F.R.I. PROJECT RECORD

NO. 1646

PHOSPHROUS UPTAKE OF RADIATA PINE ON SOILS OF DIFFERENT PHOSPHORUS RETENTION, FERTILISED WITH SUPERPHOSPHATE AND A-GRADE ROCK

COMPILED
BY

I.R. HUNTER
J.A.C. HUNTER
J.D. GRAHAM
J.M. PRINCE
G.M. NICHOLSON
E.D. ROBERTSON

REPORT NO. 16 SEPTEMBER 1987

Note: Confidential to Participants of the National Forest Fertilising Co-operative Program

: This material is unpublished and must not be cited as a literature referance

PREFACE

The research presented in this report was supported financially and otherwise by The New Zealand Forest Service/ New Zealand Forestry Corporation.

Initially the results were detailed in a confidential report available only to the Forestry Corporation. However, the corporation has now wholeheartedly endorsed the release of this report to the National Forest Fertilising Cooperative.

PHOSPHORUS UPTAKE OF RADIATA PINE ON SOILS OF DIFFERENT PHOSPHORUS RETENTION, FERTILISED WITH SUPERPHOSPHATE AND A-GRADE ROCK.

A REPORT PREPARED FOR AUCKLAND CONSERVANCY.

I.R. HUNTER

J.A.C. HUNTER

J.D. GRAHAM

J.M. PRINCE

G.M. NICHOLSON

E.D. ROBERTSON

Soils and Site Amendment Research Field,

Forest Management and Resources Division,

Forest Research Institute.

MARCH 1987

MANAGEMENT SUMMARY

We calculated the amount of phosphorus taken up by radiata pine 7 years after fertilising with 150 kg/ha of P. We did this by subtracting the P content of unfertilised trees from that of those fertilised with Rock P and superphosphate.

There was approximately 20 kg/ha more P in Rock phosphate fertilised trees, and 15 kg/ha more in superphosphate fertilised ones. (Table 3). Therefore, uptake efficiency is low (10 - 15% of that applied), indicating that with further investigation it may be possible to reduce application rates. Rock P has a higher efficiency than superphosphate.

There was, however, approximately 4 - 5 more kg/ha of P in the litter layer of the fertilised plots (Table 5) and the soil had a much higher available P (Table 8) in the fertilised plots. So the percentage taken up by the trees can be expected to increase slightly as time goes by.

The trees were closing canopy when we carried out our study and the weeds were basically shaded out. In the fertilised plots the shading was more severe than in the controls so the nutrient content of the weeds is sometimes actually less in the fertilised plots than in the controls. (Table 7). These figures seem to show that nutrient uptake by weeds is not a problem. However, if the study had been done earlier, a different conclusion would probably have been reached.

****

INTRODUCTION

A series of three phosphate trials were established in the spring of 1978 to:-

1. To study the response of radiata pine, on known phosphorus deficient soils of different P retentions, to various types of finely ground pelletised rock phosphate.

2. To compare the response to rock phosphate with the response of superphosphate at the same rates of phosphorus applied, and

3. From the results of the first two objectives, evaluate the economics of applying the different materials by air on a large scale.

The sites are (a) Waipoua State Forest, on a Tangikiti sandy loam and sand - Te Kopuru sand mixture, with a P retention of 1 %, (b) a Waikare silt loam - Okaka clay and silty clay mix in Riverhead State Forest, with a P retention of 42 %, and (c) a clay soil from andesitic ash with a P retention of 90 % in Tairua State Forest.

At each site there had been no silvicultural treatment prior to the establishment of the trials. At Riverhead and Tairua the trees were age 4, while at Waipoua the trees were of similiar size but age 7.

Three randomised blocks were established at each site with plots of 20 m X 20 m of identified measurement trees.

****

METHODS.

