FOREST OVERSOWING AND GRAZING TRIAL SERIES

By

G.G. WEST AND M.G. DEAN

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FOREST OVERSOWING AND GRAZING TRIAL SERIES - PROGRESS REPORT

GG. West and M. G. Dean

SUMMARY

From 1981 to 1985 five major trials were established in Aupouri, Waiuku, Maramarua, Kaharoa, and Kaingaroa forests to quantify the effects on tree growth of oversowing Maku lotus and grazing . Treatments of weed control with grazing or herbicides and the addition of nitrogenous fertiliser have been added at sites where this was appropriate.

Results from these trials to date indicate that :

1) Oversowing with lotus has significantly improved basal area growth on three of the trial sites - Aupouri, Waiuku, and Kaingaroa. At Maramarua and Kaharoa the trial design dos not allow this treatment effect to be analysed.

2) Oversowing with lotus has not improved height growth.

3) The benefits in basal area growth from lotus occurs with and without grazing at Kaingaroa.

4) The benefit in basal area growth from lotus will depend on tree stocking.

5) Competition from pampas grass results in significant losses in tree diameter growth but not height growth.

6) Grazing of pampas will significantly reduce losses in basal area caused by pampas competition.

7) Considerable gains in basal area growth from N fertiliser have been indicated at the Aupouri trial.

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INTRODUCTION

Oversowing forest cutover with grasses and legumes is a potential biological method for weed control and site improvement that is well aligned with the recent ethos of environmental care and sustainable land management. As many forests begin their second and in some cases third rotation weed invasion or weed re-establishment has escalated into a substantial management problem. On these sites the cost of providing effective long term weed control solutions has also escalated . New herbicides have been formulated and these have proved to be very effective for killing most weeds prior to tree planting. However, the period of weed control achieved with herbicides and/or mechanical site preparation techniques is generally only short term. On most sites weeds re-establish and compete with trees, reducing growth (Richardson and West, 1993) and increasing silvicultural costs.

Grazing of plantation forests with livestock in New Zealand has historically been spasmodic and extensive with little benefit to the forest or the grazier. Results indicating substantially improved tree growth when radiata pine is planted onto farm sites suggest that the introduction of a more intensive grazing systems based on forage legumes may provide similar tree growth benefits on traditional forest sites. Lower tree stockings and early pruning and thinning gives greater opportunity for weed growth, with canopy closure generally delayed to age 12-15 years. This also increases the potential understorey forage productivity for livestock grazing. Studies measuring forage yields of Maku lotus and wild grasses in Kaingaroa have recorded annual dry matter production at the level of 3000 - 5000 kg/ha (West et al 1991).

Several large scale forest grazing schemes implemented in the 1980s have proven that livestock could be grazed in stands from an early tree age to control weeds and managed to improve overall profitability (Breach, 1988; Dale and Todd, 1988; Hansen, 1988). Potential benefits to the tree crop are in the form of reduced weed competition, reduced tending costs (through better access), improved tree growth and decreased fire risk.

From 1981 to 1985 five major trials were established in Aupouri, Waiuku, Maramarua, Kaharoa (NW Mamaku), and Kaingaroa forests to quantify the effects on tree growth of oversowing Maku lotus and grazing . Treatments of weed control with grazing or herbicides and the addition of nitrogenous fertiliser have been added at sites where this was appropriate. Early results from these trials have been reported in West *et al* (1988) , West and Dean (1990), West *et al* (1991), West and Dean (1992), West and van Rossen (1994).

In July 1991 this series of trials became part of the research programme funded by the Site Management Research Cooperative. This report gives progress with the management of these trials and an update of tree growth results.

Description of trials

Table 1 gives the year planted , year of trial establishment, and current age of the trials.

Table 1: Trial description

Location	Year planted	Date established	Current tree age
Aupouri	1983	1985	12
Waiuku	1975	1981	20
Maramarua	1980	1984	15
Kaharoa	1983	1984	12
Kaingaroa	1980	1983	15

Table 2 gives a comparison of treatments covered at each trial

Table 2: Treatments by trial

Treatments	Aupouri	Waiuku	Maramarua	Kaharoa	Kaingaroa
Control	*	*	*	*	*
Herbicide#		*	*		
Graze to kill weeds		*			
Manage graze weeds		*			
Lotus+Graze weeds	*	*	*	*	*
Lotus ungrazed				*	*
Lupin	*				
N fertiliser	*				

* treatment represented in trial
# Total weed control with repeated herbicide applications

AUPOURI TRIAL - AK1021

Trial history and Treatments

This trial has had a stand history similar to most first rotation stands established on coastal sand. One year after Marram grass was established, lupin (*Lupinus arboreus*) was sown and left to grow for three years. Prior to tree planting the lupin was crushed and any regrowth killed with herbicide. Pampas grass (*Cortaderia species*) had become endemic in the south of the forest and was expected to spread north through the trial area. At tree age 2 years the trial was established with treatments aimed at comparing the effects of a range of alternative sources of nitrogen on stand growth. The trial design is a randomised complete block design , see map appendix 1. Treatments were as follows:

1. Control
2. Lupin
3. N fertiliser
4. Lotus + grazing

To encourage legume and tree growth the whole trial area was fertilised at trial establishment with 200 kg/ha of superphosphate. Lupin was resown (at 10 kg seed/ha) in the "Lupin" treatment to encourage regrowth. N fertiliser (Urea) treatment involved two applications/yr (spring and autumn) of 50 kg N/ha every year. To date a total of aprox 800 kgN/ha has been applied. Maku lotus was sown at 5 kg of seed /ha in the "Lotus + Graze" treatment. Grazing of the lotus began in the second year using cattle. Initially the trial received 2 grazings/year with some Marram grass included in the forage consumed. This changed to a single grazing by tree age 8 and since tree age 9 the trial has not been grazed due to a lack of cattle in the local area.

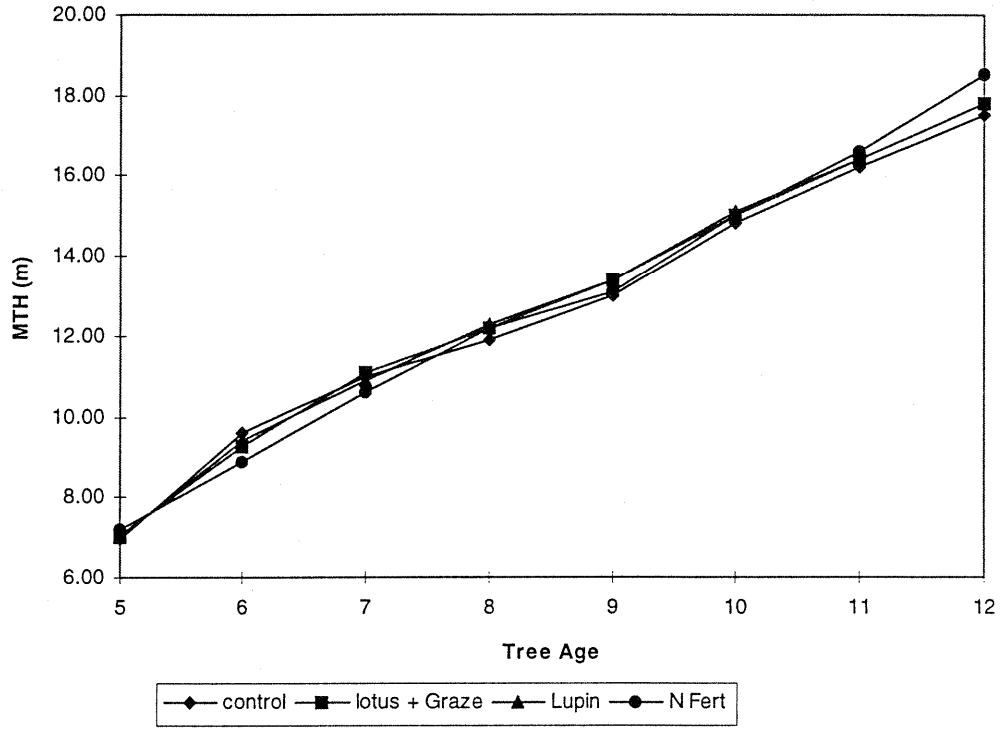
In 1989 the lupin was decimated by the fungus *Colletotrichum gloeosporioides*. To retrieve something from the plots of this treatment, these plots were oversown with Maku lotus in 1990. This proved to be relatively unsuccessful with poor lotus establishment at this late stage in the rotation.

The silvicultural regime in this trial has been the standard forest practice of pruning to 6.0m combined with a production thinning regime. The trial was waste thinned from approx 1300 to 800 stems/ha at age 6. The second thinning has not yet occurred.

Tree Growth

Figure 1 gives height development through time for each treatment.

Figure 1:
Aupouri - Mean Top Height by tree age



Up to age 12 tree height growth has not been influenced by treatments.
Figure 2 gives basal area development through time for each treatment.

