/1	494	14736	19607	23258	29242	14090	28826	33697	37348	43332
/2	326	18273	24675	29590	37295	16643	34916	41318	46233	53938
/3	188	17999	24951	30571	38687	13236	31235	38187	43807	51923
R911/1	345	17827	24016	28809	36314	14363	32190	38379	43172	50677
/2	199	25201	33741	40191	50583	16429	41680	50220	56670	67064
R681/1	691	12902	17129	20259	25446	19134	32036	36263	39393	44580
/2	525	13526	17761	20861	26160	20046	33572	37807	40907	46206
/3	444	14428	19112	22583	28357	16538	30966	35650	39121	44895
/4	364	15439	20599	24519	30829	15399	30838	35998	39918	46228
/5	296	16496	22303	26804	33790	14876	31372	37179	41680	48666
/6	198	14608	19932	24109	30452	12927	27535	39259	37036	43379

FURTHER CALCULATIONS AND DISCUSSION

Lack of within-trial replication has resulted in a confused picture. It is not possible to state that differences in revenue between stockings are not the result of chance. Two trials (R680 and R911) indicate that 200 stems/ha may yield more revenue than 300 stems/ha, but the other trials indicate the opposite.

The effect of growing costs and harvesting costs still remain to be included in the analysis. Table 7 compares the compounded growing costs (variable costs only) of 300 stems/ha against 200 stems/ha. The calculation assumes an expensive silviculture (with a 4:1 selection ratio, two thinnings and two prunings) and a high interest rate. Silviculture and cost information is as according to Maclaren (1989). The comparison therefore represents the maximum difference likely to be encountered between these two stockings.

TABLE 7

Calculation of variable growing costs.
Comparison of 300 s/ha and 200 s/ha.

Operation	Year	Compound Period	Cost of 200	Compounded @ 10%	Cost of 300	Compounded @ 10%
Planting	0	27	75	983	136	1783
First prune	6	21	454	3360	577	4270
2nd prune	8	19	118	722	246	1505
First thin	6	21	146	1080	196	1450
2nd thin	8	19	114	697	150	917
			TOTAL	**6842**		**9925**

Difference = $3083

In order to account for differences in logging cost due to piece size, data from the MARVL outputs for R488 and R681 was run through the model HARPCE. Results are in Table 8.

TABLE 8
Differences in harvesting costs with stocking

	R488		R681	
	326 s/ha	**188 s/ha**	**296 s/ha**	**198 s/ha**
Logging cost ($/m^3)	7.45	6.52	7.34	6.66
Recov. vol	774.3	617.8	723.8	577.5
Cost/ha	5768.54	4028.06	5306.82	3846.25
Difference	$1740.48/ha		$1460.67/ha	

Growing and harvesting costs combine to make the lower stocking at R488 marginally more profitable at all price scenarios. The higher stocking at R681 still continues to yield a slightly greater profit with price scenarios C and D.

CONCLUSIONS AND FURTHER WORK REQUIRED

Beyond stating that maximum profits in direct regimes appear to lie in stockings below about 350 stems/ha, this study has not succeeded in narrowing down the range of stockings that could be considered "optimum". Nevertheless, the approach used here could be useful in this respect when more data becomes available.

Many of the results merely confirm existing knowledge. But there are some insights that may lead to fruitful research. The observation that height growth is reduced at low stockings demands examination with additional data.

The observation that pruned volume is roughly constant emphasises the need to provide precise quantification of the benefits that are expected to occur with increased small end diameter.

The fact that the top 100 trees are influenced by other trees on the site at all stockings, but especially at lower stockings, needs to advertised more widely.

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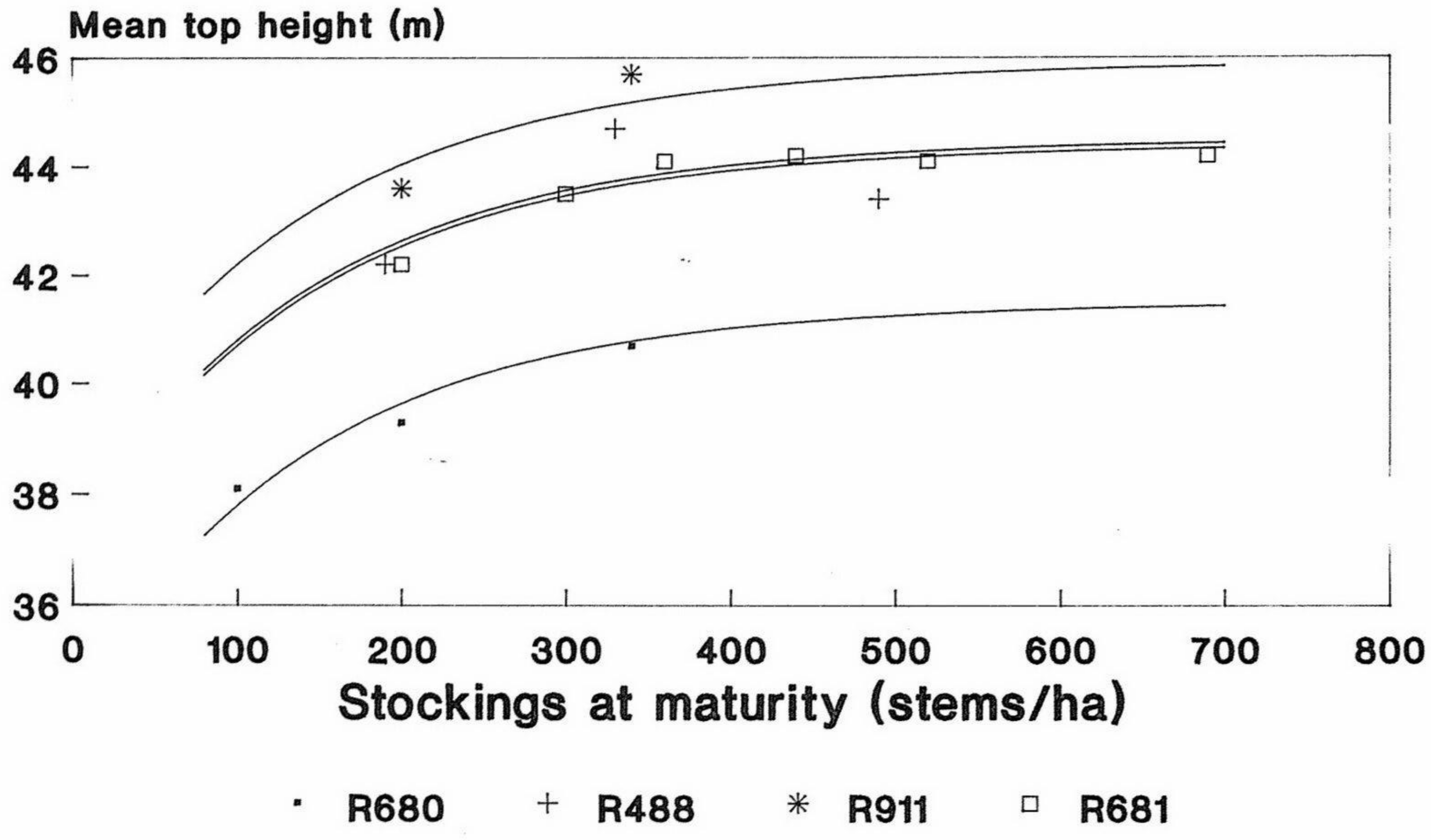
Figure 1