FERTILISER TREATMENTS

TREATMENT No.	TREATMENT
1	Control, no added phosphate
2	Pelletised A-grade rock at 75 Kg/ha P
3	Pelletised A-grade rock at 150 Kg/ha P
4	Pelletised Citraphos at 75 Kg/ha P
5	Pelletised Citraphos at 150 Kg/ha P
6	Superphosphate at 75 Kg/ha P
7	Superphosphate at 150 Kg/ha P
8	Pelletised C-grade rock at 75 Kg/ha P
9	Pelletised C-grade rock at 150 Kg/ha P

Waipoua has treatments 1 - 7 only

Riverhead has all treatments plus one plot each of :-

Agricultural lime at 2500 Kg/ha, and

Agricultural lime at 2500 Kg/ha + superphosphate at 150 Kg/ha P

Tairua has all 9 treatments.

In 1985 we decided to determine the amount of fertiliser taken up by the trees and to attempt to locate the remainder in soil,weeds and forest floor.

Furtheruptake was calculated by differences based on a biomass to determine the weight of tree components (i.e. foliage divided into age classes, dead wood, live branch and stem wood and bark) and analysis for nutrient contents in relation to their fertiliser treatments was conducted.

The treatments sampled were :-

Treatment 1 (Control)

Treatment 3 (A-grade)

and Treatment 7 (Superphosphate).

Forest floor litter, amd soil samples were taken throughout the treatment concerned.

A biomass to determine the amount of weeds in each of the treatments and the relative amounts of nutrients in them, was carried out at the same time as the tree biomass.

These figures all contribute to a model showing the distribution of nitrogen and phosphorus in trees, weeds,litter on the forest floor, and soil on the site.

It is important to note that this study represents a "snaphot" in time. The results presented below represent what was happening to the forest at the time the study was performed.

(A) FIELD BIOMASS PROCEDURE.

BRANCHES - (GREEN AND DEAD).

Selection of trees for the biomass, was by means of randomised tree numbers before going into the field.

Three trees per plot, were felled to give a total of 9 trees per treatment per site.

The total height and diameter at breast height were measured, plus the height of the base of green crown.(i.e. the height where the first green branch was present).

The length of the tree between base of green crown and the total height was calculated and then divided into six equal zones. One representative branch from each of these zones was selected, to be brought back to the lab for further sub-dividing and analysis.

All the branches from each zone,including the dead branches below the green crown, were pruned flush with the stem (sample branch included) and weighed in their respective zones. The sample branch was then removed and weighed separately.

STEM.

The stem was cut up into manageable size sections, and a subsample of approximately six disks of 2-3 cm thick taken per tree.

The total stem was weighed green, then the subsample weighed separately.

Thus the total green weight of the tree was obtained, and a representative subsample of that tree selected for further processing.

Each part of the tree was weighed green, in the field, so that it could be converted back to a total dry weight of tree and it's components.

SUB-SAMPLING OF TREES.

Each green sample branch was divided into needle age classes:-

1 YEAR FOLIAGE
2 YEAR FOLIAGE
3 YEAR FOLIAGE
COMPOSITE (4 years and older)
WOOD (branch wood)

The dead sample branch was classified as DBWOOD.
Stem wood sections were divided into BARK and SWOOD.

These samples were then dried at 70 C for a period of 10 days and oven dry weight obtained. These weights were used in a GENSTAT analysis with the total weights of the corresponding tree (from the field) to calculate the total weight of each component. This was then converted up to a per hectare basis, using the basal area ratio method.

The samples were then ground for nitrogen and phosphorus tissue analysis, by processes outlined in Nicholson 1984.

(B) WEED BIOMASS.

Six truly random locations (co-ordinates) per plot were selected before entering the field (to reduce any bias). A 1.128 metre diameter plastic hoop, i.e. 1 m2, was used to define an area with the centre of the hoop being placed on the co-ordinate. All understorey that fell inside the hoop was clipped off at ground level and bulked together for each plot. This was dried and weighed. A weight per m2 was calculated, and then multiplied up to a per hectare basis.

