F.R.I. PROJECT RECORD

NO. 1645

GROWTH OF RADIATA PINE IN A LONG TERM PHOSPHORUS TRIAL

Site A. RIVERHEAD FOREST

Site B. WHANGAPOUA FOREST

COMPILED
BY

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REPORT NO. 17 SEPTEMBER 1987

PREFACE

The research presented in the following papers was supported financially and otherwise by The New Zealand Forest Service/ New Zealand Forestry Corporation.

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

GROWTH OF RADIATA PINE TO AGE 19

IN A LONG TERM PHOSPHORUS FERTILISER TRIAL.

RIVERHEAD STATE FOREST.

A Report Prepared for Auckland Conservancy.

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JANUARY 1987.

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MANAGEMENT SUMMARY.

1. Phosphorus fertilised trees produced at age 19 a volume of 270 m3/ha. This shows that with appropriate management good crops of radiata pine can be grown on very P deficient soils. Recently fertilised trees have been growing at 40 m3/ha/yr.

2. The unfertilised trees lagged 200 m3/ha behind the fertilised plots, and had a very poor 57 m3/ha volume, at age 19. They will be as poor, if not poorer than the Museum plots on Barlow Road.

3. As with the Whangapoua trials the rate of return to fertilising exceeds 20 % and is maximised by applying frequent light rates of fertiliser.

4. Our conclusion from the Whangapoua trials that the best way to do this is to regularly foliage sample stands and apply fertiliser when growth falls:-

- below 0.11 % P for young crops up to age 16
- below 0.10 % P for older crops,

is not altered.

INTRODUCTION.

The trial is situated in Riverhead State Forest, 20 km northwest of Auckland city.

The soil type is now mapped in a recent publications by the DSIR Soil Bureau as a mixture of Mahurangi fine sandy loam and Warkworth clay and sandy clay loam. At trial establishment the soil had a medium P retention (approximately 40 %), with a Bray P of 1.9 ppm. A medium to low soil nitrogen of 0.13 %, and pH of 4.8. As such, it is a site which is fairly typical of many being managed in the Auckland area.

The trial was established in 1973 in 6 year old unthinned, unpruned radiata pine. The trees were thinned to 370 sph at age 13. Slopes within the site vary around 10 to 20 degrees.

FERTILISER TREATMENTS.

The treatments used were:-

1. No fertiliser
2. 625 kg/ha of superphosphate at trial establishment
3. 1250 kg/ha of superphosphate at trial establishment
4. 625 kg/ha at establishment and again after 10 years
5. 625 kg/ha at establishment and again after 5,10,15 years
6. 625 kg/ha delayed until 5 years after trial establishment
7. 625 kg/ha applied every time foliar P fell below 0.13 % - the "management treatment".
8. 1250 kg/ha applied every time foliar P fell below 0.13 %.
9. 2500 kg/ha superphosphate at trial establishment.

A further two treatments which are not part of the trial series were included but have not been taken into consideration when presenting the results :-

10. 1250 kg/ha superphosphate at establishment + 270 kg/ha of urea.
11. As above + micronutrients

Each of the above treatments were replicated twice, giving a total of 22 plots.

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VOLUME AT AGE 19.

	Treatment	Volume (m3/ha)
1.	no fertiliser	57
2.	625 kg/ha	257
3.	1250 kg/ha	289
4.	625 * 2 kg/ha	270
5.	625 * 4 kg/ha	263
6.	625 kg/ha delayed	217
7.	625 on foliar P	289
8.	1250 on foliar P	283
9.	2500 kg/ha	270

The treatment effect is statistically very significant. The standard error of difference between the fertilised treatments is 39 m3/ha. The major contributing factor being the difference between the unfertilised treatment and the fertilised ones

1. The unfertilised treatment at 57 m3/ha is 160 m3/ha behind the lowest fertiliser response (625 delayed).

2. The remaining treatments averaging 275 m3/ha approximately.

3. The 625 delayed treatment has clearly the lowest response of the fertilised treatments.

PERIODIC ANNUAL VOLUME INCREMENT

From the volume measurements made at ages 6,9,12,14,and 19 it is possible to calculate 4 periodic volume increments (6-9, 9-12, 12-14, 14-19).

These have been divided by the number of years in the period to produce annual volume increment.

	Periodic annual volume increment m3/ha/yr			
	6-9	9-12	12-14	14-19
1. Not fertilised	2.8	7.6	3.8	6.6
2. 625 kg/ha	8.2	28.6	17.6	33.8
3. 1250 kg/ha	7.8	28.3	20.6	39.7
4. 625 * 2 kg/ha	5.4	24.2	17.4	37.1
5. 625 * 4 kg/ha	5.0	21.9	20.0	37.6
6. 625 kg/ha delayed	4.0	14.0	13.2	32.8
7. 625 by foliar P	7.3	28.9	20.6	40.0
8. 1250 on foliar P	8.4	31.6	20.5	37.5
9. 2500 kg/ha	7.3	28.0	19.6	37.0

These volume increments can be related to the average foliar P concentration over the period.

	Average Foliar Phosphorus. (Period)			
	6-9	9-12	12-14	14-19
1. Not fertilised	0.060	0.060	0.069	0.071
2. 625 kg/ha	0.096	0.099	0.106	0.096
3. 1250 kg/ha	0.120	0.122	0.156	0.137
4. 625 * 2 kg/ha	0.094	0.095	0.117	0.133
5. 625 * 4 kg/ha	0.100	0.090	0.176	0.165
6. 625 kg/ha delayed	0.071	0.076	0.155	0.155
7. 625 by foliar P	0.114	0.127	0.169	0.153
8. 1250 on foliar P	0.120	0.128	0.220	0.186
9. 2500 kg/ha	0.128	0.130	0.200	0.173

Volume increment is graphed against foliar P in figures 1 - 5 The fitted line is a SAS generated spline curve. It seems that a slightly higher level of foliar P is needed in younger crops (> 0.11 %) than in older ones (> 0.10 %). Younger crops are actively acquiring P from the soil, older ones are recycling P through litter, and have smaller nett demands.

MEAN TOP HEIGHT AT AGE 19

	Treatment	Height (m)
1.	Not fertilised	15.0
2.	625 kg/ha	27.5
3.	1250 kg/ha	26.3
4.	625 * 2 kg/ha	22.4
5.	625 * 4 kg/ha	23.5
6.	625 kg/ha delayed	22.5
7.	625 by foliar P	24.3
8.	1250 by foliar P	26.7
9.	2500 kg/ha	24.7

Height growth is adversely affected by extreme phosphorus deficiency, and by delayed fertilising, but there is no difference between the other fertiliser treatments.

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ECOMONICS.

As with the Whangapoua trials we assume that the fertiliser cost $ 200/tonne applied and the wood is worth $ 30/m3 now. The site returned 57 m3/ha without fertilising. This wood is virtually worthless. The internal rate of return, is calculated using the simple volume difference between the average unfertilised response and that in the various fertiliser rates.

Treatment	Internal rate of return
1. Not fertilised	-
2. 625 kg/ha	35 %
3. 1250 kg/ha	29 %
4. 625 * 2 kg/ha	35 %
5. 625 * 4 kg/ha	32 %
6. 625 kg/ha delayed	58 %
7. 625 on foliar P	33 %
8. 1250 on foliar P	26 %
9. 2500 kg/ha	22 %

The first point to note is that, for an existing land owner maintaining the growth rate of potentially P deficient stands is one of the most profitable avenues to pursue - almost certainly exceeding the rate of return on new planting and tending.

The second main point is that, unless the landowner intended to fell his trees at age 19, the precise ranking of these treatments would vary by age 30.