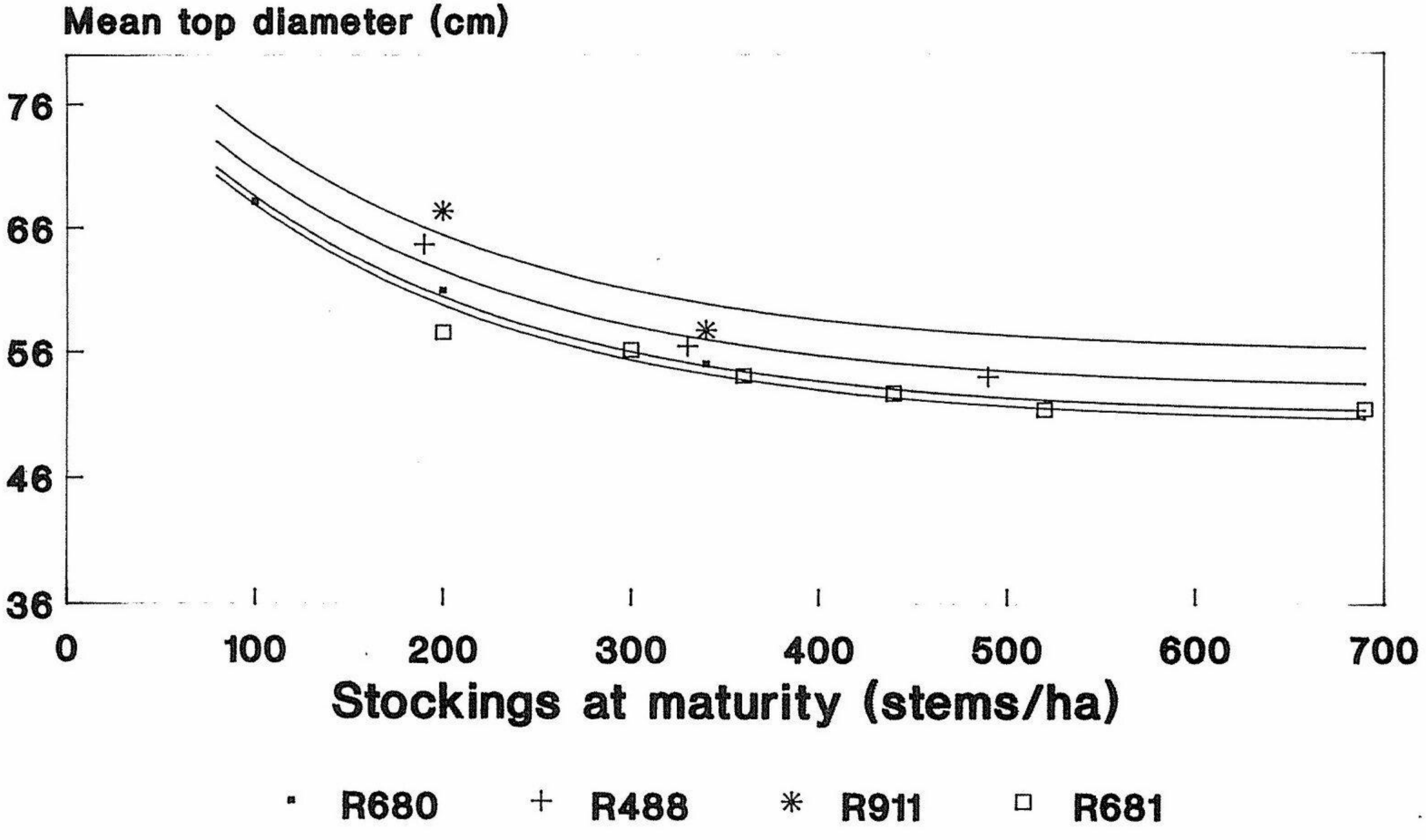
Effects of Stocking
on Mean Top Height



Statistical signif: sph**, trials**