Figure 2:
Aupouri - Total Basal Area by Tree age

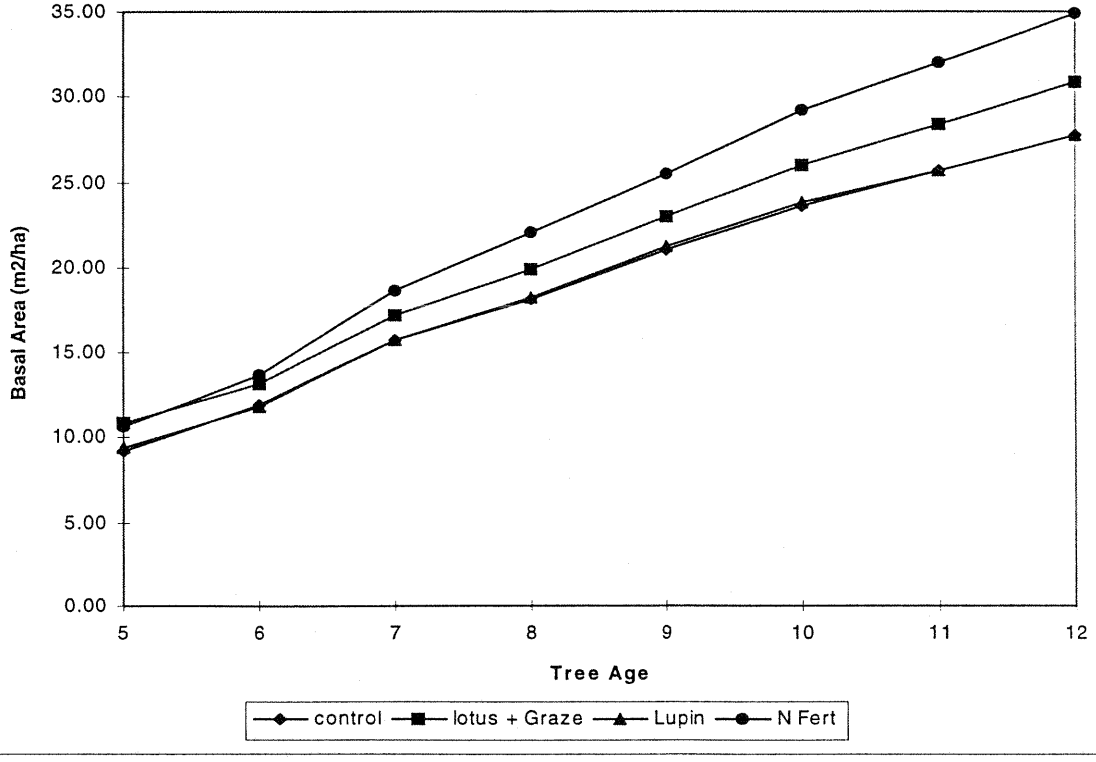
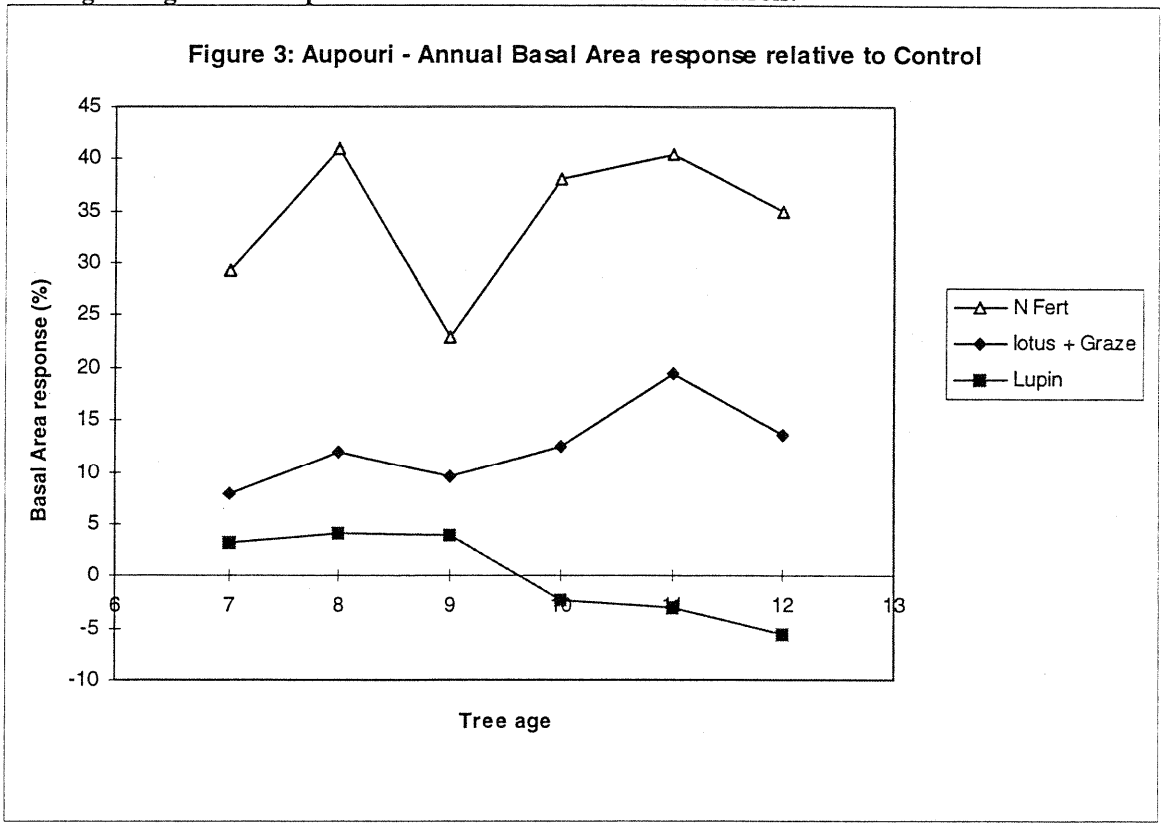


Figure 3 gives the response in basal area relative to the controls.



For the last 6 years, basal area increment for the N fertiliser treatment (100 kg N/ha/yr) has shown a 30% improvement over the control. The lotus + graze treatment has averaged approximately 10% improvement over the same period. This approximately one third of the N fertiliser effect. Because of the early lupin mortality this treatment should be considered the same as the control. Table 3 gives results of analysis of variance of annual basal area increment.

Table 3: Treatments with the same letter are not significantly different - P= 0.05

Tree age	7	8	9	10	11	12
N Fert	A	A	A	A	A	A
lotus + Graze	A	B	A	B	B	B
Lupin	A	B	A	C	C	C
control	A	B	A	C	BC	BC

WAIUKU TRIAL - AK 847

Trial history and Treatments

This trial was established in a second rotation stand growing in coastal iron-sand. By the time of trial establishment (tree age 6) thick pampas grass had developed throughout the stand. Treatments for this trial were developed to quantify the effect of pampas grass on tree growth and to examine alternative strategies for controlling this weed. Treatments in this trial include:

1. Control - Nil treatment resulting in dense pampas understorey.
2. Spray - repeat applications of glyphosate to achieve total weed control.
3. Manage Graze - grazing pampas with cattle 2-3 times a year to maintain a low understorey of pampas for forage.

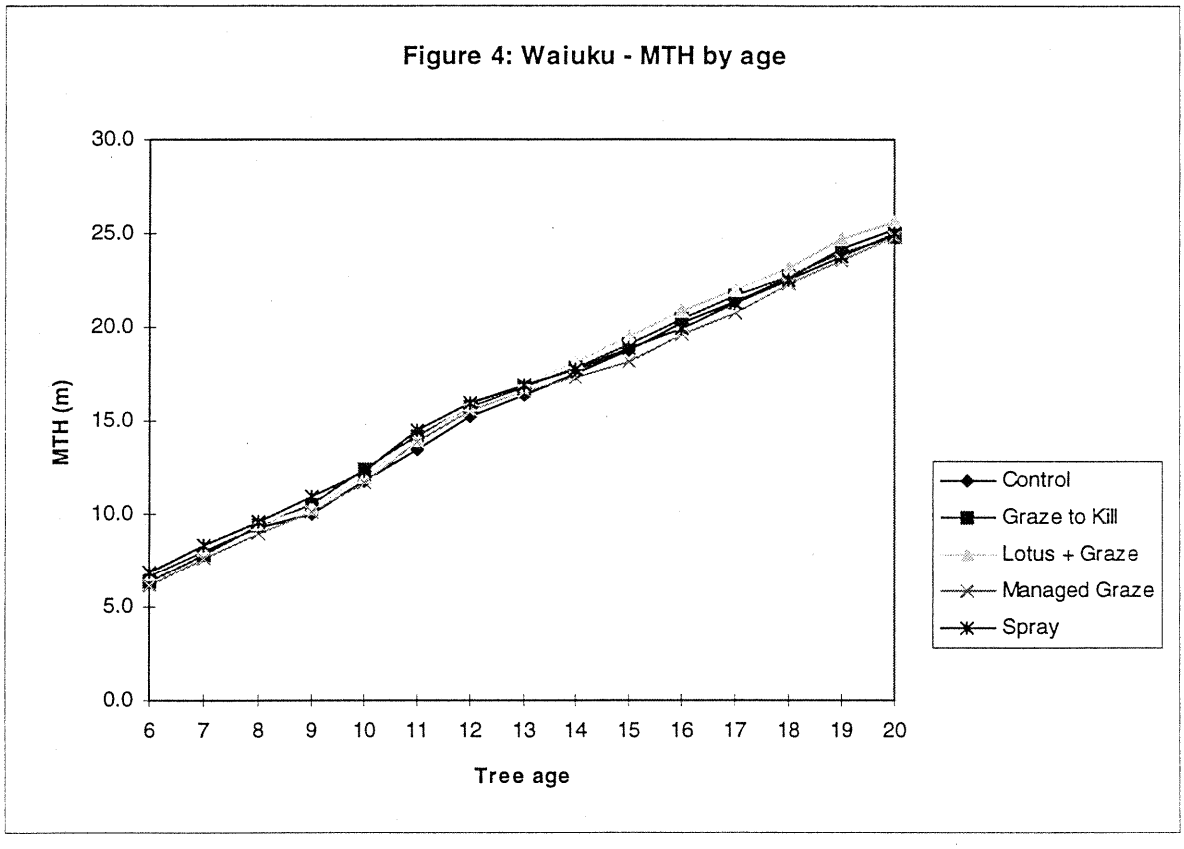
4. Graze to Kill - graze pampas 4-6 times a year to kill plants (Due to light grazing this did not occur for the first 3-4 years)
5. Lotus + Graze - oversow with Maku lotus and graze as in 3 above.

The trial is a randomised complete block design (see map appendix 2)with initial basal area used to identify blocking strata.
Prior to oversowing with lotus, the appropriate plots were grazed with cattle to reduce the ground cover. No fertiliser has been used in the treatments of this trial

The pruning and thinning within the trial has generally followed a direct sawlog regime thinning down to a final crop stocking of 200 stems/ha and pruning to 6.0m by tree age 11 years.

Tree growth

Figure 4 gives height development through time for each treatment.



Height growth at this trial has not been effected by treatments. NB This includes severe competition from pampas in the controls.

Figure 5 gives basal area development through time for each treatment.