Nevertheless, it is clear, as we have stated with the Whangapoua trials that the delayed expenditure on the 625 delayed treatment appears to be the most profitable. It is a risky treatment however because the height growth loss that accompanies severe P deficiency is often associated with tip dieback and malformation.
We cannot fairly cost that risk in this exercise.
As a strategy it should only be adopted by a manager who is aware of, and prepared to accept this risk. The other treatments are fairly similiar in rate of return, although using a high rate of fertiliser early in the life of the crop (eg 1250) is not as profitable as spreading the same amount over two applications 10 years apart (i.e. 625 kg/ha at 6 and 16).

Another way of expressing the difference is to look at the marginal return to the higher rates (with their slightly higher volumes) over the 625 kg/ha rate.

Treatment	Marginal rate of return over 625 kg/ha at age 6.
625 * 2	42 %
625 * 4	poor
1250	17 %
2500	3 %

This table emphasises the fact that applying high rates early in the rotation is not as profitable as applying lighter rates more often.

CONCLUSION

Our conclusion is that fertilising P deficient radiata pine is one of the most profitable things a manager can do in his forest. The best way to maximise profitability seems to be to apply light rates of fertiliser whenever foliar P falls below 0.11 % for younger crops (up to age 16), and 0.10 % for older crops.

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FIGURE 1

Periodic Annual Volume Increment (Ages 6 – 9)
Related to Foliar Phosphorus

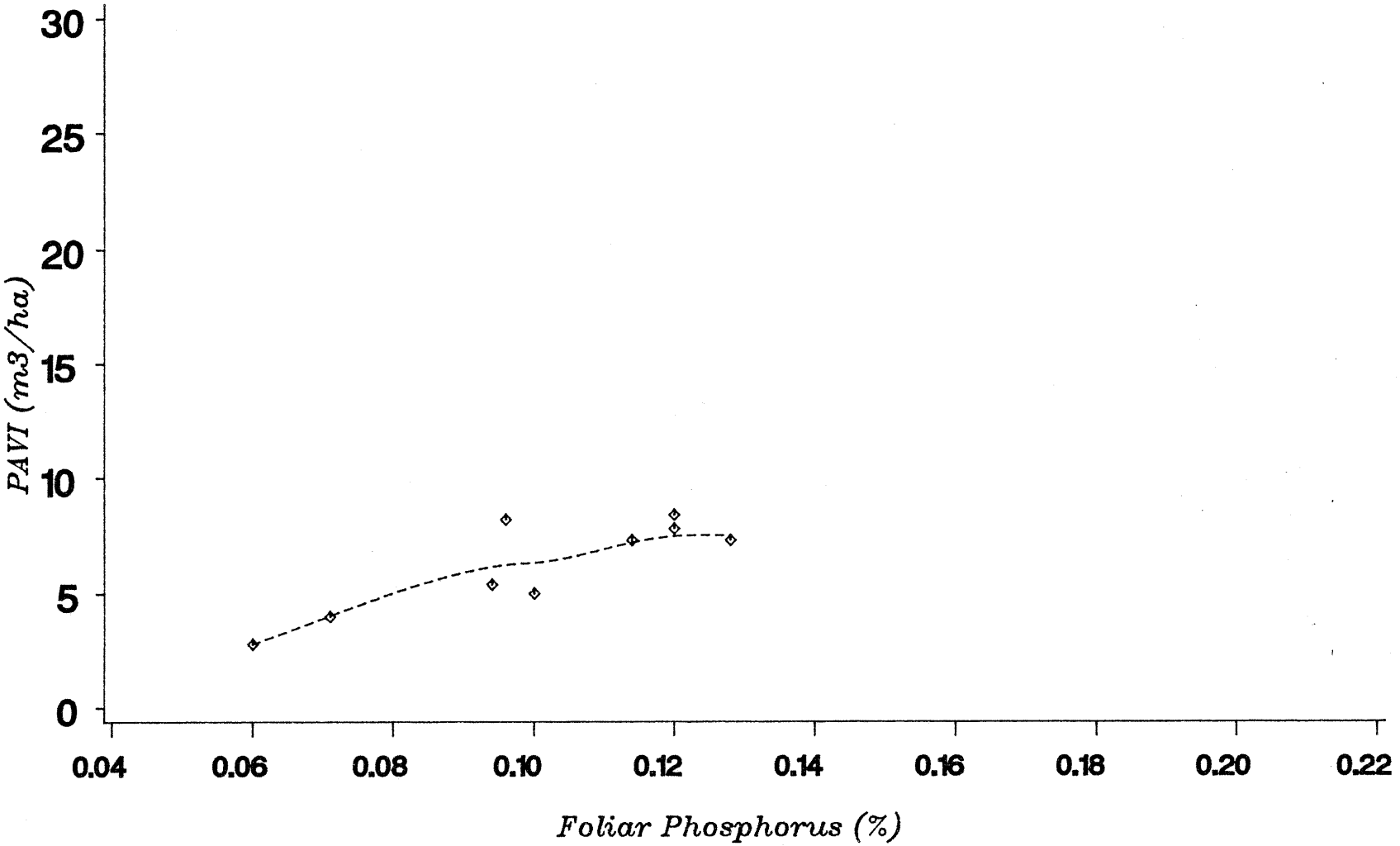


FIGURE 2

Periodic Annual Volume Increment (Ages 9 – 12)
Related to Foliar Phosphorus

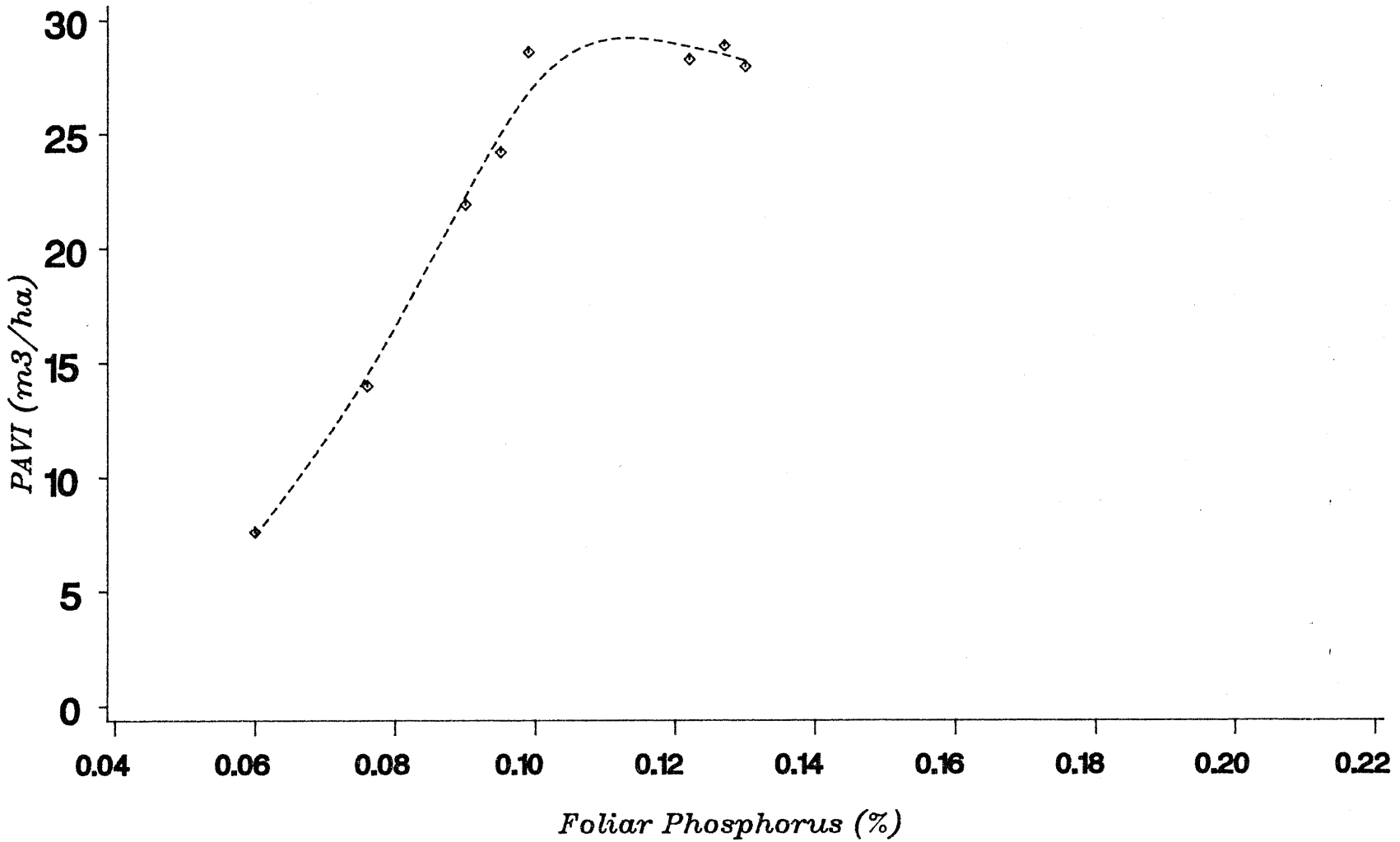


FIGURE 3

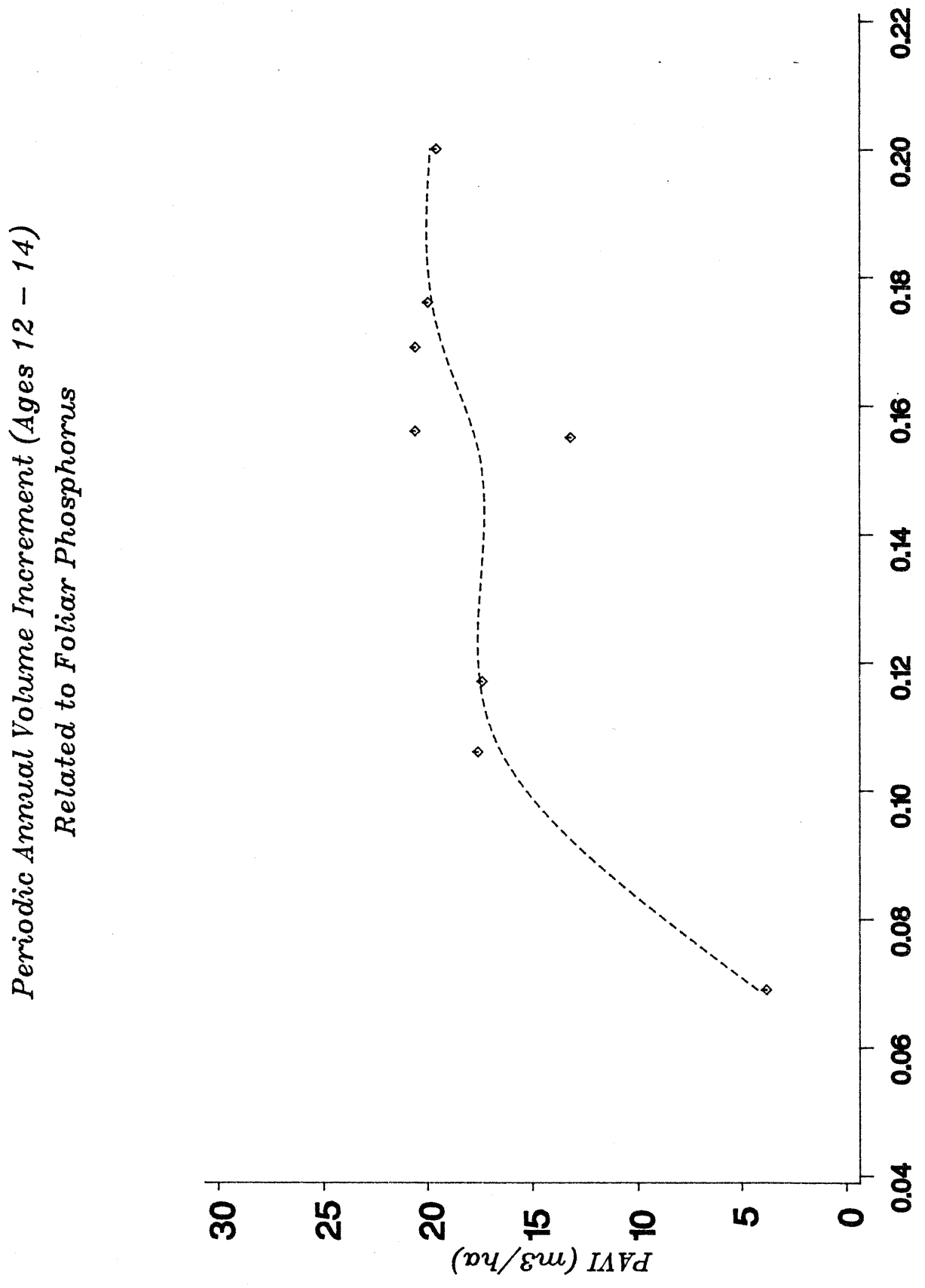

Periodic Annual Volume Increment (Ages 12 – 14)
Related to Foliar Phosphorus
PAVI (m3/ha)
30
25
20
15
10
5
0
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
Foliar Phosphorus (%)