Figure 2

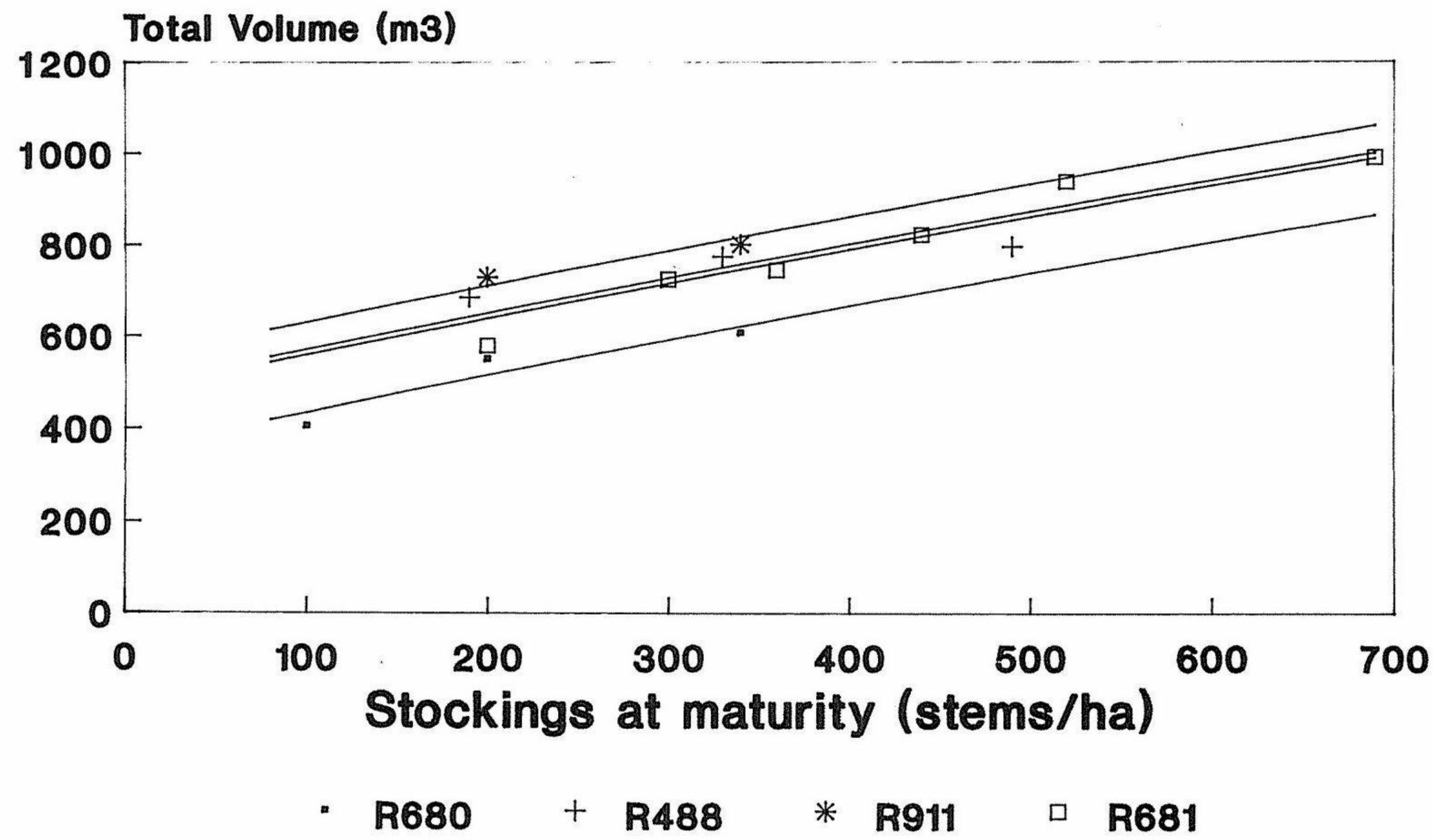
Effects of Stocking on Mean Top Diameter