(C) FOREST FLOOR LITTER COLLECTIONS

A sample of the forest floor litter was taken using a 0.25 m2 metal frame at 12 positions on and between tree rows across the plot. (i.e. 3 m2 per plot).

This sample was weighed wet, and a subsample of approximately 10 % taken and weighed. This was oven dried at 70 C - Oven dry weight obtained and a wet/dry ratio calculated. From this ratio the total amount of litter per hectare was obtained.

This was also analysed for nutrient content.

(D) SOIL SAMPLING.

A subsample of 150 cores per treatment to a depth of 10 cm was taken with a Hoffer tube, and 15 cores per treatment with a dutch clay auger to a depth of 10 - 30 cm and 30 - 60 cm.

****

RESULTS.

TABLE 1. Total weights (kg/ha) of tree components.

WAIPOUA

	CONTROL	A-GRADE	SUPERPHOSPHATE
1 YR FOL	2248	4352	2632
2 YR FOL	1722	2896	1898
3 YR FOL	848	1267	1040
COMPOSITE	362	576	378
DB WOOD	2427	3451	3371
WOOD(BRANCH)	7698	10977	7794
SWOOD	71320	85439	76479
BARK	8101	9871	8744
TOTAL	94726	118829	102336

RIVERHEAD

	CONTROL	A-GRADE	SUPERPHOSPHATE
1 YR FOL	3687	6314	5183
2 YR FOL	2698	5031	4683
3 YR FOL	1892	1245	2048
COMPOSITE	650	126	79
DB WOOD	3134	7952	5132
WOOD(BRANCH)	14074	23922	14769
SWOOD	62733	95885	92432
BARK	7151	9222	8268
TOTAL	96019	149697	132594

TAIRUA

	CONTROL	A-GRADE	SUPERPHOSPHATE
1 YR FOL	4887	7153	6167
2 YR FOL	4518	5246	4488
3 YR FOL	2153	2617	2338
COMPOSITE	468	551	401
DB WOOD	6021	10670	8838
WOOD(BRANCH)	23493	29728	21611
SWOOD	79689	104946	98131
BARK	11552	11225	9915
TOTAL	132781	172136	151889

In terms of dry weight, the A-Grade treatment at all three sites has the highest weight and the controls have the lowest.

Waipoua has the lowest biomass of the three sites, although the trees are 3 years older than the others.

TOTAL WEIGHTS (KG/HA) OF NITROGEN AND PHOSPHORUS FOR EACH TREATMENT AT EACH SITE.

TABLE 2 (a)

CONTROL - NUTRIENT COMPONENTS Kg/ha

WAIPOUA

	NITROGEN	(SIG)	PHOSPHORUS	(SIG)
1 YR FOL	28.7	(0.295)	2.42	(0.199)
2 YR FOL	18.6	(0.318)	1.65	(0.157)
3 YR FOL	8.22	(0.150)	0.85	(0.031)
COMPOSITE	3.11	(0.627)	0.34	(0.495)
DB WOOD	2.73	(0.499)	0.28	(0.134)
WOOD(BRANCH)	20.2	(0.616)	3.39	(0.280)
SWOOD	31.0	(0.621)	4.60	(0.243)
BARK	37.3	(0.678)	2.55	(0.095)
TOTAL	149.86		16.08	

RIVERHEAD

	NITROGEN	(SIG)	PHOSPHORUS	(SIG)
1 YR FOL	57.0	(0.083)	3.64	(0.060)
2 YR FOL	37.0	(0.176)	2.24	(0.078)
3 YR FOL	22.5	(0.255)	1.42	(0.219)
COMPOSITE	6.66	(0.033)	0.44	(0.038)
DB WOOD	3.88	(0.044)	0.34	(0.021)
WOOD(BRANCH)	32.4	(0.199)	3.37	(0.108)
SWOOD	37.5	(0.059)	6.38	(0.050)
BARK	23.3	(0.217)	2.76	(0.152)
TOTAL	220.38		20.73	

TABLE 2(a) continued.