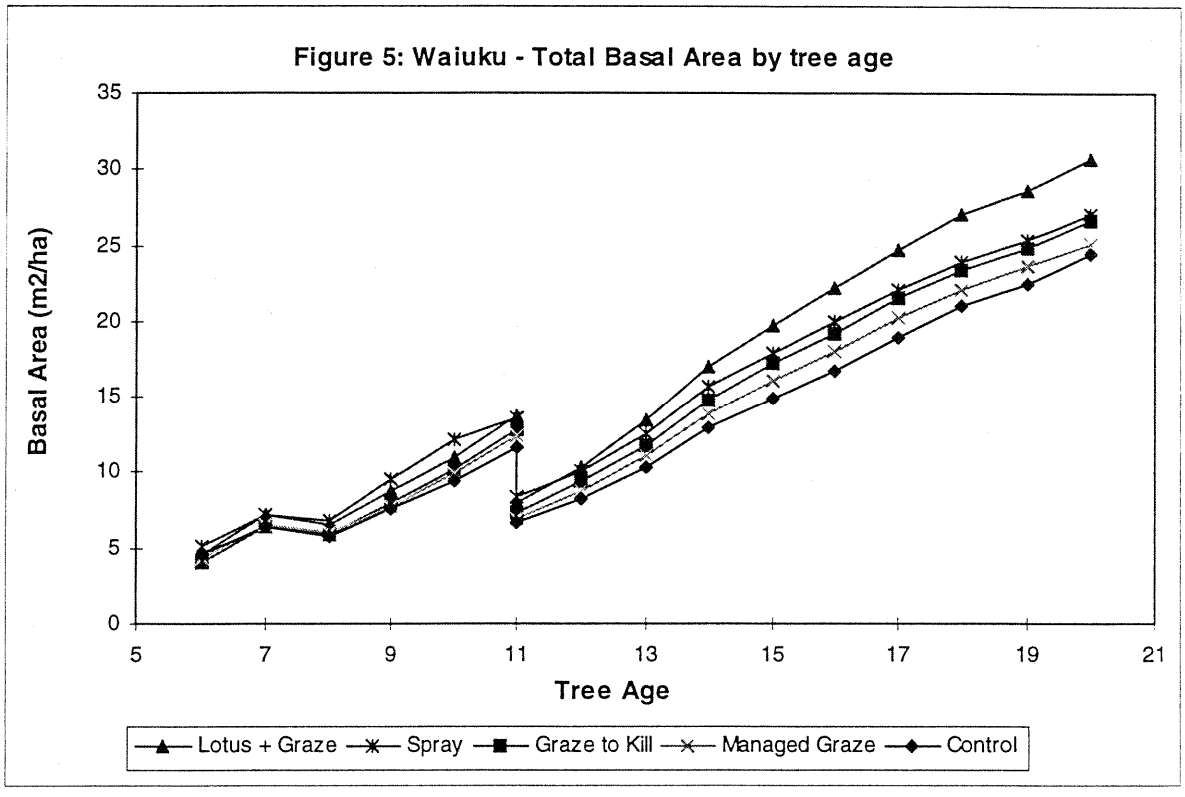
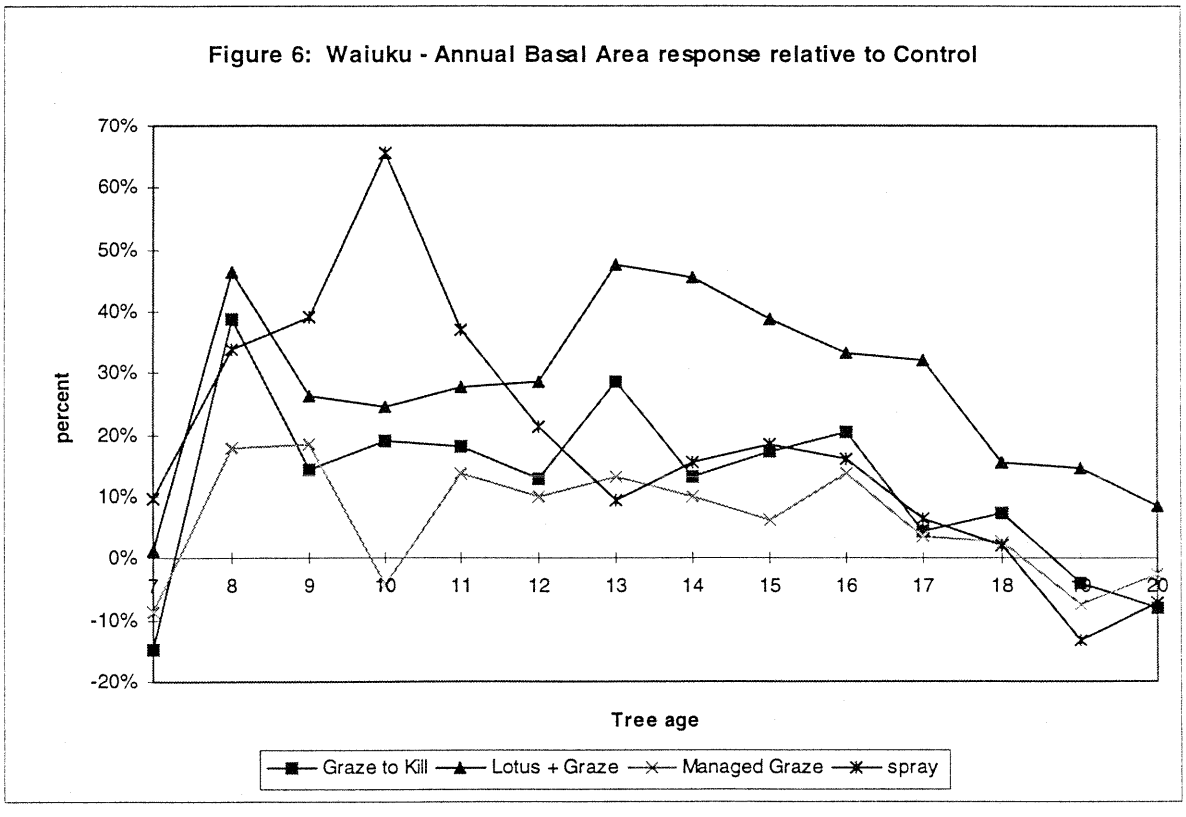


Figure 6 gives the response in basal area relative to the controls.



Relative to the controls basal area growth has been significantly influenced in the first five years by the removal of pampas in the "Spray" treatment (total weed control). Over most of the measurement period the "Lotus + Graze" treatment has also significantly improved basal area growth. A considerable

difference is evident between the "Manage Graze" and "Lotus + Graze" treatments. This difference is expected to be the contribution of lotus to tree growth through N fixation. A small difference between "Graze to kill" and "Manage Graze" is evident but both are significant improvements over the control. Table 4 gives results of analysis of variance of annual basal area increment. Initial basal area has been used to provide covariance adjustment in the initial 7 years of basal area increment.

Table 4: Treatments with the same letter are not significantly different - P= 0.05

Tree age	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lotus + Graze	A	A	B	AB	A	A	A	A	A	A	A	A	A	A
Spray	A	A	A	A	A	C	B	B	A	B	A	B	A	A
Graze to Kill	A	A	B	ABC	AB	B	B	B	A	B	A	B	A	A
Managed Graze	AB	A	B	BC	AB	BC	B	B	A	B	A	B	A	A
control	B	A	B	C	B	C	B	B	A	B	A	AB	A	A

MARAMARUA TRIAL - AK1005

Trial history and Treatments

This trial was established into a second rotation stand with heavy clay soils. At tree age 2, invading pampas was operationally sprayed with Velpar and at tree age three 450 kg/ha of triple superphosphate was applied. At the date of trial establishment (tree age 4) the site was heavily infested with pampas grass . Treatments in this trial were aimed at quantifying the effects on tree growth of grazing pampas grass and oversown lotus. The treatments are as follows:

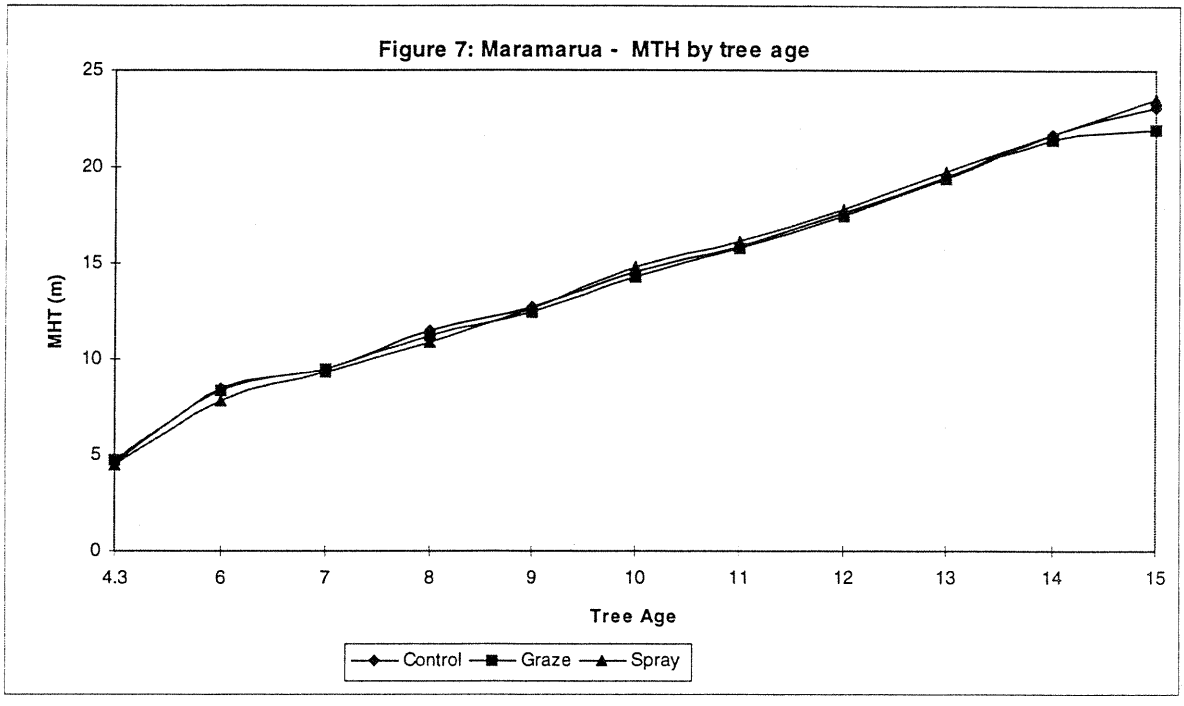
1. Control
2. Spray - repeat applications of herbicide for total weed control
3. Lotus + graze - grazing of pampas and lotus with cattle

The trial is a randomised complete block design (see map appendix 3) with percentage ground cover of pampas grass used to identify blocking strata.