Statistical signif: sph**, trials**

Figure 3

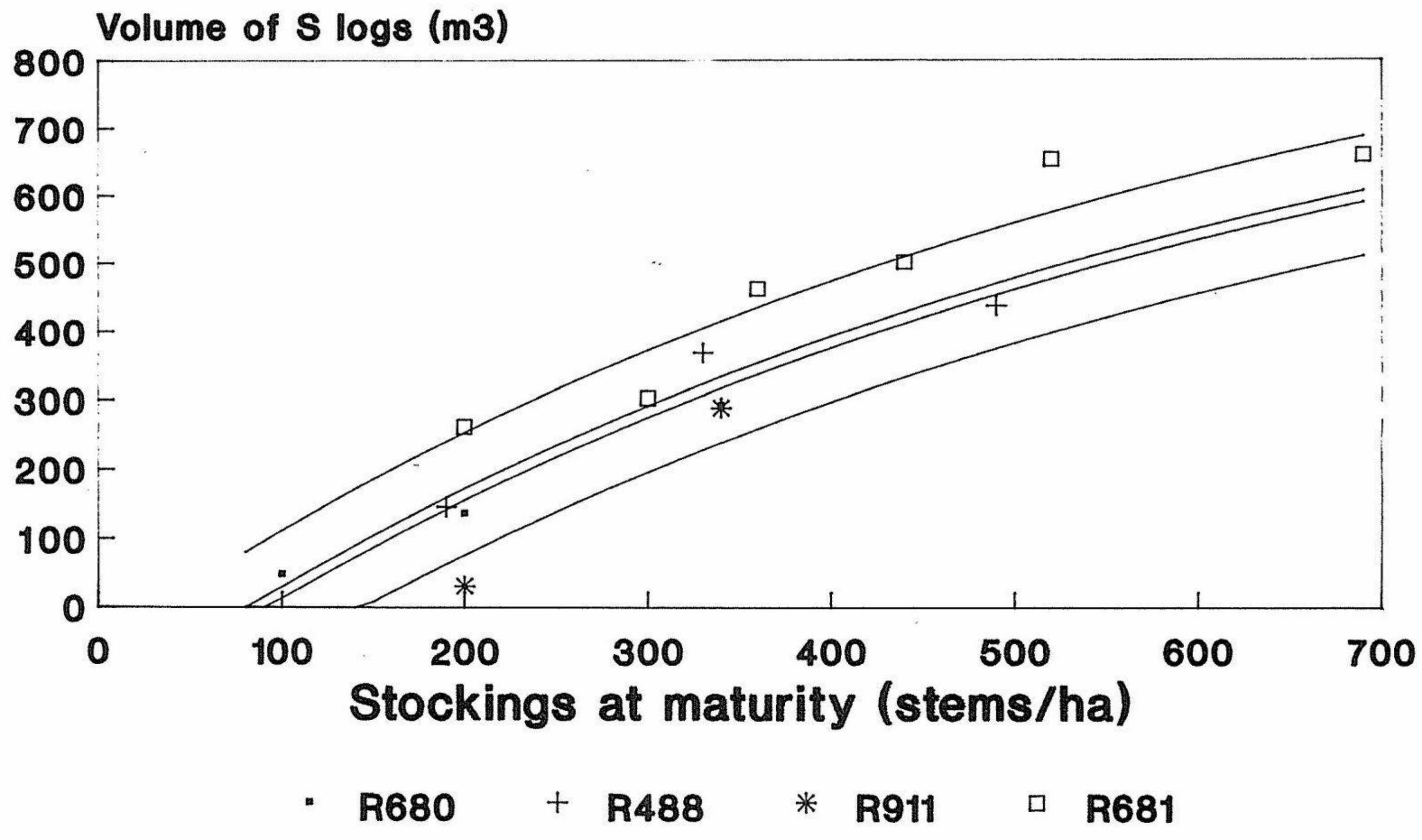
Effects of Stocking
on Total Volume



Statistical signif: sph**, trials*

Figure 4

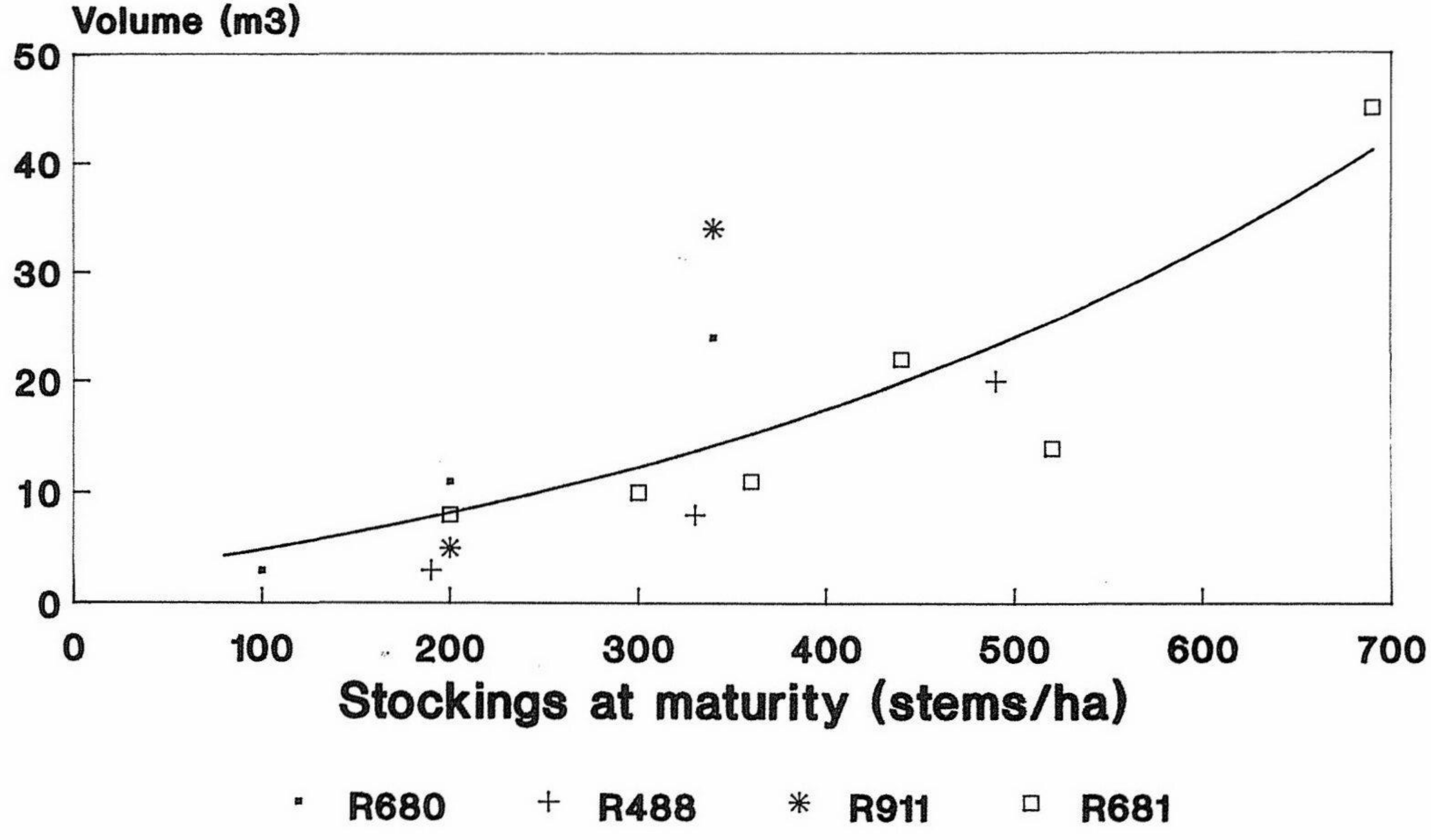
Effects of Stocking