FIGURE 4

Periodic Annual Volume Increment (Ages 14 – 19)
Related to Foliar Phosphorus

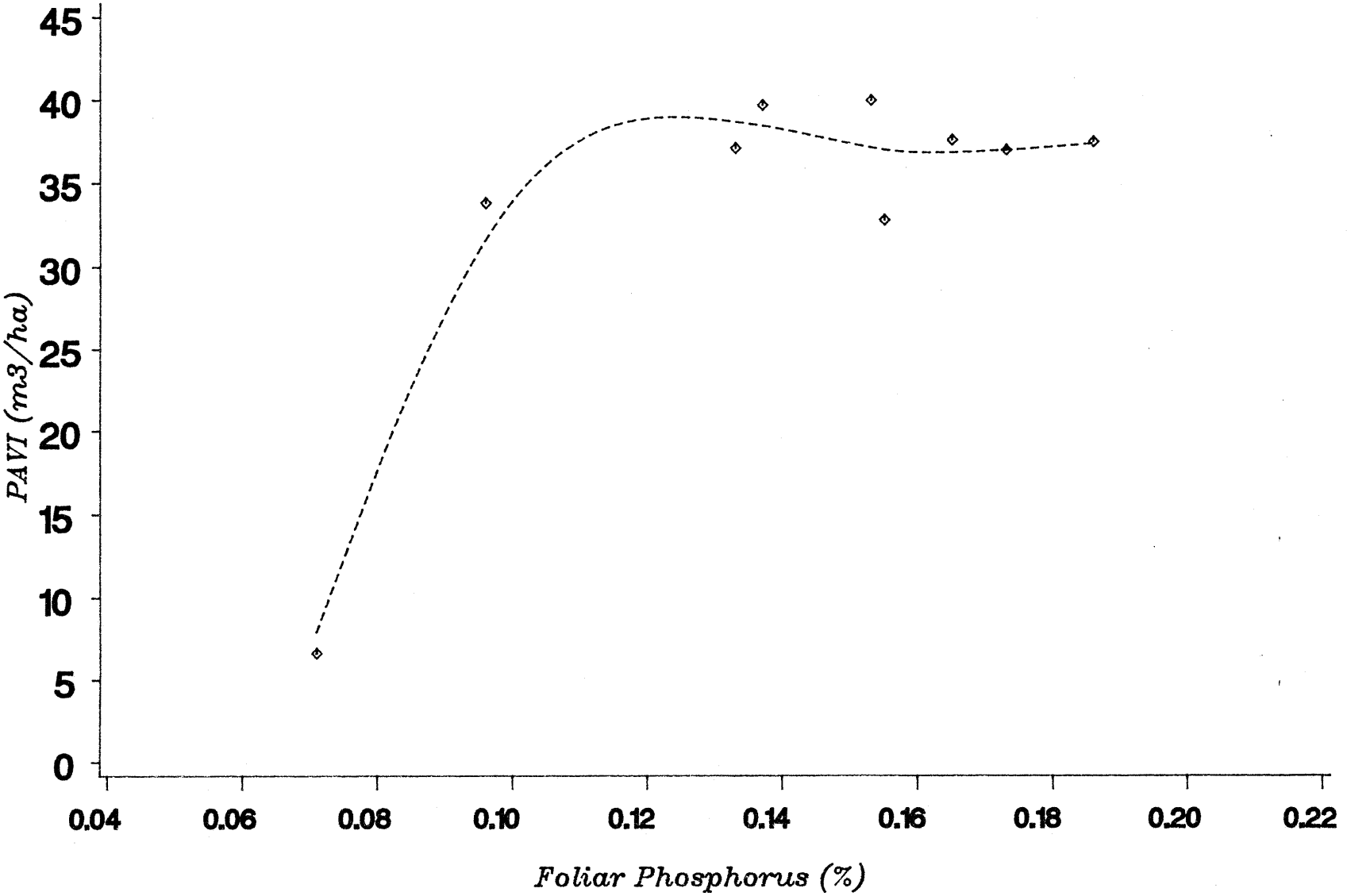
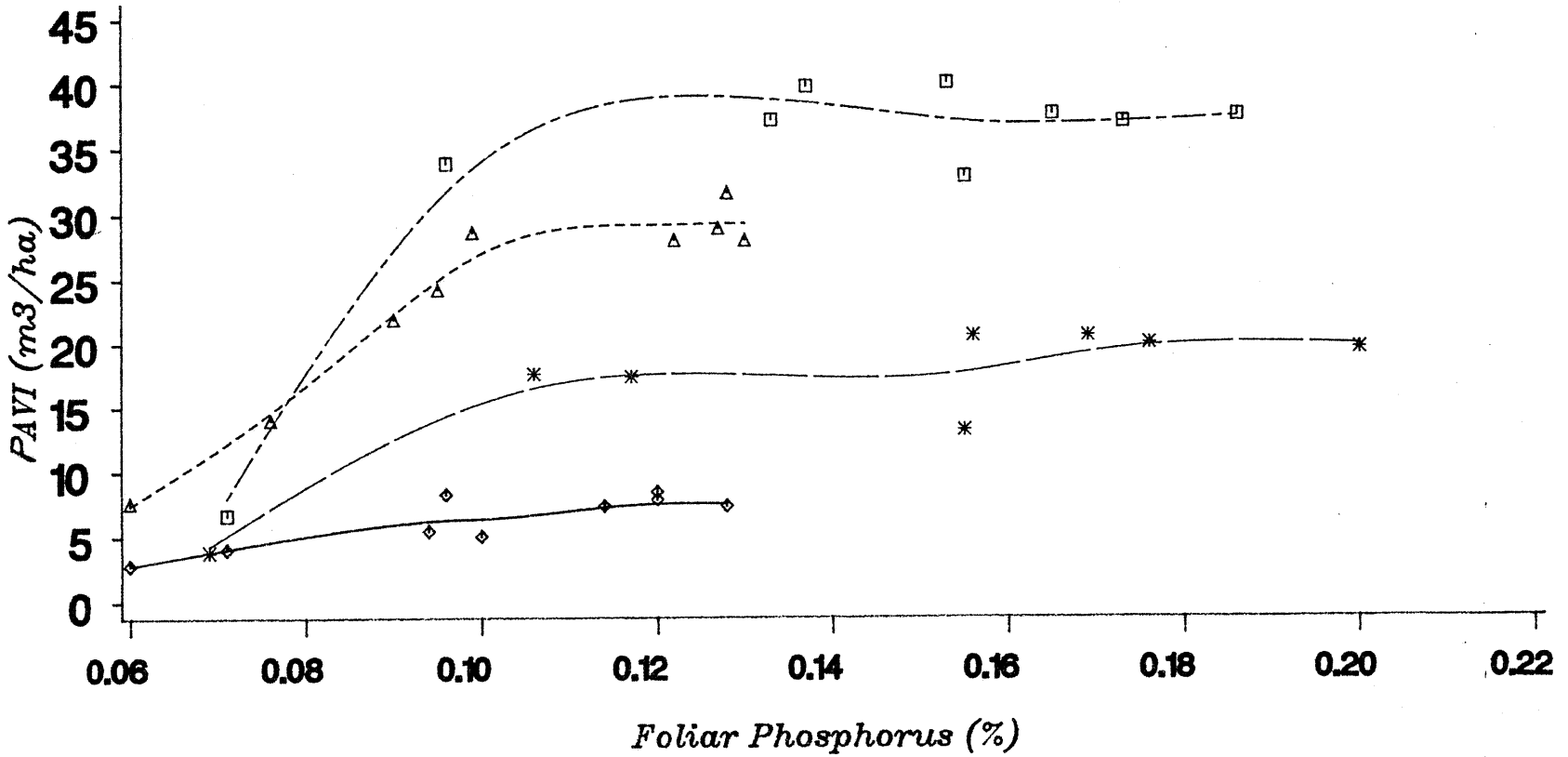