Although repeated applications with glyphosate attempted to achieve total weed control, some woody weeds and Gahnia grass persisted at low intensities. Grazing in the appropriate plots has occurred with cattle as part of the normal rotational grazing of the forest. Grazing has been 3-4 times a year up to tree age 8 and then declined in frequency (due to canopy closure) to where grazing currently occurs only once a year.

The pruning and thinning regime at this trial has generally followed a direct sawlog regime; thinning to a final crop of 250 stems/ha and pruning to 4.3m by tree age 7 years.

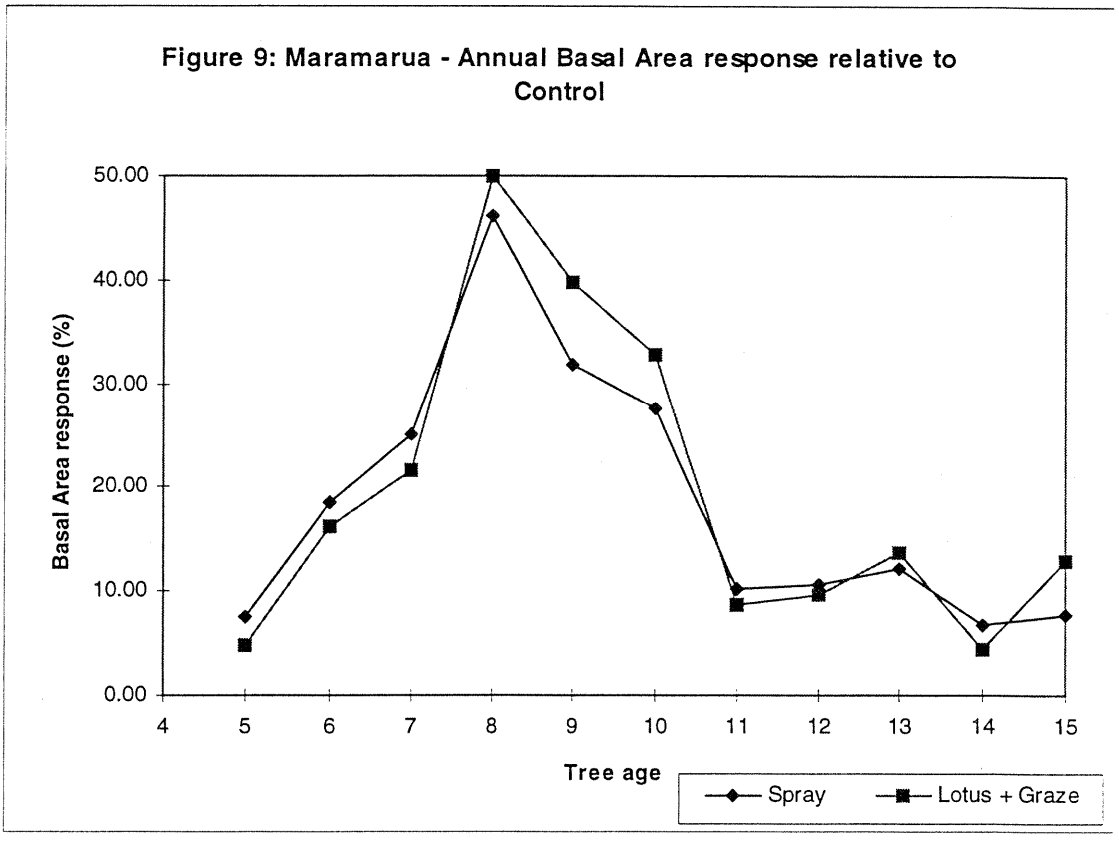
Figure 7 gives height development through time for each treatment.



Height growth in this trial has not been influenced by treatments , NB This includes severe competition from pampas grass in the controls.

Figure 8 gives basal area development through time for each treatment.

Figure 9 gives the response in basal area relative to the controls.



Relative to the controls annual basal area increment for the "Spray" and "Lotus + Graze" treatments has shown significant improvement. This peaked at age 8 (4 years after trial establishment) and has since declined. The "Lotus + Graze" treatment has indicated little difference from the "Spray" treatment. Initially the "Spray" treatment (no competition) was intended to be equivalent to a grazing only treatment (with no lotus) with any difference between the two treatments being attributable to the lotus. However as indicated by the Waiuku trial this is not the case. The comparison to give the lotus effect is confounded by a number of factors and cannot be used, ie this treatment can only be compared with a treatment of grazing with no lotus. Table 5 gives results of analysis of variance of annual basal area increment. Initial basal area has been used to provide covariance adjustment in the initial three years of basal area increment.

Table 5: Treatments with the same letter are not significantly different - P= 0.05

Tree age	5	6	7	8	9	10	11	12	13	14	15
Lotus + Graze	A	A	A	A	A	A	A	A	A	A	A
Spray	A	A	A	A	A	A	A	A	A	A	A
Control	A	A	B	B	A	A	A	A	A	A	A

For many years a substantial response to treatment is recorded (fig 9) but shown in table 5 as not statistically significant. This is partly due to the small residual degrees of freedom resulting from 3 treatments x 4 replicates. However many years would be significant at P=0.10.

KAHAROA TRIAL- RO2036

Trial history and Treatments

This trial was established in a indigenous cutover site in 1984. The area had been root raked and windrowed removing much of the topsoil. The whole stand had been oversown with lotus by helicopter

in the spring after planting . At age 4 the whole trial area was given an application of superphosphate at 300 kg/ha .

Treatments were as follows:

1. Control
2. Lotus + graze
3. Lotus ungrazed

The trial is a randomised complete block design with four replicates (see map appendix 4). Lotus growth in the first year was slow (due to low soil P) and because the entire area had been sown, control plots had to be created by the killing of emerging lotus plants with herbicide. This proved impossible to achieve. Although repeated applications of a range of herbicides over the first 3-4 years severely reduced the lotus understorey, the lotus re-established each year (probably from rhizomes) and this has confounded the experiment. The only useful comparison this trial can now be used for is to compare the effect of grazing versus no grazing of lotus .

Figure 10 gives height development through time for each treatment.

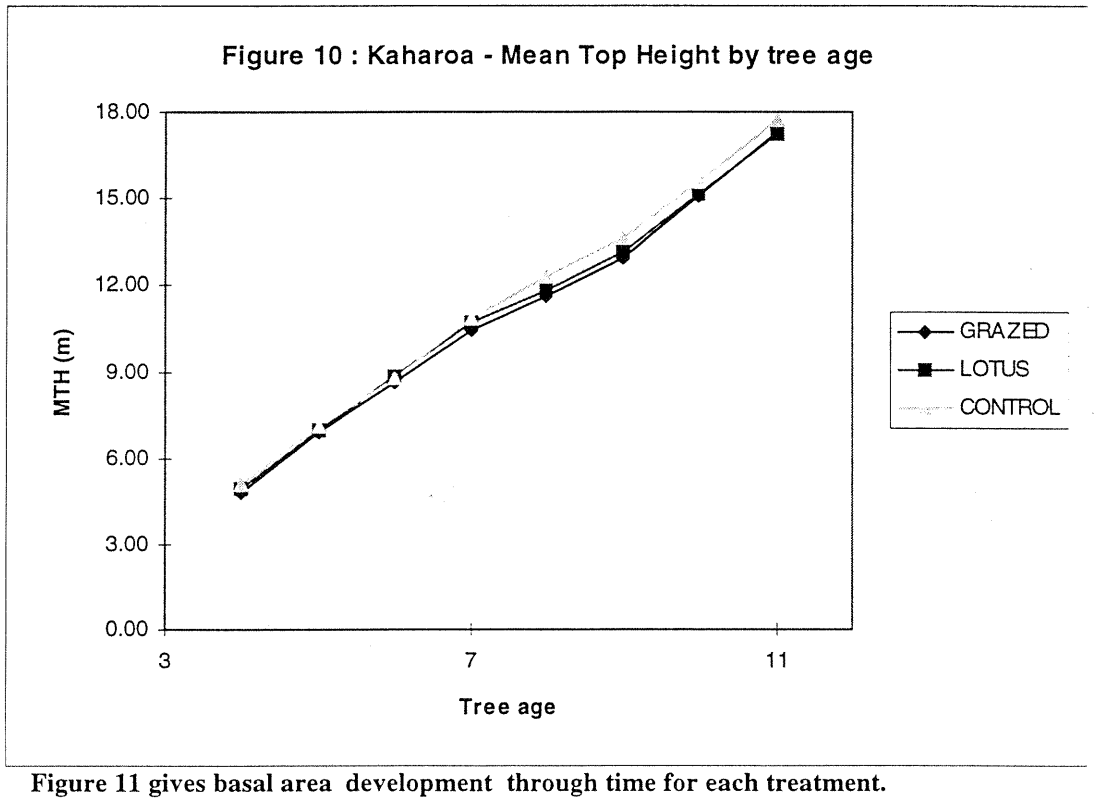


Figure 11 gives basal area development through time for each treatment.

Figure 11 : Kaharoa - Basal Area by Tree age

Treatment effects for this trial are nonsignificant except for year 10 when the increment of the Lotus + grazed plots was better than the other two treatments.

KAINGAROA TRIAL - RO1891

Trial history and Treatments

This trial was established in October 1983 (tree age 3) in a second rotation stand near the half-mile fire break in central Kaingaroa.