on Volume of S logs



Statistical signif: sph**, trials*

Figure 5

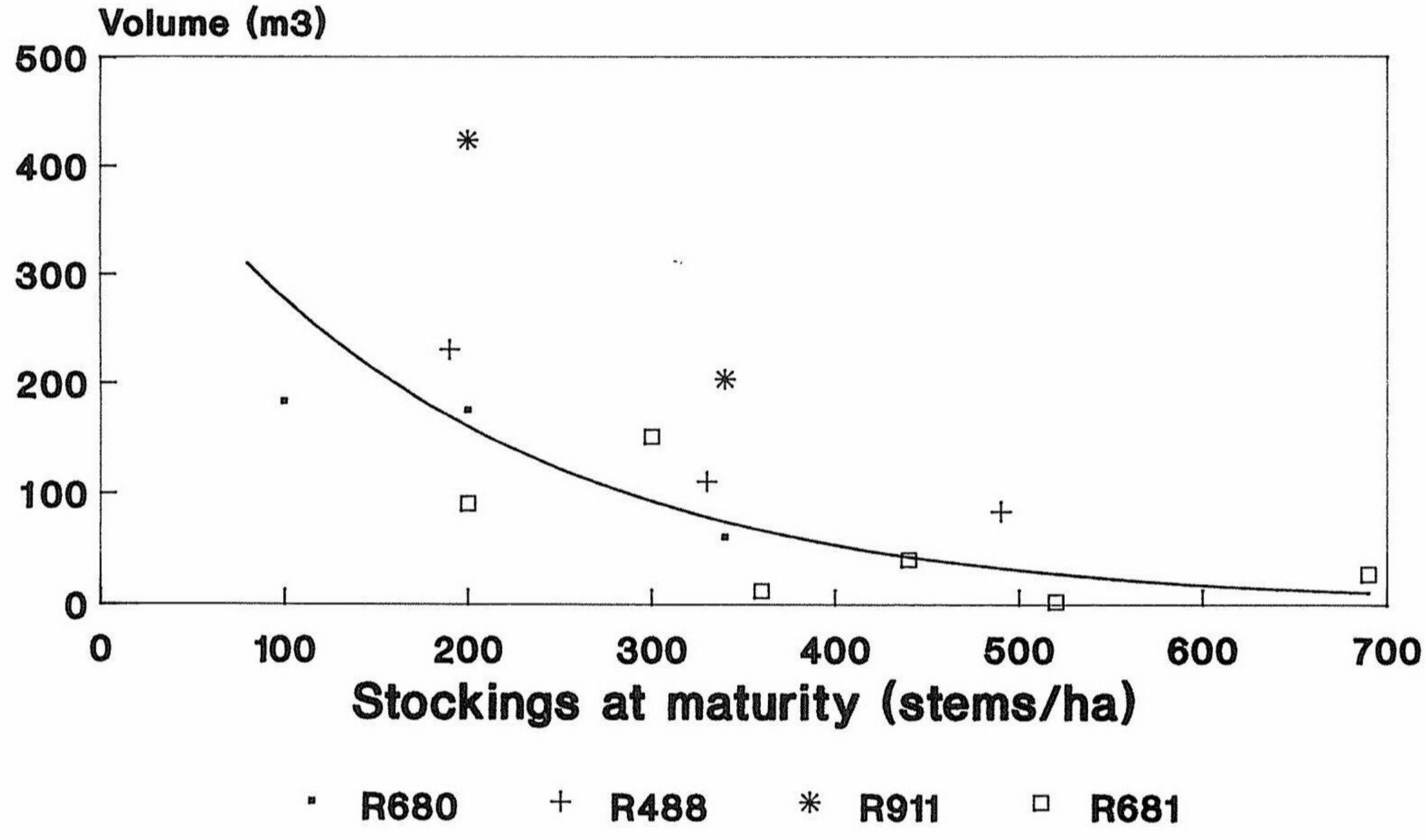
Effects of Stocking
on pulp log volume



Statistical signif: sph, trials N.S.**

Figure 6

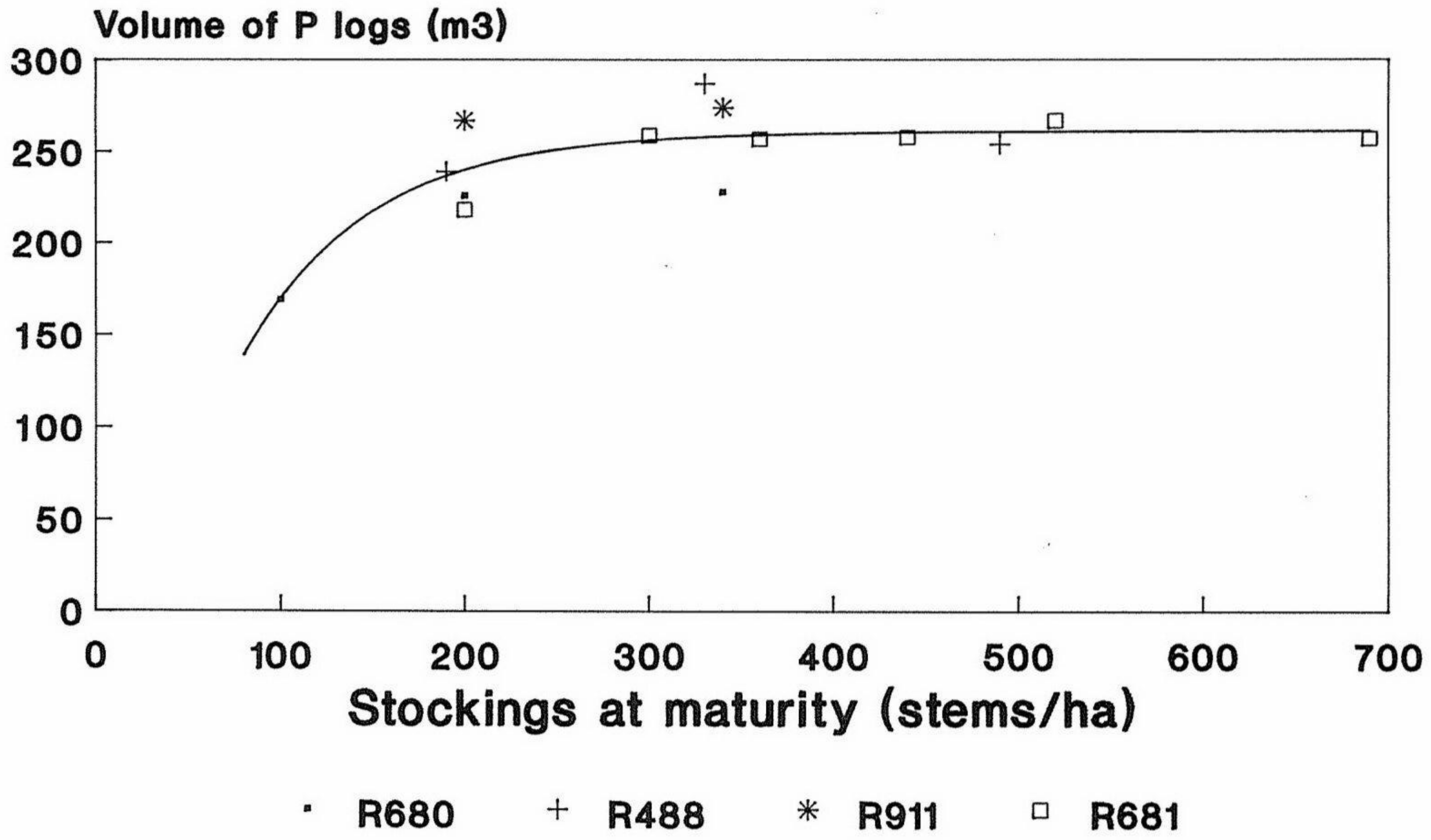