FIGURE 5

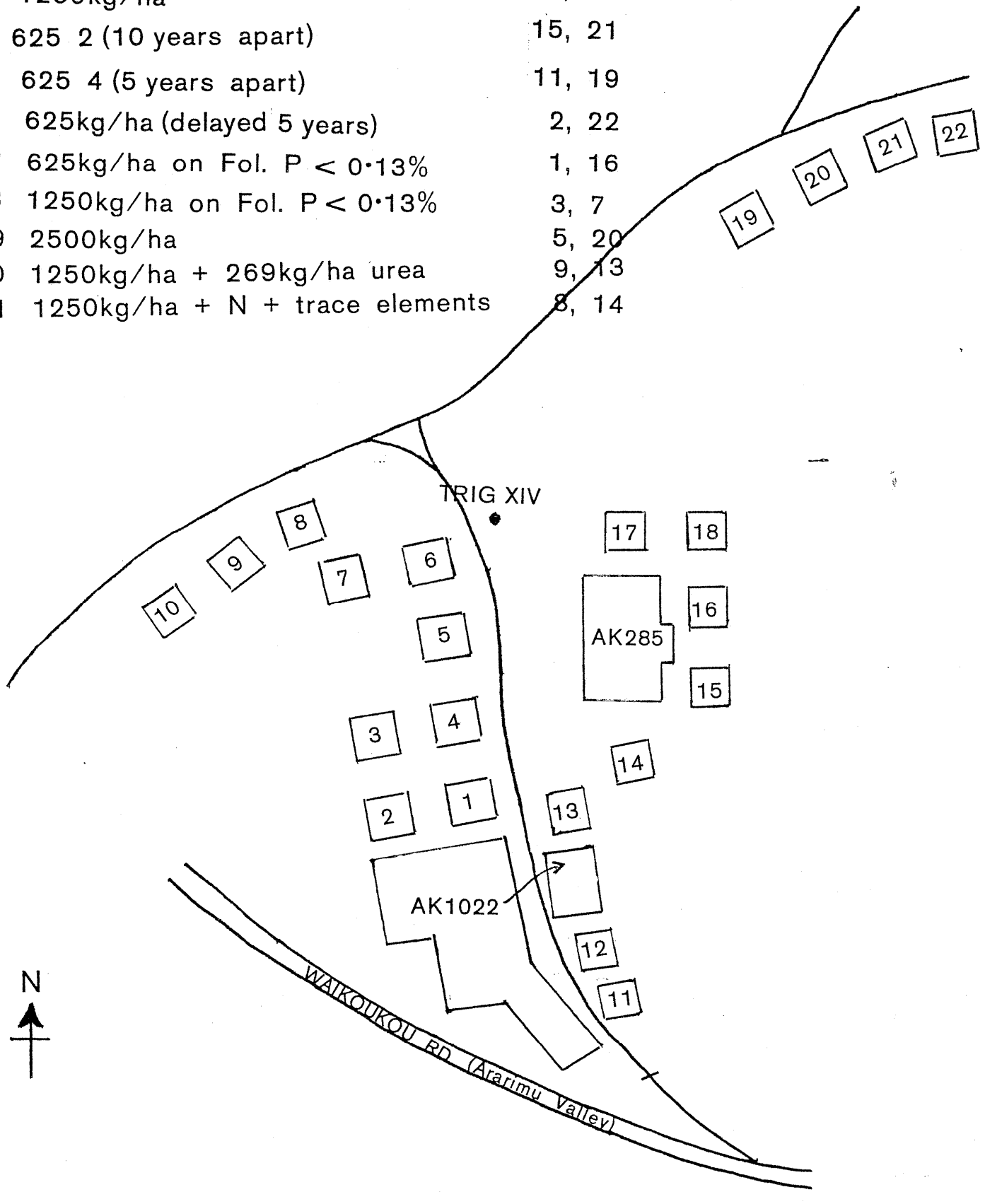
Periodic Annual Volume Increment (Combined Figures 1 – 4)
Related to Foliar Phosphorus



LEGEND:PAVI 6–9___ PAVI 9–12___ PAVI 12–14___ PAVI 14–19__

LOCATION MAP AK286/6 RIVERHEAD Cpt. 18

	TREATMENT	PLOTS
1	No fertiliser	6, 12
2	625kg/ha	4, 18
3	1250kg/ha	10, 17
4	625 2 (10 years apart)	15, 21
5	625 4 (5 years apart)	11, 19
6	625kg/ha (delayed 5 years)	2, 22
7	625kg/ha on Fol. P < 0·13%	1, 16
8	1250kg/ha on Fol. P < 0·13%	3, 7
9	2500kg/ha	5, 20
10	1250kg/ha + 269kg/ha urea	9, 13
11	1250kg/ha + N + trace elements	8, 14



SCALE 1cm = 26m

GROWTH OF RADIATA PINE TO AGE 25

IN A LONG TERM PHOSPHORUS FERTILISER TRIAL.

WHANGAPOUA STATE FOREST.

A Report Prepared for Auckland Conservancy.

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Forest Management and Resources Division,

Forest Research Institute.

JANUARY 1987.

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MANAGEMENT SUMMARY.

1. Phosphorus fertilised trees produced at age 25 the very satisfactory volume of 700 m3/ha. This shows that with appropriate management good crops of radiata pine can be grown on P deficient soils.

2. The unfertilised trees lagged 270 m3/ha behind the fertilised plots.

3. The rate of return to fertilising exceeds 20 % and is maximised by applying frequent light rates of fertiliser.

4. The best way to do this is to regularly foliage sample stands and apply fertiliser when growth falls:-

- below 0.11 % P for young crops up to age 16
- below 0.10 % P for older crops.

INTRODUCTION.

The trial is situated in Whangapoua State Forest at the northern end of the Coromandel Peninsula. The soil is a clay weathered from very old volcanic ash. At trial establishment the soil had a low Bray Phosphorus (less than 8 ppm). It had only a medium P retention (approximately 60 %) and a reasonable soil nitrogen (average of 0.26 % N). As such, it is a site which is fairly typical of many being managed in the Auckland region.

The trial was established in 1967 in 6 year old unthinned radiata pine. The trees were thinned to 400 sph at age 10.

FERTILISER TREATMENTS.

The treatments used were:-

1. No fertiliser
2. 625 kg/ha of superphosphate at trial establishment
3. 1250 kg/ha of superphosphate at trial establishment
4. 625 kg/ha at establishment and again after 10 years
5. 625 kg/ha at establishment and again after 5,10,15 years
6. 625 kg/ha delayed until 5 years after trial establishment
7. 625 kg/ha applied every time foliar P fell below 0.13 % - the "management treatment".

Treatments were replicated three times but the following points must be noted.

1. Blocks 1 and 2 were fertilised in 1967, block 3 in 1969. However after such a long time that difference in establishment date has little effect on the interpretation of trial results.

2. Treatment 6 - the delayed application is present only in blocks 1 and 2.

3. Treatment 7 - the management treatment - is present only in blocks 2 and 3.

VOLUME AT AGE 25.

	Treatment	Volume (m3/ha)
1.	no fertiliser	382
2.	625 kg/ha	646
3.	1250 kg/ha	720
4.	625 * 2 kg/ha	686
5.	625 * 4 kg/ha	723
6.	625 kg/ha delayed	659
7.	625 on foliar P	716

The treatment effect is statistically very significant. The standard error of difference between the fertilised treatments is 49 m3/ha, so the treatments sort themselves out into three groups:

1. The unfertilised treatment at 380 m3/ha is 270 m3/ha behind the lowest fertiliser.

2. The two lowest fertiliser rates (2 and 6) at 650 m3/ha approximately.

3. The remaining treatments averaging 700 m3/ha approximately.

PERIODIC ANNUAL VOLUME INCREMENT

From volume measurements at age 11, 16, 20 and 25 it is possible to calculate 3 periodic volume increments (11-16, 16-20, 20-25). These have been divided by the number of years in the period to produce annual volume increment.

	Periodic annual volume increment m3/ha/yr		
	11-16	16-20	20-25
1. Not fertilised	20	19	23
2. 625 kg/ha	38	38	40
3. 1250 kg/ha	43	41	46
4. 625 * 2 kg/ha	41	41	42
5. 625 * 4 kg/ha	41	46	44
6. 625 kg/ha delayed	31	50	46
7. 625 by foliar P	37	38	50

These volume increments can be related to the average foliar P concentration over the period.

	Average Foliar Phosphorus. (Period)		
	11-16	16-20	20-25
1. Not fertilised	0.090	0.073	0.084
2. 625 kg/ha	0.138	0.113	0.107
3. 1250 kg/ha	0.148	0.129	0.121
4. 625 * 2 kg/ha	0.132	0.118	0.124
5. 625 * 4 kg/ha	0.140	0.136	0.151
6. 625 kg/ha delayed	0.101	0.104	0.102
7. 625 by foliar P	0.134	0.136	0.128

Volume increment is graphed against foliar P in figures 1 - 4. The fitted line is a SAS generated spline curve. It seems that a higher level of foliar P is needed in younger crops (> 0.11 %) than in older ones (> 0.10 %). This makes sense. Younger crops are actively acquiring P from the soil, older ones are recycling P through litter, and have smaller nett demands.