TAIRUA

	NITROGEN (SIG)		PHOSPHORUS (SIG)	
1 YR FOL	77.6	(0.812)	3.64	(0.007)
2 YR FOL	64.0	(0.287)	3.81	(0.049)
3 YR FOL	25.7	(0.938)	1.59	(0.522)
COMPOSITE	4.5	(0.750)	0.29	(0.404)
DB WOOD	7.8	(0.578)	0.52	(0.506)
WOOD(BRANCH)	51.0	(0.359)	4.35	(0.190)
SWOOD	63.8	(0.220)	3.78	(0.011)
BARK	44.4	(0.132)	4.50	(0.506)
TOTAL	338.8		23.3	

From the Table 2 (a), the results from the control plots show that Waipoua is the least fertile site of the three, with Tairua being the most fertile. The significance values show the probability differences between fertiliser treatments at any one site. There are :-

(a) basically no significant differences in Waipoua

(b) Some differences in Riverhead i.e. in the 1YRFOL, COMP and SWOOD in both nutrients, and 2YRFOL and DBWOOD in phosphorus.

and (c) At Tairua the only significant differences being in P (1 & 2YRFOL and SWOOD)

If we divide the uptake by the tree age it is possible to say that if a soil is incapable of supplying 2 kg P/ha/yr the trees growing on it will be P deficient.

TABLE 2 (b)

A-GRADE - NUTRIENT COMPONENTS Kg/ha

WAIPOUA

	NITROGEN	PHOSPHORUS
1 YR FOL	55.0	7.36
2 YR FOL	31.7	4.79
3 YR FOL	12.8	2.17
COMPOSITE	5.23	0.92
DB WOOD	4.67	0.72
WOOD(BRANCH)	28.8	7.28
SWOOD	40.2	9.23
BARK	24.8	4.29
	258.4	36.78

RIVERHEAD

	NITROGEN	PHOSPHORUS
1 YR FOL	96.8	7.84
2 YR FOL	60.5	5.04
3 YR FOL	13.4	1.09
COMPOSITE	1.24	0.105
DB WOOD	8.77	0.988
WOOD(BRANCH)	50.3	8.09
SWOOD	59.2	11.55
BARK	31.1	5.02
	321.3	39.7

TAIRUA

	NITROGEN	PHOSPHORUS
1 YR FOL	103.6	8.83
2 YR FOL	65.3	5.69
3 YR FOL	27.3	2.22
COMPOSITE	4.8	0.462
DB WOOD	12.9	1.04
WOOD(BRANCH)	53.5	6.52
SWOOD	70.8	8.23
BARK	33.6	7.9
	371.8	40.9

TABLE 2 (c)

SUPERPHOSPHATE - NUTRIENT COMPONENTS Kg/ha

WAIPOUA

	NITROGEN	PHOSPHORUS
1 YR FOL	34.9	5.35
2 YR FOL	20.3	3.98
3 YR FOL	10.47	2.33
COMPOSITE	3.41	0.92
DB WOOD	4.29	0.827
WOOD(BRANCH)	23.0	5.66
SWOOD	37.1	7.73
BARK	23.9	4.22
	157.37	31.16

RIVERHEAD

	NITROGEN	PHOSPHORUS
1 YR FOL	74.8	6.72
2 YR FOL	56.7	5.43
3 YR FOL	21.8	2.29
COMPOSITE	0.72	0.087
DB WOOD	7.21	0.966
WOOD(BRANCH)	38.6	6.38
SWOOD	69.9	11.53
BARK	32.4	4.78
	302.13	38.81

TAIRUA

	NITROGEN	PHOSPHORUS
1 YR FOL	88.7	8.00
2 YR FOL	54.7	4.73
3 YR FOL	24.7	2.20
COMPOSITE	3.5	0.35
DB WOOD	10.1	0.84
WOOD(BRANCH)	38.3	5.05
SWOOD	74.6	9.38
BARK	32.0	4.6
	326.6	35.15

Both the A-Grade and the superphosphate treatments show that Waipoua has the least amount of total P in the tree components, and Tairua has the most. This is directly related to biomass on the site. Table 3 shows how much fertiliser has been taken up i.e. the total amount of nutrients present minus the value of the control plots, Table 3 was constructed.