Effects of Stocking
on volume of L logs



Statistical signif: sph**, trials N.S.

Figure 7

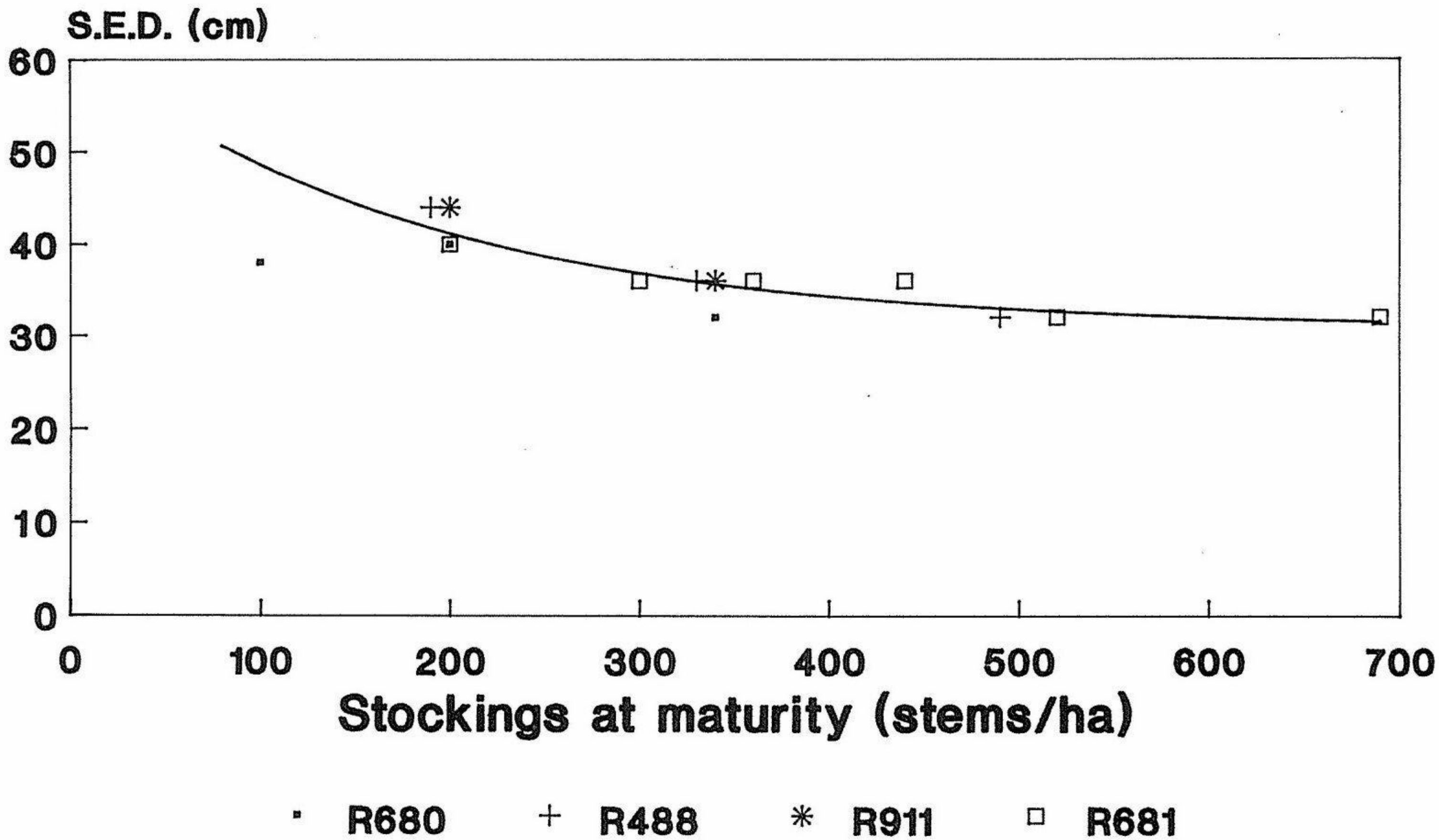
Effects of Stocking
on Volume of P logs



Statistical signif: sph**, trials N.S.