MEAN TOP HEIGHT AT AGE 25.

	Treatment	Height (m)
1.	Not fertilised	30.4
2.	625 kg/ha	36.5
3.	1250 kg/ha	37.5
4.	625 * 2 kg/ha	36.8
5.	625 * 4 kg/ha	37.9
6.	625 kg/ha delayed	35.2
7.	625 by foliar P	37.6

Height growth is adversely affected by phosphorus deficiency.

ECOMONICS.

In this exercise we assume that the fertiliser cost $ 200/tonne applied and the wood is worth $ 30/m3 now. The site returned 380 m3/ha without fertilising. There is considerable variability between the unfertilised plots, one returning almost as much as the fertilised plots, the other two, produced little of harvestable value. For the purpose of this exercise, the simple difference between the average unfertilised response and that in the various fertiliser rates is converted to an internal rate of return.

Treatment	Internal rate of return
1. Not fertilised	-
2. 625 kg/ha	23 %
3. 1250 kg/ha	20 %
4. 625 * 2 kg/ha	24 %
5. 625 * 4 kg/ha	22 %
6. 625 kg/ha delayed	32 %

The first point to note is that, for an existing land owner maintaining the growth rate of potentially P deficient stands is one of the most profitable avenues to pursue - almost certainly exceeding the new rate of return on new planting and tending.

The second main point is that, unless the landowner intended to fell his trees at age 25, the precise ranking of these treatments could vary a little by say age 30.

Nevertheless, it is clear, that the delayed expenditure on the 625 delayed treatment appears to be the most profitable. It is a risky treatment however because the height growth loss that accompanies severe P deficiency is often associated with tip dieback and malformation. We cannot fairly cost that risk in this exercise. As a strategy it should only be adopted by a manager who is aware of, and prepared to accept this risk. The other treatments are fairly similiar in rate of return, although using a high rate of fertiliser early in the life of the crop (eg 1250) is not as profitable as spreading the same amount over two applications 10 years apart (i.e. 625 kg/ha at 6 and 16).

Another way of expressing the difference is to look at the marginal return to the higher rates (with their slightly higher volumes) over the 625 kg/ha rate.

Treatment	Marginal rate of return over 625 kg/ha at age 6.
625 * 2	25 %
625 * 4	22 %
1250	20 %

CONCLUSION

Our conclusion is that fertilising P deficient radiata pine is one of the most profitable things a manager can do in his forest. The best way to maximise profitability seems to be to apply light rates of fertiliser whenever foliar P falls below 0.11 % for younger crops (up to age 16), and 0.10 % for older crops.

Current Annual Volume Increment (At Age 13)
Related to Foliar Phosphorus

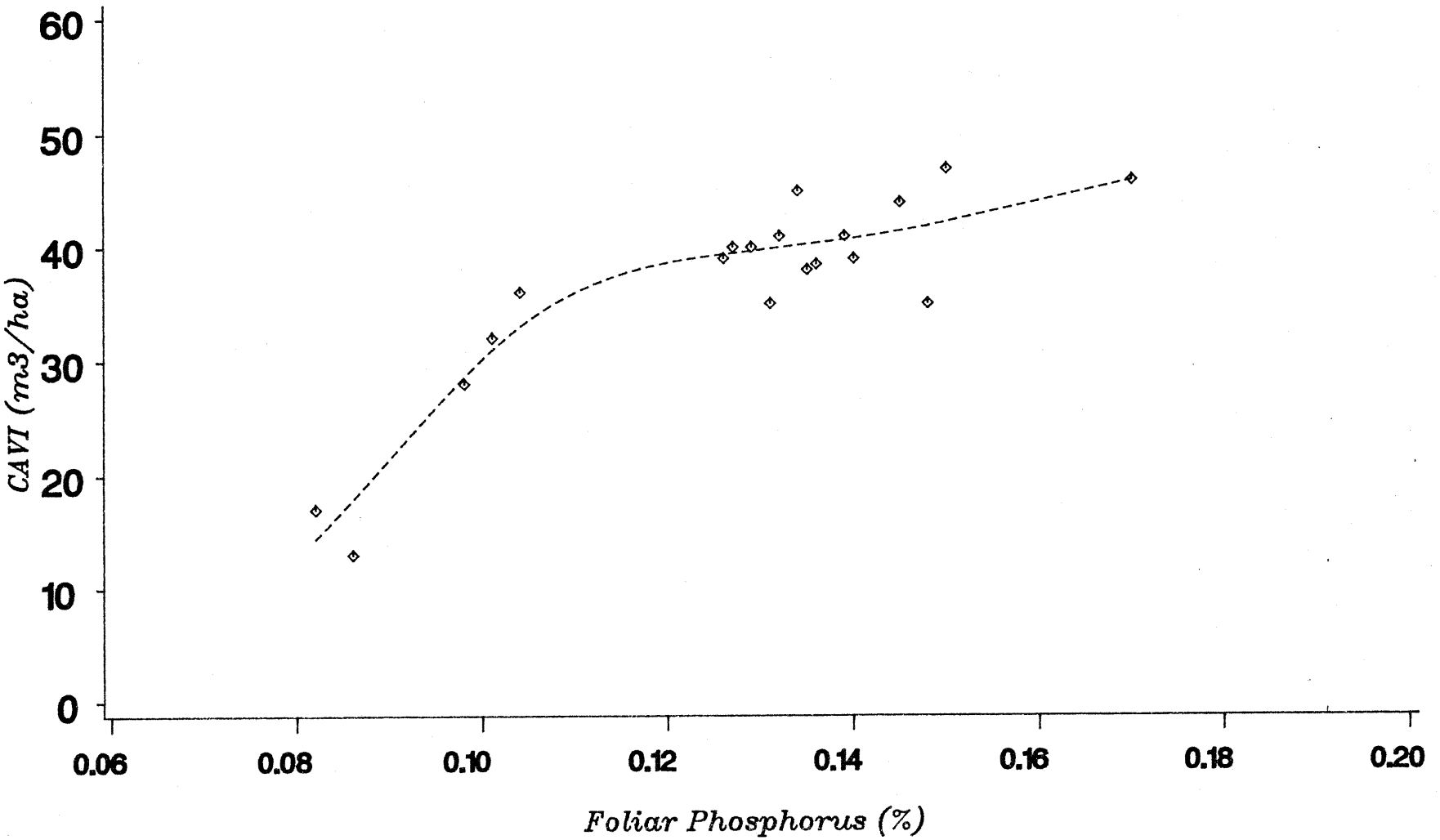
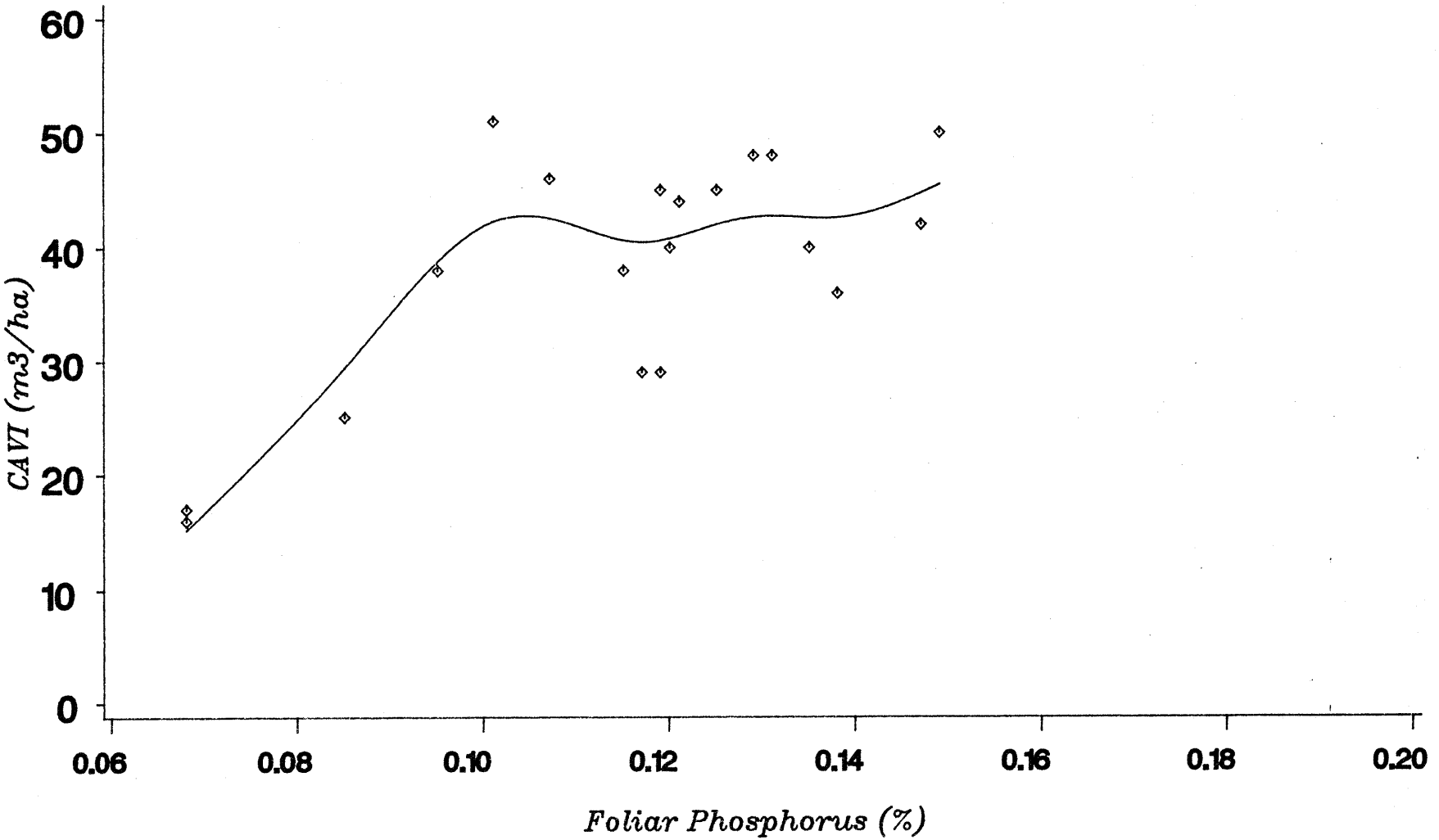