TABLE 3. UPTAKE OF NUTRIENTS (kg/ha)

A-GRADE

	NITROGEN	PHOSPHORUS
WAIPOUA	53.34	20.03
RIVERHEAD	100.9	18.97
TAIRUA	33.0	17.6

SUPERPHOSPHATE

	NITROGEN	PHOSPHORUS
WAIPOUA	7.51	15.08
RIVERHEAD	81.7	18.08
TAIRUA	-12.2	11.85

(Seven years after the application of P fertiliser)

In Riverhead Forest nitrogen was taken up from the site even though there was no nitrogen fertiliser applied. We do not know why this happens, but it may be due to an alteration in the carbon to phosphorus ratio in organic matter allowing faster release of N.

A-Grade has the most phosphorus present in the tree at the time the biomass was performed. This was as expected, because the phosphorus was taken up over a longer period of time. The superphoshate was initially more avaliable to the trees, but has tailed off. If we had performed the biomass at age 2 or 3, we would probably expect the superphosphate treatment to have higher values than the A-grade.

TABLE 4.

FOREST FLOOR (LITTER) CONTENTS

Weight (Kg/ha) of Litter on Forest Floor

	CONTROL	A-GRADE	SUPERPHOSPHATE
WAIPOUA	8143	11982	11823
RIVERHEAD	13008	12632	11682
TAIRUA	10839	12243	10220

TABLE 5.

WEIGHT OF NUTRIENTS IN FOREST LITTER (Kg/ha)

CONTROL

	NITROGEN	PHOSPHORUS
WAIPOUA	68.0	4.00
RIVERHEAD	128.0	5.70
TAIRUA	148.0	6.73

A-GRADE

	NITROGEN	PHOSPHORUS
WAIPOUA	108.6	8.06
RIVERHEAD	123.0	9.20
TAIRUA	155.0	13.22

SUPERPHOSPHATE

	NITROGEN	PHOSPHORUS
WAIPOUA	98.3	7.93
RIVERHEAD	128.0	10.00
TAIRUA	143.0	10.09

The litter has large pools of phoshorus and nitrogen, and again Waipoua has the lowest values, and Tairua the highest. The A-Grade treatment litter usually had the highest contents.

TABLE 6. WEED BIOMASS CONTENTS

Weight (Kg/ha) of Weeds.

	CONTROL	A-GRADE	SUPERPHOSPHATE
WAIPOUA	8434	6809	9732
RIVERHEAD	5955	6389	2682
TAIRUA	4885	3512	1743

Waipoua has the highest amount of weeds on site, and Tairua the least. Weeds tend to be more abundant on sites with less tree biomass, and therefore less overhead shade.

Figure 1 shows the relationship between the weight of weed and trees on the sites.

TABLE 7. WEIGHT OF NUTRIENTS IN THE FOREST WEEDS (Kg/ha)

CONTROL

	NITROGEN	PHOSPHORUS
WAIPOUA	36.4	3.60
RIVERHEAD	27.9	1.70
TAIRUA	29.3	1.84

A-GRADE

	NITROGEN	PHOSPHORUS
WAIPOUA	24.9	3.52
RIVERHEAD	25.3	3.02
TAIRUA	24.1	2.59

SUPERPHOSPHATE

	NITROGEN	PHOSPHORUS
WAIPOUA	37.1	5.68
RIVERHEAD	17.1	1.67
TAIRUA	12.2	1.48

These results show that there is very little phosphorus actually taken up by the weeds. The most being taken up in Waipoua and the least in Tairua.