Figure 8

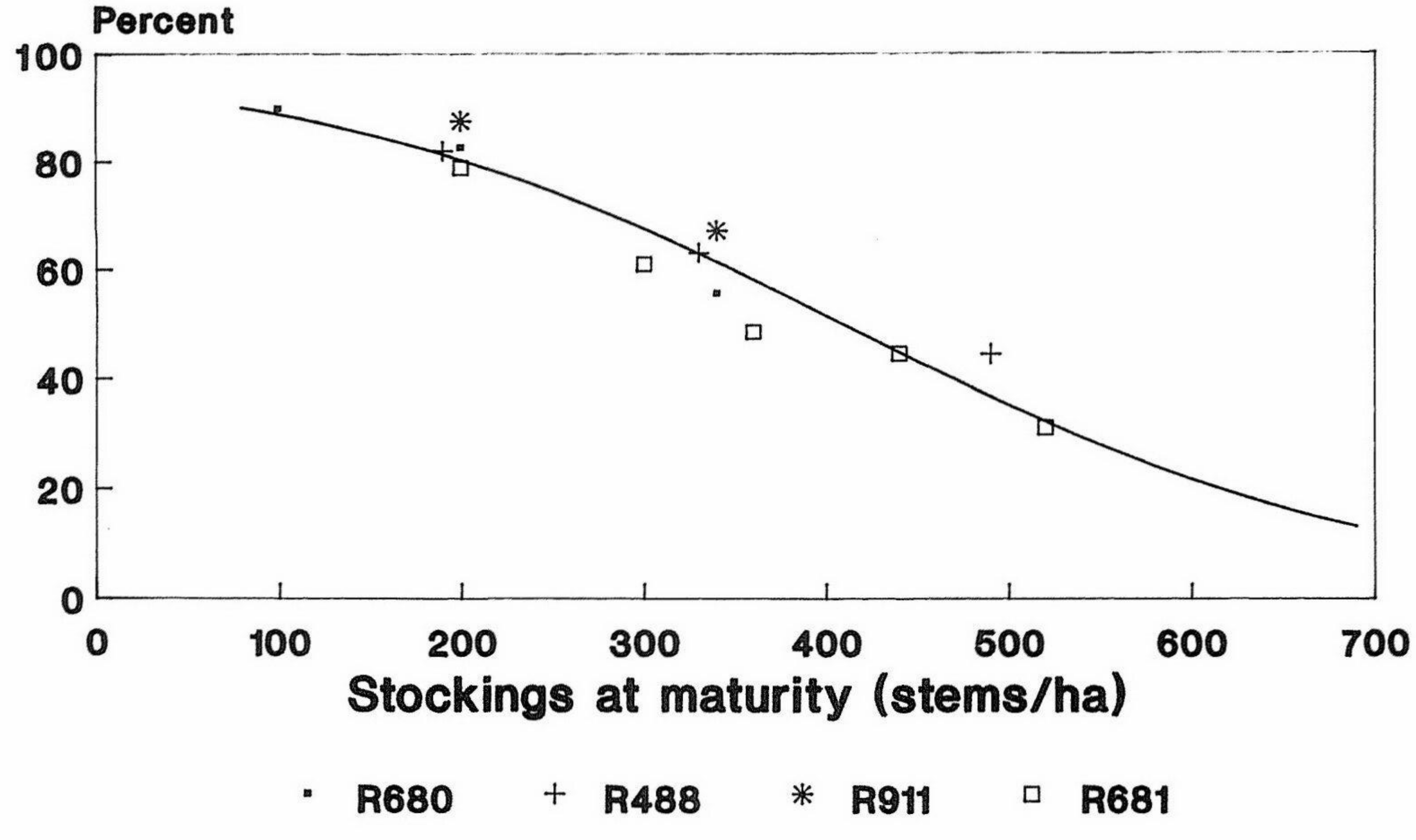
Effects of Stocking
on small end diameter of pruned logs



Statistical signif: sph, trials N.S.**

Figure 9

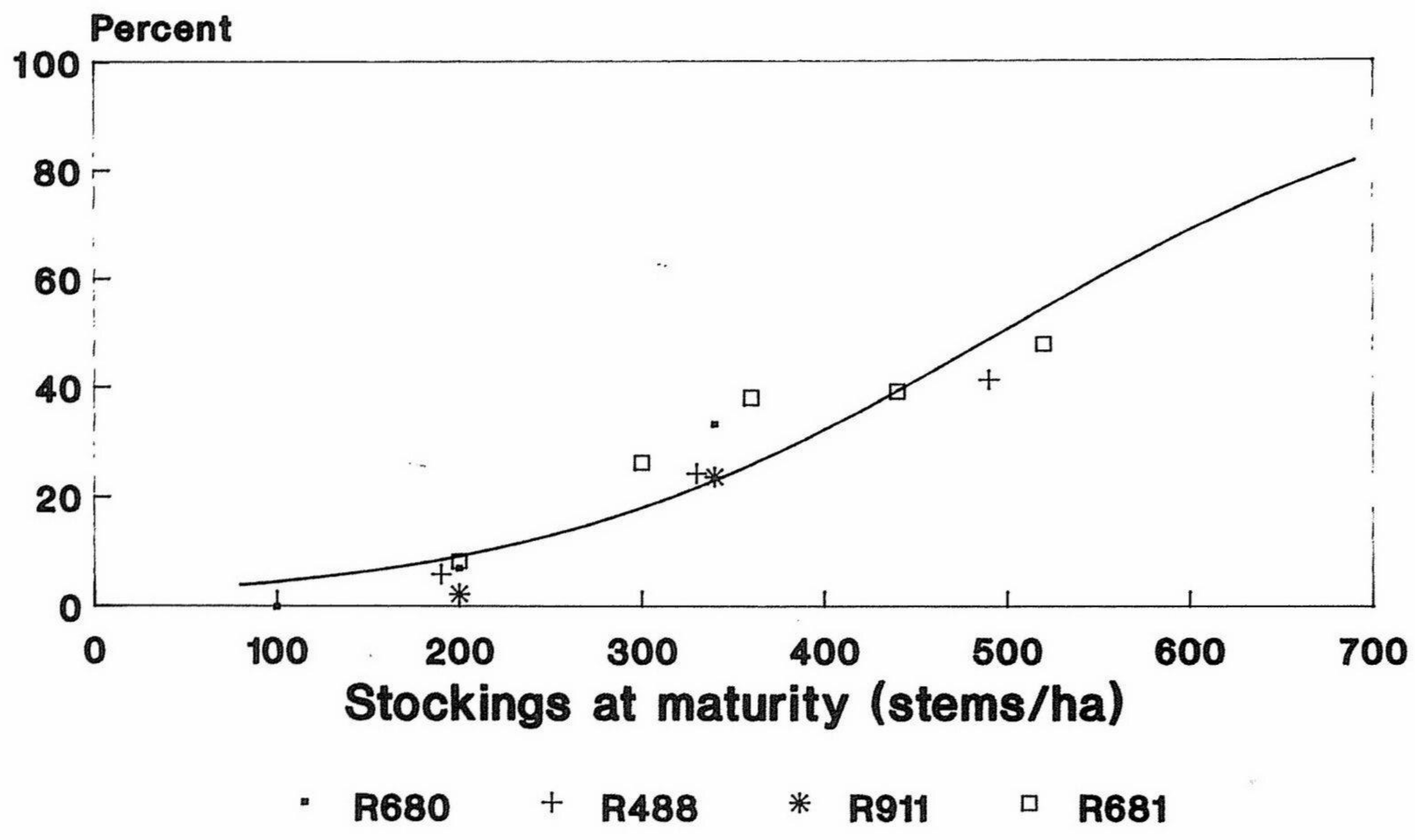
Effects of Stocking
on percent of pruned logs that are P1