FIGURE 1

LEGEND:CAVI13

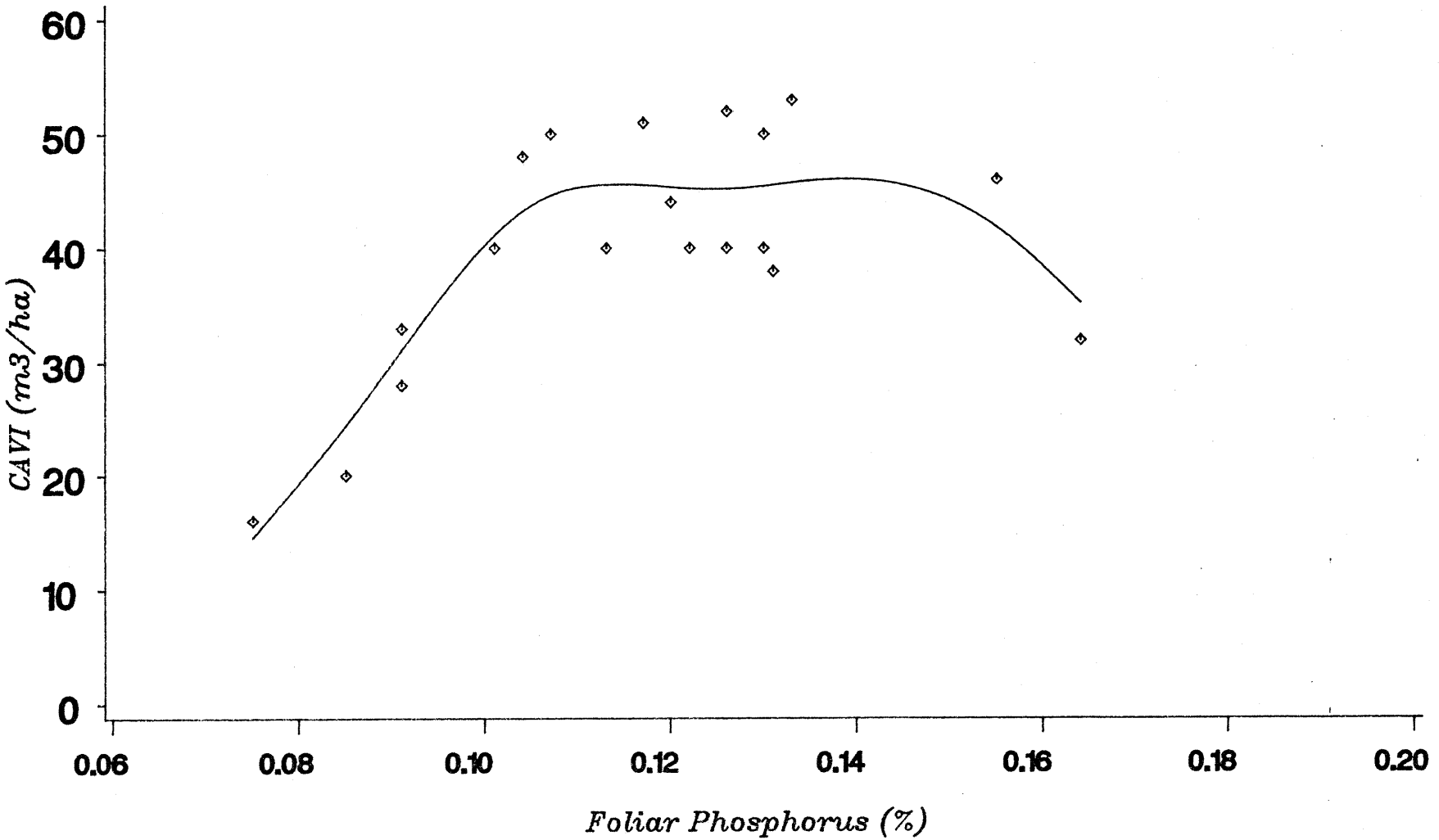
Current Annual Volume Increment (At Age 18)
Related to Foliar Phosphorus



LEGEND:CAVI18___

FIGURE 2.