The site had been over-sprayed for weed control in the first year after planting (1980) and had remained relatively weed free. Treatments in this trial were aimed at measuring the effect on tree growth of oversowing lotus and grazing with cattle. Because lotus growth was expected to be influenced by tree stocking, a range of tree densities were included. The following treatments were used:

Legume and grazing
1. Cattle grazing of oversown lotus (plus wild grasses and weeds)
2. Oversown lotus, no grazing (at 200 stems/ha only)
3. Control - No oversowing and no cattle grazing

Tree crop
1. Final stocking of 100 stems/ha
2. Final stocking of 200 stems/ha
3. Final stocking of 400 stems/ha

The trial is a randomised complete block design (see map appendix 5) with tree stocking as the main plot treatment and lotus + grazing as a split plot application.

At trial establishment, lotus was oversown at 5 kg seed/ha and superphosphate (with molybdenum and cobalt) applied at 400 kg/ha. After the first year grazing occurred 3 times / year until age 14 when the trial was not grazed. Unfortunately cattle are no longer available from the nearby farm for this treatment.

Figure 12 gives height development through time for each treatment.

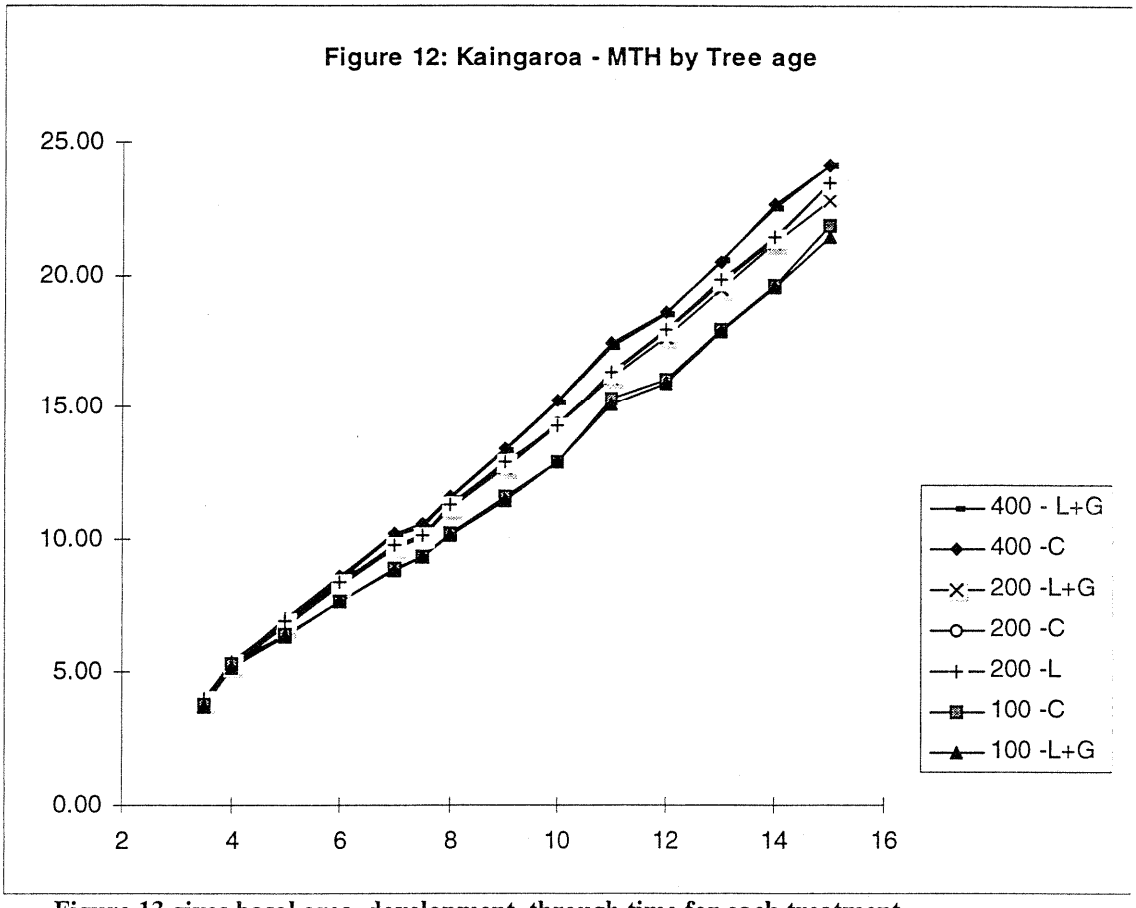
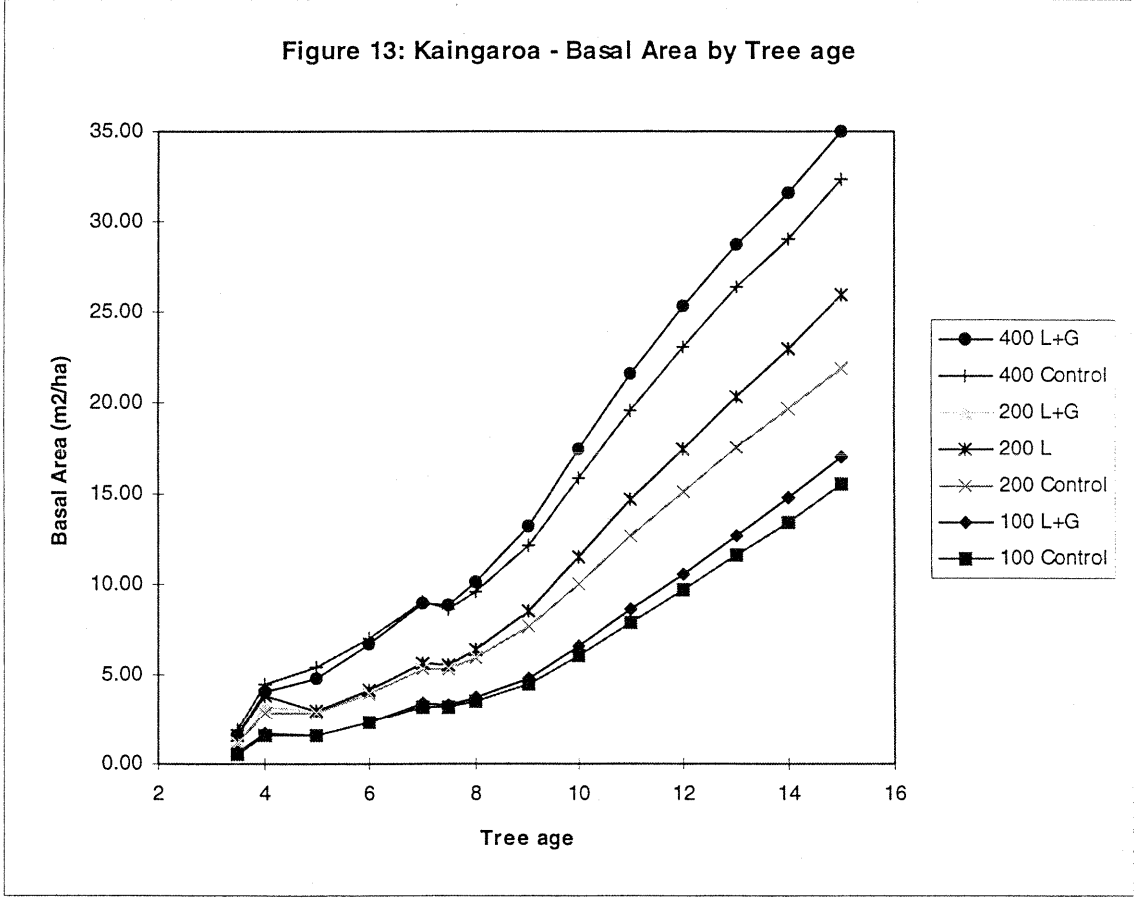


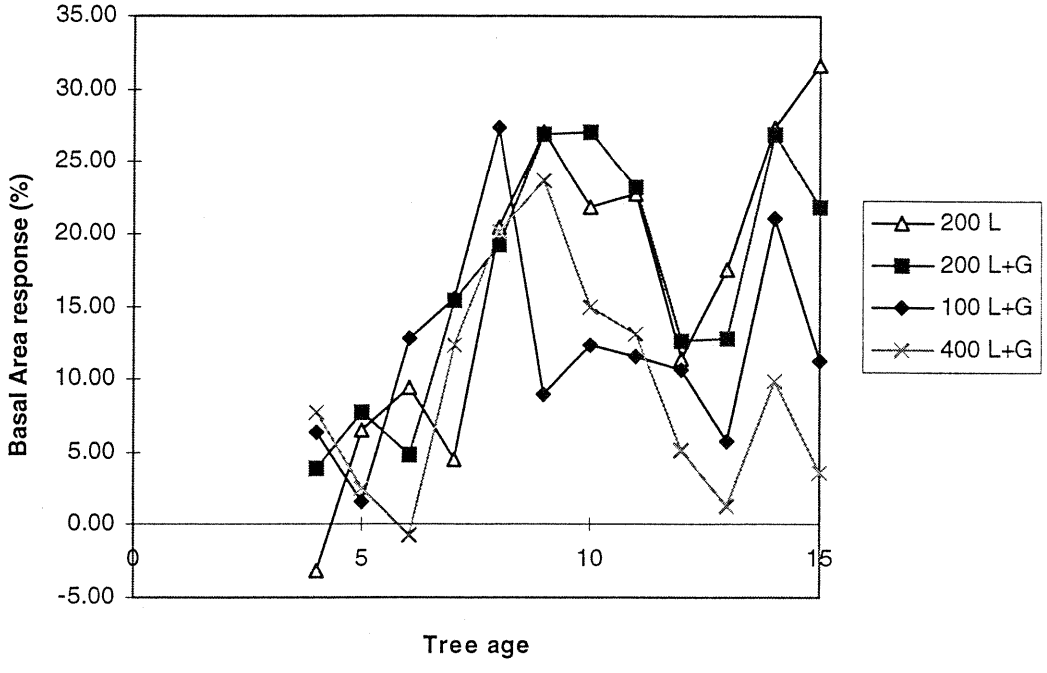
Figure 13 gives basal area development through time for each treatment.



Height growth in this trial has not been affected by the lotus + graze treatment. However, height growth has been considerably affected by tree stocking. This phenomenon has been reported by Maclaren *et al* (1995), with lower height growth often being recorded on sites where trees are grown at stockings below 400 stems/ha.

Figure 14 gives the response in basal area relative to the controls.