Statistical signif: sph, trials N.S.**

Figure 10

Effects of Stocking
on percent of pruned logs that are P2



Statistical signif: sph**, trials N.S.

Appendix A

MATURE STOCKING TRIALS IN KAINGAROA

In addition to the trials analysed in this report, the following may merit further investigation:

Trial code	Compt	Estab year	Stockings	Reps	Pruned height (m)
R589	890/	1966/	117	4	6
	917/	1967/	150	6	6
	1354	1968	250	14	6
			350	4	6
			383	2	6
R685	477	1964	200	2	?
			370	2	?
R695	84	1964	200	4	6
			300	4	6
			400	4	6
			500	4	6
			600	4	6
			700	4	6
			Unthin	4	6
R696	375	1966	200	2	2.1
			400	2	Unpruned
			400	4	2.1
			400	2	6
			600	As for 400	
			800	2	2.1
R697	109	1965	200	4	Unpruned
			400	4	Unpruned
R699	128	1969	200	4	2.1
			400	2	2.1
			400	2	6
			600	1	Unpruned
			600	1	1.8
			600	2	6.0
R687	917	1966	200	3	?
			400	3	?
			500	3	?

Note: this is a preliminary table only. PSP and Stand Records may be inaccurate and may require amendment as a result of visits to the stands. R695, R696 and R699 are described in Woolens R.C. and A.G.D.Whyte,1989. NZ Forestry, Vol 34, No.3, pp 12-15.

Appendix B

THE QUALITY CODE DICTIONARY USED

*** Code A ***
Pruned, straight, peeler quality

*** Code B ***
Pruned, straight, not peeler quality

*** Code C ***
Pruned, moderate sweep, peeler quality

*** Code D ***
Pruned, moderate sweep, not peeler quality

*** Code E ***
Unpruned, branches < 6 cm, straight, not peeler quality

*** Code G ***
Unpruned, branches < 6 cm, moderate sweep

*** Code I ***
Internodal, branches < 6 cm

*** Code J ***
Internodal, branches 6-14 cm

*** Code K ***
Unpruned, branches 6-14 cm, moderate sweep

*** Code L ***
Unpruned, branches 6-14 cm, straight

*** Code N ***
Unpruned, branches < 6 cm, straight, peeler quality

*** Code P ***
Pulp

*** Code W ***
Waste

<u>Appendix C</u>

CUTTING STRATEGY 1

To maximimise volume of major log types

*** Dictionary used ***
c:\marvl\lib\std.dic

LOG TYPE	MIN SED (cm)	MAX SED (cm)	MAX LED (cm)	$ /cu.m	QUALITIES
PRUNED LOGS 0.50 - 20.00m	30.0	150.0	150.0	200.00	ABCD
LARGE BRANCHED LOGS 0.50 - 20.00m	15.0	150.0	150.0	100.00	ABCDINEGJLK
PULP LOGS 0.50 - 20.00m	10.0	150.0	150.0	50.00	ABCDINEGJLKP
SMALL BRANCHED LOGS 0.50 - 20.00m	15.0	150.0	150.0	150.00	ABCDINEG
WASTE 0.50 - 20.00m	0.0	150.0	150.0	0.00	ABCDINEGJLKPW

*** Other parameters ***
Stump height = 0.1000
Round-off length = 0.500000
Cost of saw cut = 0.010

Appendix D

CUTTING STRATEGY 2

"Realistic" stumpages

Dictionary used : c:\marvl\lib\std.dic
Stump height : 0.3000m
Round-off length : 0.50000m
Cost of saw cut :$ 0.500

LOG TYPE	MIN SED (cm)	MAX SED (cm)	MAX LED (cm)	$ /cu.m	QUALITIES
LARGE PRUNED LOGS P1 2.70 - 5.70m	40.0	150.0	150.0	86.00	ABCD
SMALL PRUNED LOGS P2 2.70 - 5.70m	30.0	40.0	150.0	58.00	ABCD
S1 SAWLOGS 5.50m	40.0	150.0	150.0	55.00	ABCDINEG
S2 SAWLOGS 5.50m	30.0	40.0	150.0	40.00	ABCDINEG
S3 SAWLOGS 3.10 - 6.10m	20.0	30.0	150.0	16.00	ABCDINEG
S4 SAWLOGS 3.10 - 6.10m	15.0	20.0	150.0	12.00	ABCDINEG
L1 SAWLOGS 5.50m	40.0	150.0	150.0	47.00	ABCDINEGJLK
L2 SAWLOGS 5.50m	30.0	40.0	150.0	32.00	ABCDINEGJLK
L3 SAWLOGS 3.10 - 6.10m	20.0	30.0	150.0	7.00	ABCDINEGJLK
L4 SAWLOGS 3.10 - 6.10m	15.0	20.0	150.0	6.00	ABCDINEGJLK
PULP 1.20 - 6.10m	10.0	150.0	150.0	5.00	ABCDINEGJLKP
WASTE 0.50 - 20.00m	0.0	150.0	150.0	0.00	ABCDINEGJLKPW
INTERNODAL LOGS 3.70 - 6.10m	30.0	150.0	150.0	56.00	ABCDIJ