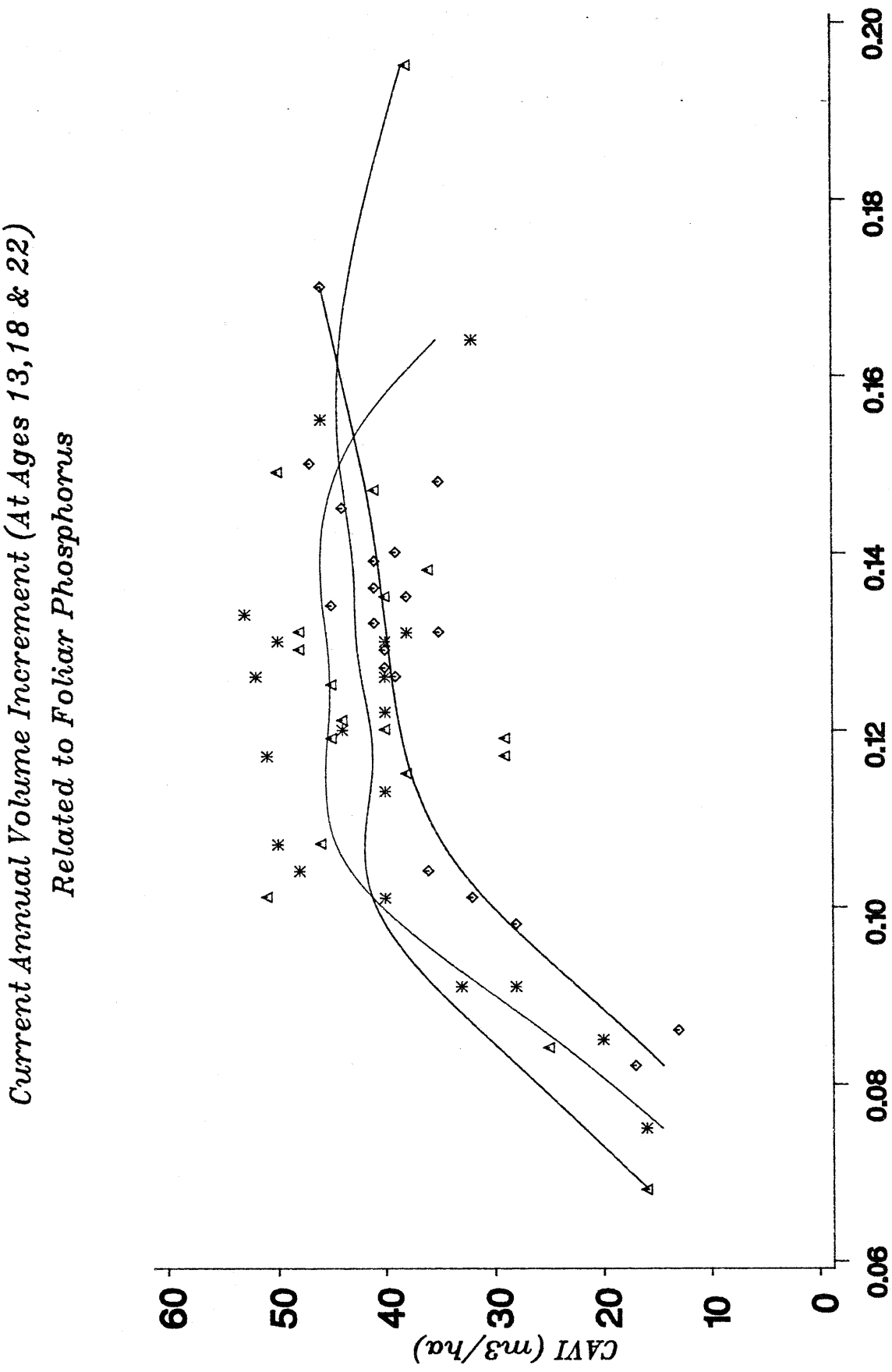
Current Annual Volume Increment (At Age 22)
Related to Foliar Phosphorus



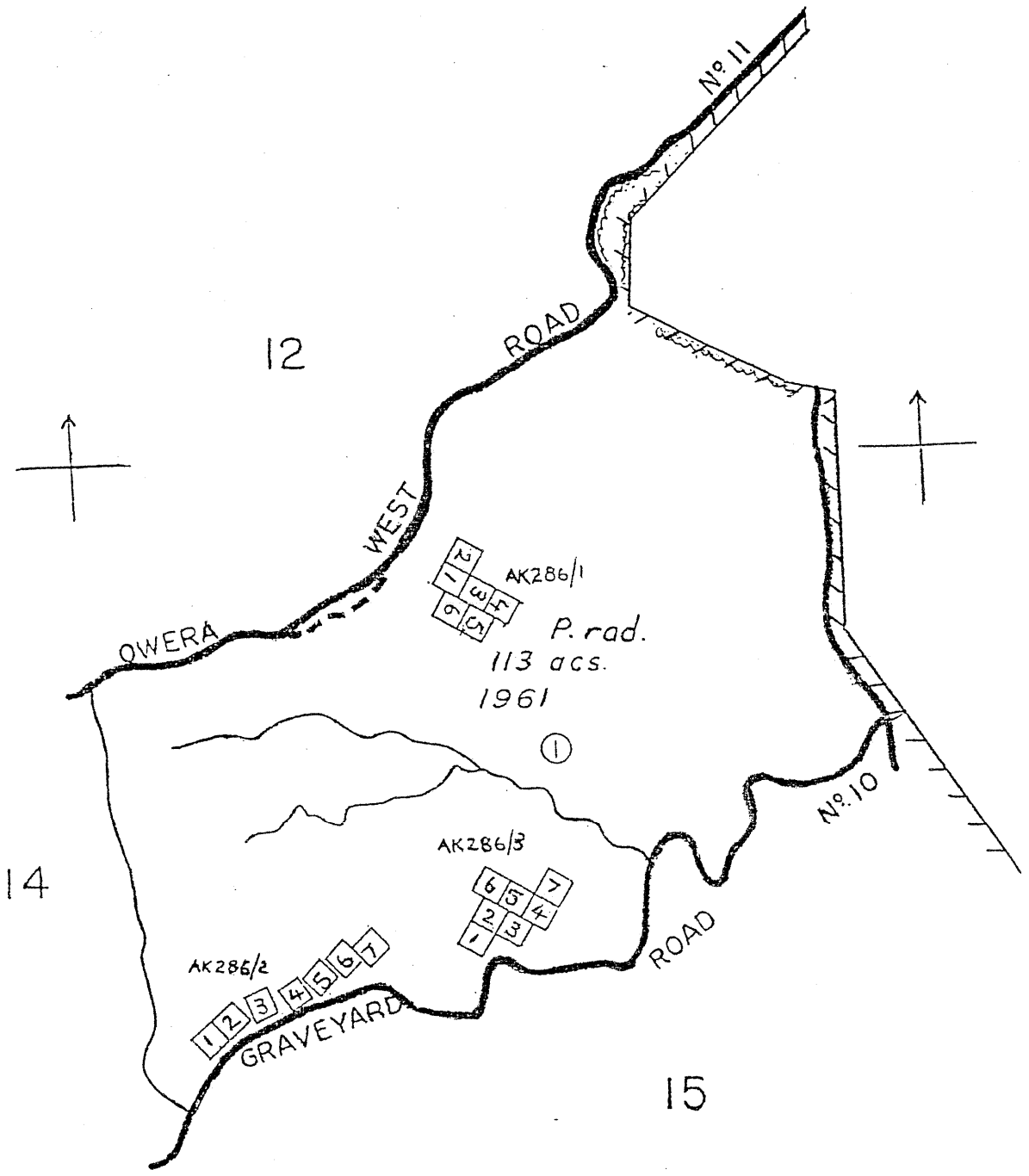
LEGEND:CAVI22___

FIGURE 3.

FIGURE 4.


Current Annual Volume Increment (At Ages 13, 18 & 22)
Related to Foliar Phosphorus
CAVI (m3/ha)
60
50
40
30
20
10
0
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Foliar Phosphorus (%)
LEGEND: CAVI13 ◇ CAVI18 △ CAVI22 *

Cpt. 13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No. 10
AK286/3
14
AK286/2
GRAVEYARD
ROAD
15

S.F. 169