Figure 14: Annual Basal Area relative to the Control



Basal area response to lotus + grazing has rapidly increased over the first 5 years after oversowing. Response has generally peaked at 27% improvement (for tree age 8-10) , then declined for several years before improving again (years 14-15). The response to the ungrazed lotus treatment (200 stems/ha only) has been very similar.

The response to lotus has been influenced by tree stocking with the 100 and 400 stockings showing less improvement than the 200 stocking. At age 15 the total accumulated basal area difference between the lotus plots and controls, at 200 stems/ha, is now 3.5 m2/ha (a 17.5 % improvement)

Table 6 gives results of analysis of variance of annual basal area increment. Initial basal area has been used to provide covariance adjustment in the initial two years of basal area increment.

Table 6: Treatments with the same letter are not significantly different - P= 0.05

		Tree age											
Treatment	Stocking	4	5	6	7	8	9	10	11	12	13	14	15
Lotus + Graze	100	A	A	A	A	A	A	A	A	A	A	A	A
Control	100	A	A	A	A	A	A	A	A	A	A	A	A
Lotus + Graze	200	A	A	A	A	A	A	A	A	A	A	A	AB
Lotus only	200	A	A	A	A	A	A	A	A	A	A	A	A
Control	200	A	A	A	A	B	B	B	B	A	A	B	B
Lotus + Graze	400	A	A	A	A	A	A	A	A	A	A	A	A
Control	400	A	A	A	A	B	B	B	B	A	A	A	A

DISCUSSION

On all five sites of the trial series a positive basal area response has been indicated from the oversowing of lotus however at the Maramarua and Kaharoa trials these effects are confounded and not statistically significant. At Kaingaroa and Waiuku the response is substantial and indicates an improvement in growth of at least 10% (merchantable volume) (West and van Rossen, 1994). At Kaingaroa the response to lotus is still persisting at the last measurement (age 15). This is unexpected as the green crown in the 200 stocking is beginning to rise (now 8.1m) indicating canopy closure. Height growth has not been influenced by lotus oversowing or from severe weed competition from pampas grass.

The removal of pampas grass competition at the Waiuku and Maramarua trials has provided substantial improvements in basal area growth. The use of cattle grazing to achieve this has been very successful particularly when combined with oversowing lotus.

Foliage samples have been taken and analysed annually (or biennially over the last three/four years) for N and P. Results from the foliage analysis are given in appendices 6 to 12. Using the Lotus + Graze treatment as a standard, appendix 6 compares foliar N and P for all five trial sites for each year. Appendix 7 makes the same comparison by tree age. Appendix 8 to 12 give individual trial results and compares the effects of treatments.

These results help to provide some explanation of the tree growth responses. For the Lotus and Graze treatment (appendix 7) P levels at Aupouri, Kaharoa, and Maramarua have been noticeably low through the early stages of stand growth and this has probably restricted lotus growth and hence N fixation. At the Aupouri trial, foliar N levels have been noticeably improved by the N fertiliser treatment over the last five years. However, the significant tree growth response to legumes at Waiuku and Kaingaroa has not been reflected in foliar N levels.

More detail on this data, including statistical analysis, will be provided in a final and more formal publication. Data on ground cover achieved with lotus and biomass of weeds will also be included.

CONCLUSIONS

Results from these trials to date indicate that :

1) Oversowing with lotus has significantly improved basal area growth on three of the trial sites - Aupouri, Waiuku, and Kaingaroa. At Maramarua and Kaharoa the trial design dos not allow this treatment effect to be analysed.

2) Oversowing with lotus has not improved height growth.

3) The benefits in basal area growth from lotus occurs with and without grazing at Kaingaroa.

4) The benefit in basal area growth from lotus will depend on tree stocking.

5) Competition from pampas grass results in significant losses in tree diameter growth but not height growth.

6) Grazing of pampas will significantly reduce losses in basal area caused by pampas competition.

7) Considerable gains in basal area growth from N fertiliser have been indicated at the Aupouri trial.

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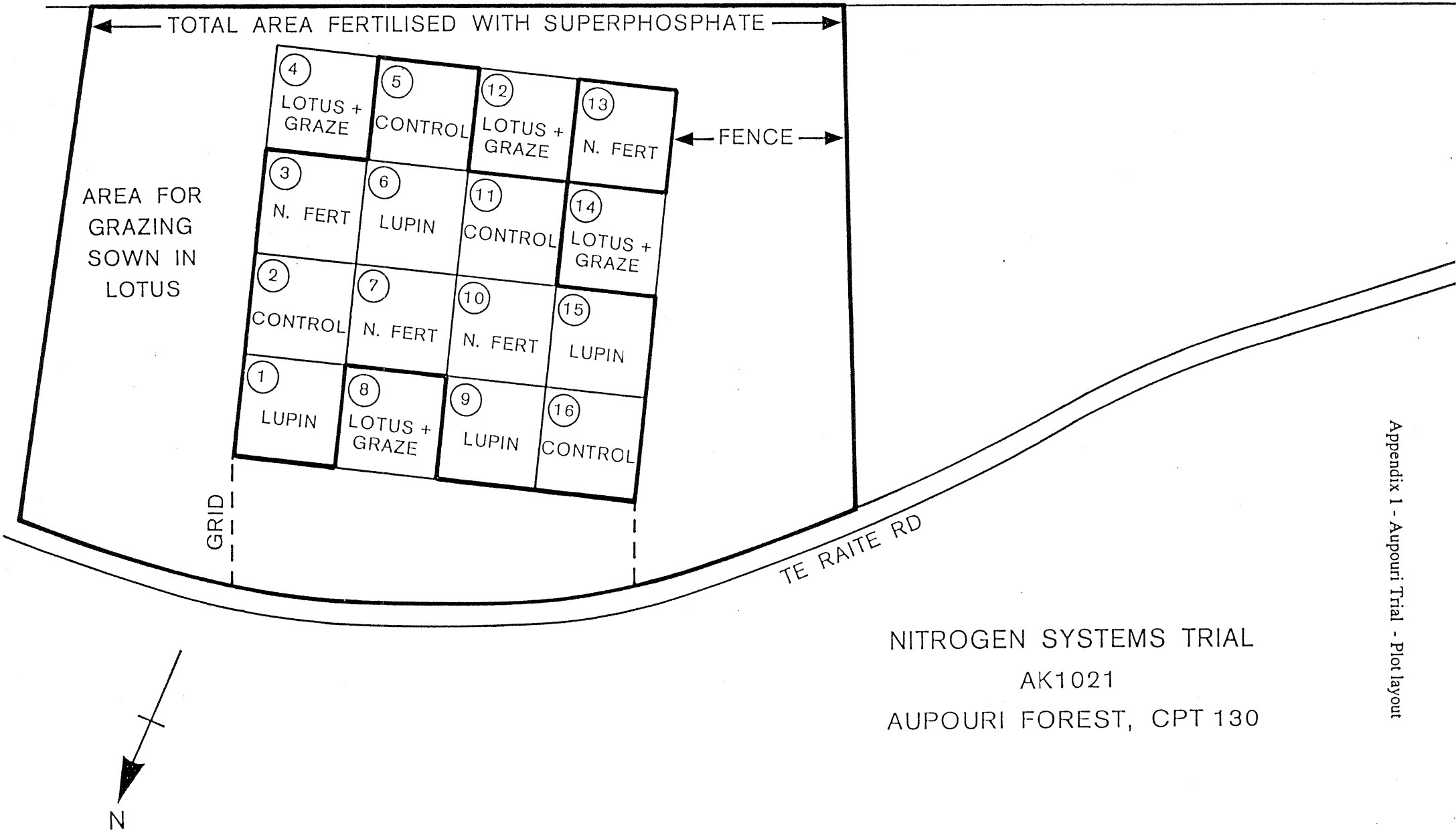