If the study had been done at a different time, particularily if done earlier, the conclusions would probably have been different.

SOIL RESULTS.

TABLE 8. Available Soil Phosphorus in kg/ha (Bray P).

	Depth (cm)	Bulk Density	Control	A-Grade Superphosphate	
			-------kg P/ha---------		
WAIPOUA	0 - 10	1.17	5.1	14.4	14.5
	10 - 30	1.51	22.2	45.4	58.2
	30 - 60	1.51	15.6	35.7	111.9
			42.9	95.5	184.6
RIVERHEAD	0 - 10	1.19	3.6	61.8	52.0
	10 - 30	1.32	4.8	12.4	9.6
	30 - 60	1.32	4.2	8.4	11.1
			12.6	82.6	72.7
TAIRUA	0 - 10	0.59	1.7	15.2	6.5
	10 - 30	0.57	1.8	3.4	1.2
	30 - 60	0.57	1.5	1.8	2.1
			5.0	20.4	9.8

TABLE 9. Total Soil Phosphorus in kg/ha.

	Depth (cm)	Bulk Density	Control	A-Grade Superphosphate	
			-------kg P/ha---------		
WAIPOUA	0 - 10	1.17	73.3	78.4	69.0
	10 - 30	1.51	171.2	191.8	191.8
	30 - 60	1.51	221.1	225.0	448.1
			465.6	495.2	708.9
RIVERHEAD	0 - 10	1.19	224.5	390.3	224.0
	10 - 30	1.32	430.3	407.4	344.8
	30 - 60	1.32	645.2	842.0	706.1
			1300.0	1639.7	1294.9
TAIRUA	0 - 10	0.59	248.4	375.2	318.6
	10 - 30	0.57	318.2	303.6	275.0
	30 - 60	0.57	363.8	289.4	233.0
			930.4	968.2	826.6

The total soil phosphorus figures are not very helpful. We should be able to find the remainder of the fertiliser here, but cannot because of the very high variability. The available phosphorus results show clearly enhanced availability of P in the fertilised plots at both Riverhead and Waipoua and a slight improvement at Tairua. The improvement is confined to the surface layers at Riverhead and Tairua. At Waipoua however it seems to be evidence of leaching of P down the profile with, as one might expect, more P leaching from the superphosphate plots than from the A-grade ones. Clearly not all the P labelled as "avaliable" is actually available to the trees since the control trees have been unable to extract more than 2 kg P/ha/yr and if they could now take up the apparently "available" P their problems would be over. We feel this result occurs because our chemical extractant is too strong and gets at too much P in the soil. We are currently testing a milder extractant which we hope will give better results.

****

REFERENCES.