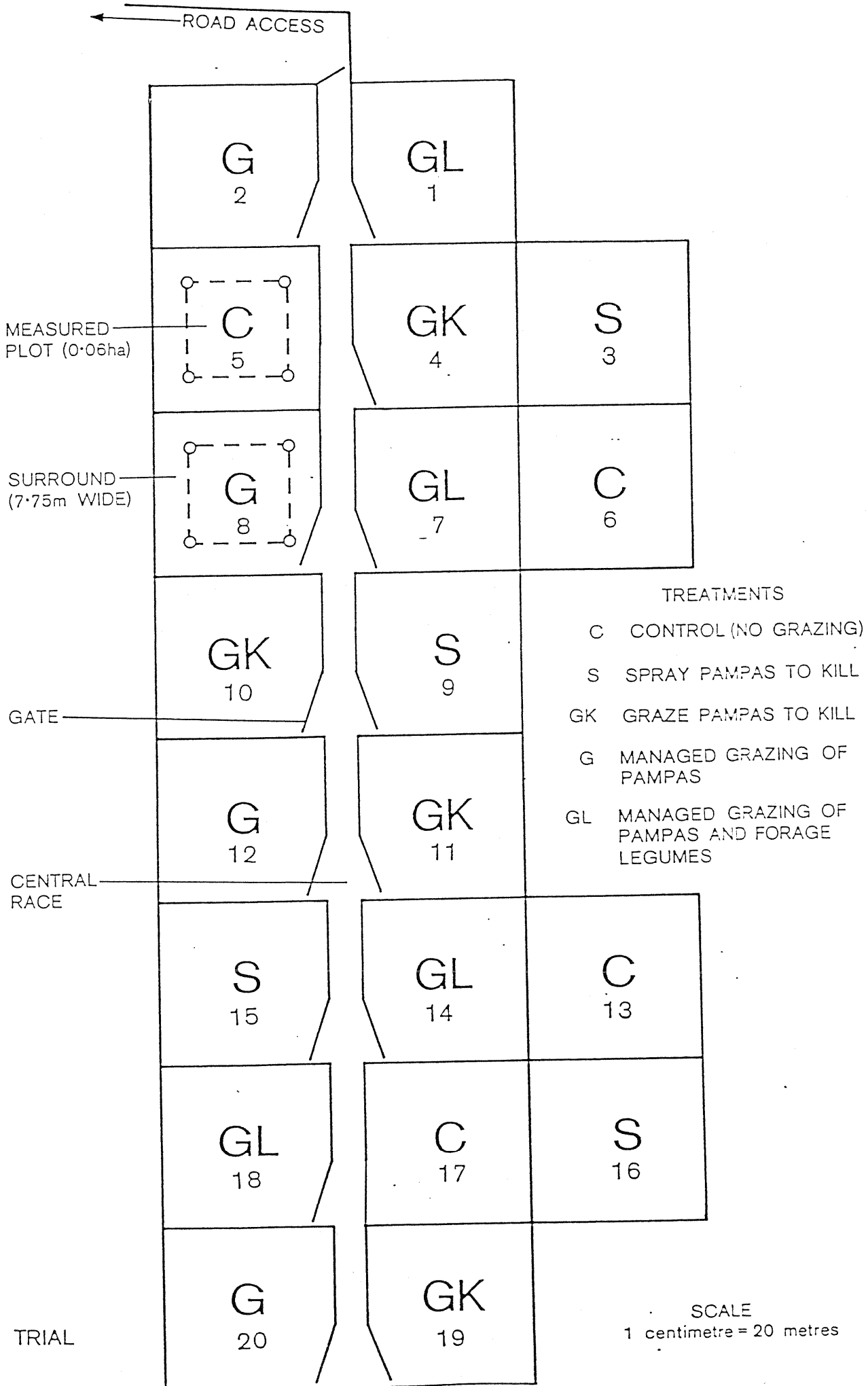
NITROGEN SYSTEMS TRIAL

AK1021

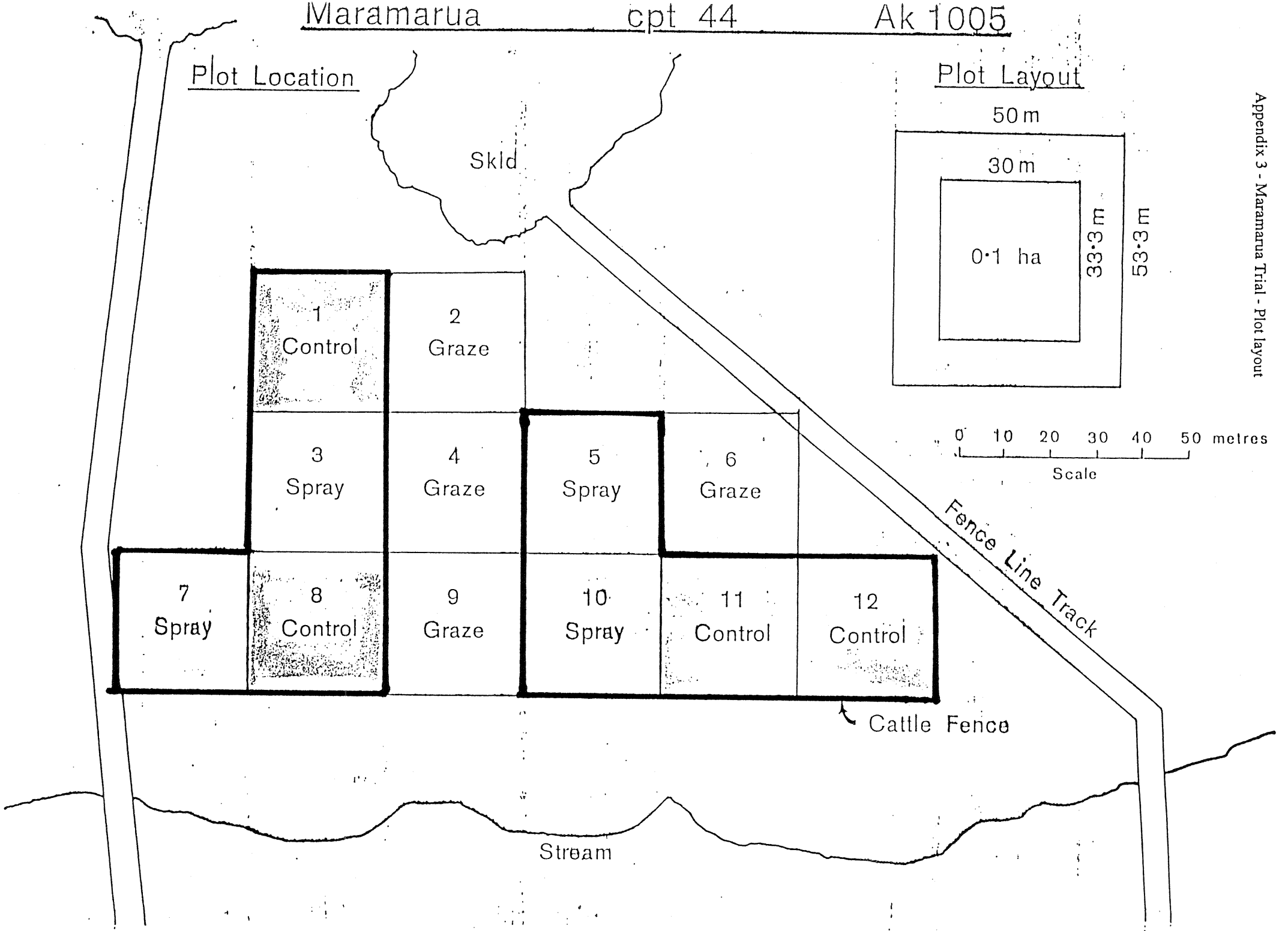
AUPOURI FOREST, CPT 130

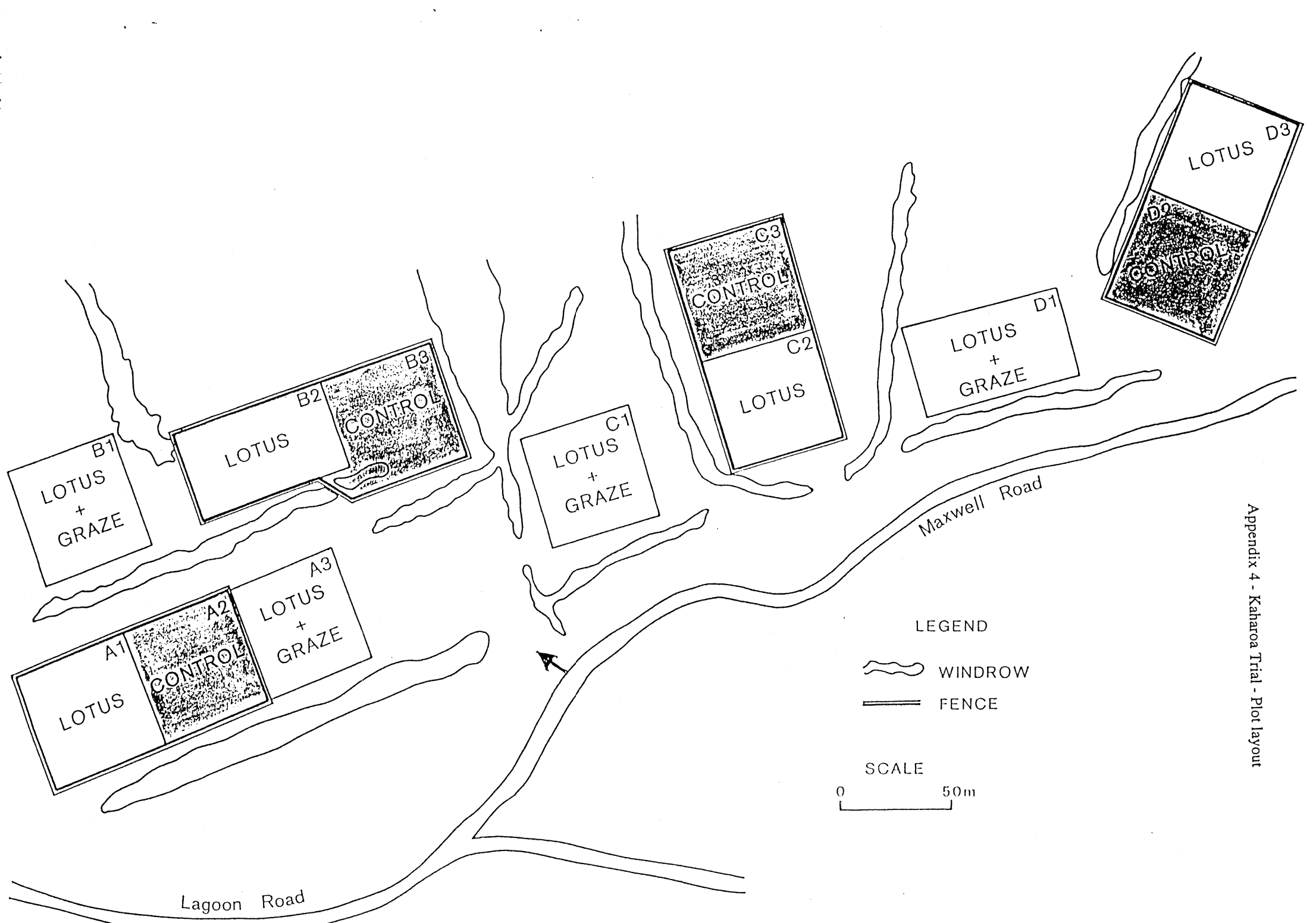
Appendix 1 - Aupouri Trial - Plot layout