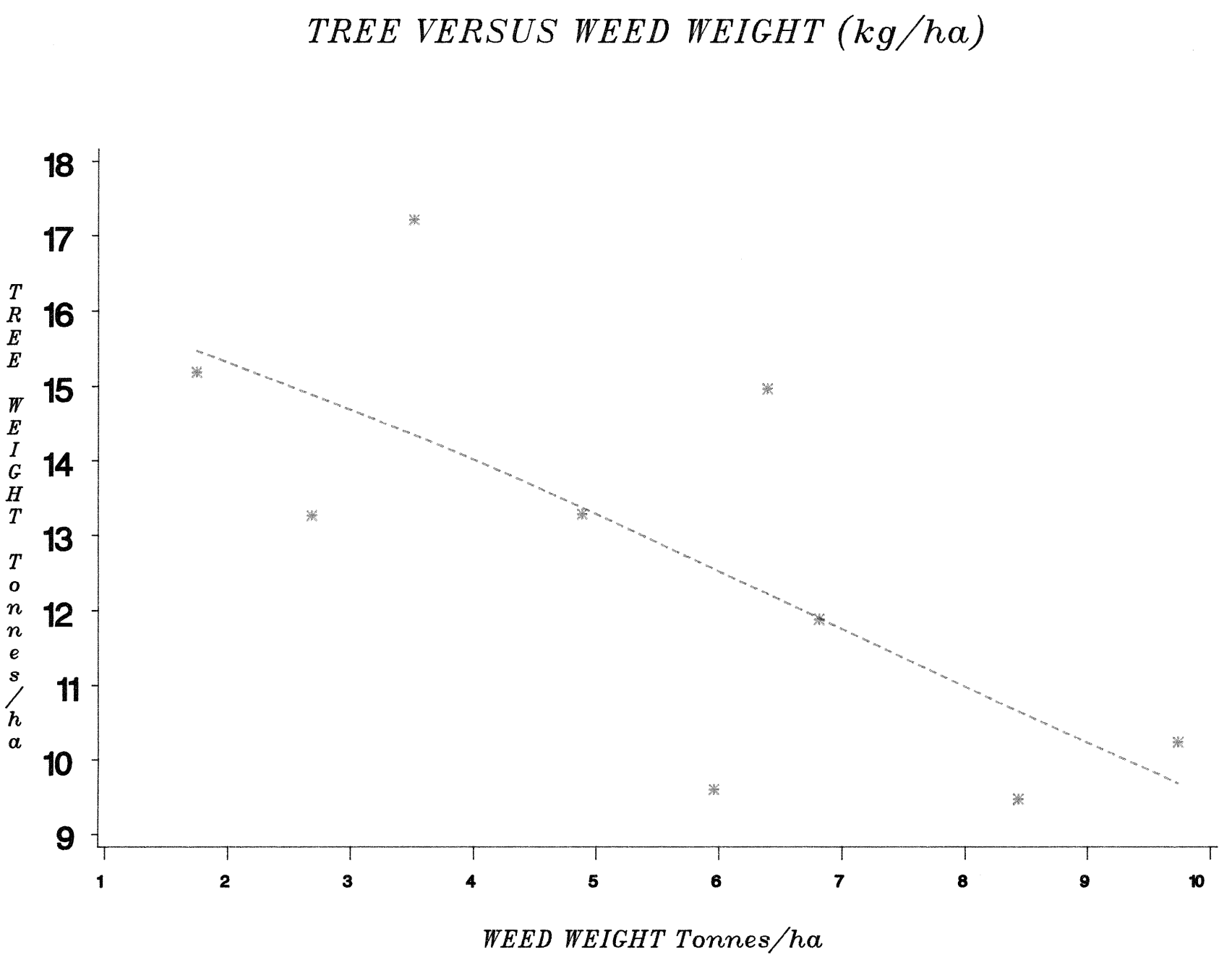
Hunter, I.R. and Graham, J.G. 1982: Growth response of phosphorus deficient Pinus radiata to various rates of superphosphate fertiliser. New Zealand Journal of Forestry Science 12 49-61.

Madgwick, H.A.I. 1981: Estimating the above ground weight of forest plota using the basal area ratio method. New Zealand Journal of Forestry Science 11 278-86.

Madgwick, H.A.I., Jackson, D.S. and Knight, P.J. 1977: Above ground dry matter,energy and nutrient contents of trees in an age series of Pinus radiata plantations. New Zealand Journal of Forestry Science 7 445-49.

Nicholson, G.M. (comp). 1984: Methods of soil, plant and water analysis. New Zealand Forest Service FRI Bulletin No.70.

FIGURE 1.


TREE VERSUS WEED WEIGHT (kg/ha)
TREE WEIGHT Tonnes/ha
18
17
16
15
14
13
12
11
10
9
1
2
3
4
5
6
7
8
9
10
WEED WEIGHT Tonnes/ha