Appendix 2 - Waiuku Trial - Plot layout



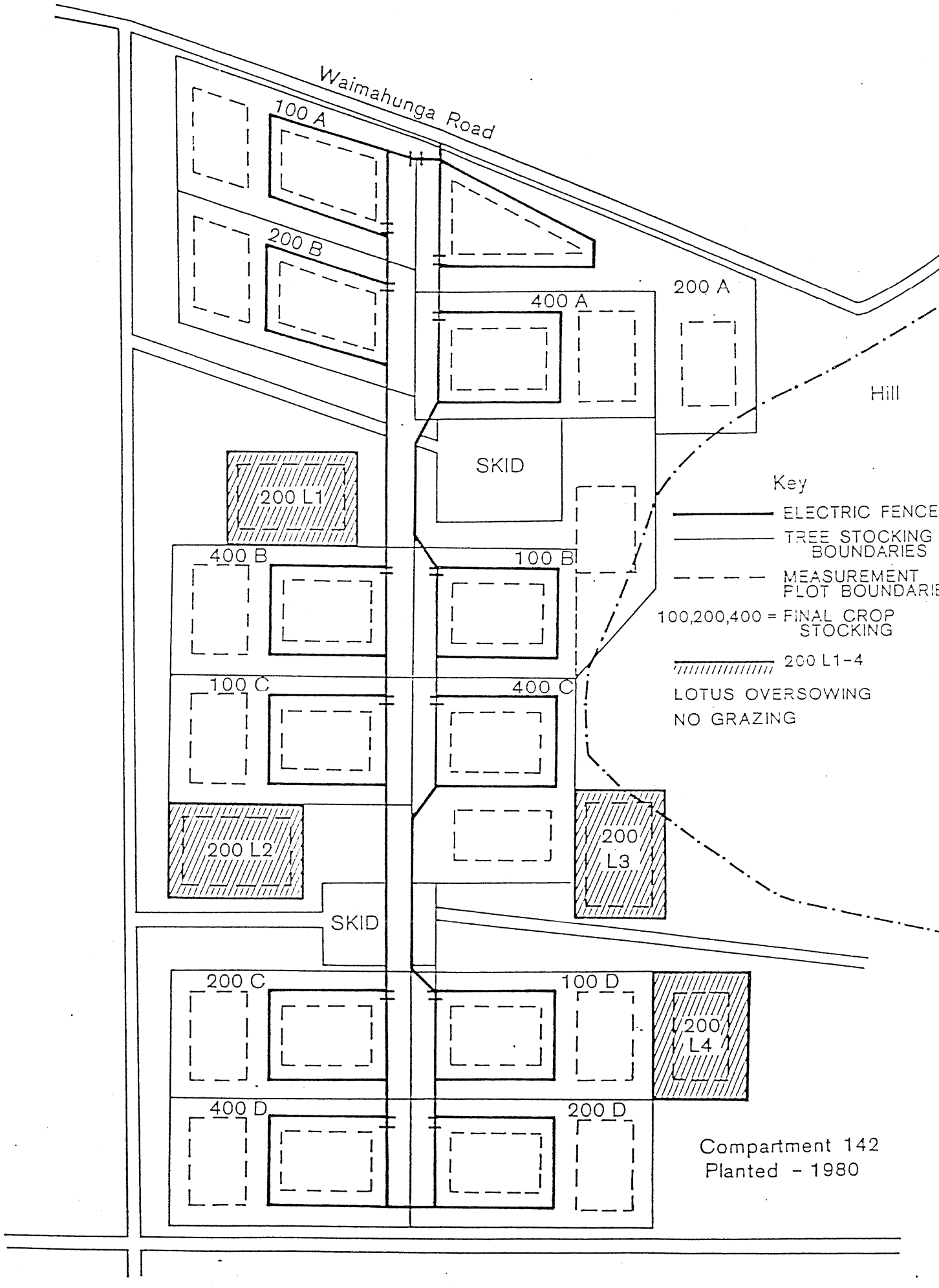
TOTAL AREA OF TRIAL
3·4ha


Maramarua cpt 44 Ak 1005
Plot Location
Skid
Plot Layout
50 m
30 m
0·1 ha
33·3 m
53·3 m
0 10 20 30 40 50 metres
Scale
1 Control
2 Graze
3 Spray
4 Graze
5 Spray
6 Graze
7 Spray
8 Control
9 Graze
10 Spray
11 Control
12 Control
Fence Line Track
Cattle Fence
Stream

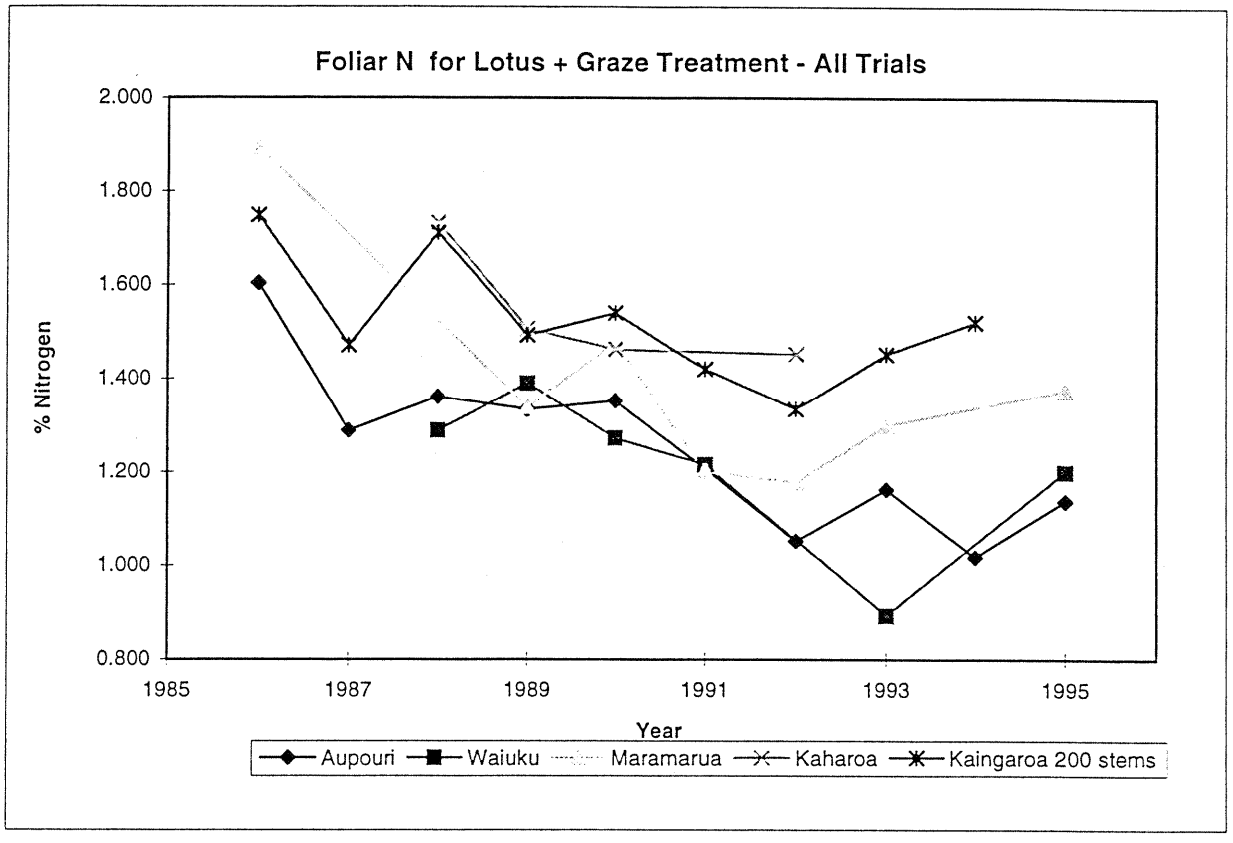


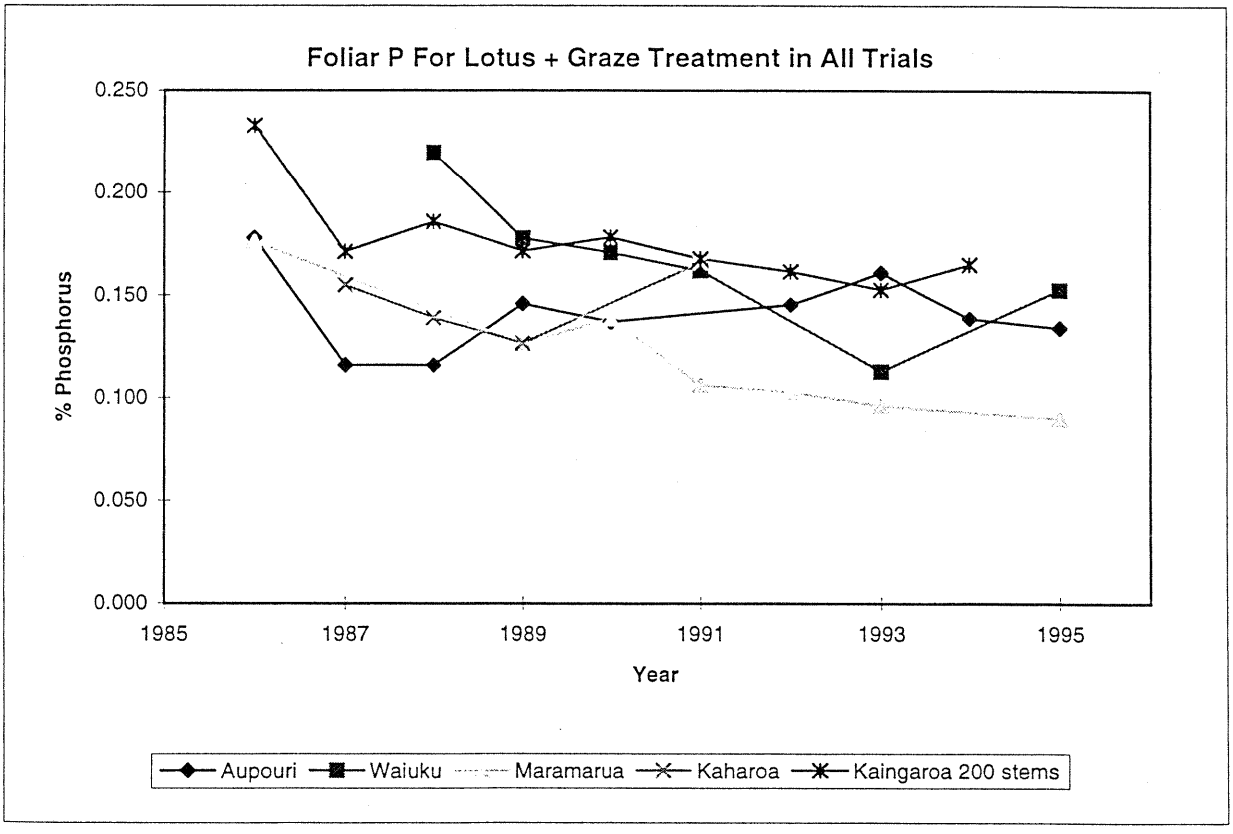
Appendix 4 - Kaharoa Trial - Plot layout

Appendix 5 - Kaingaroa Trial - Plot layout

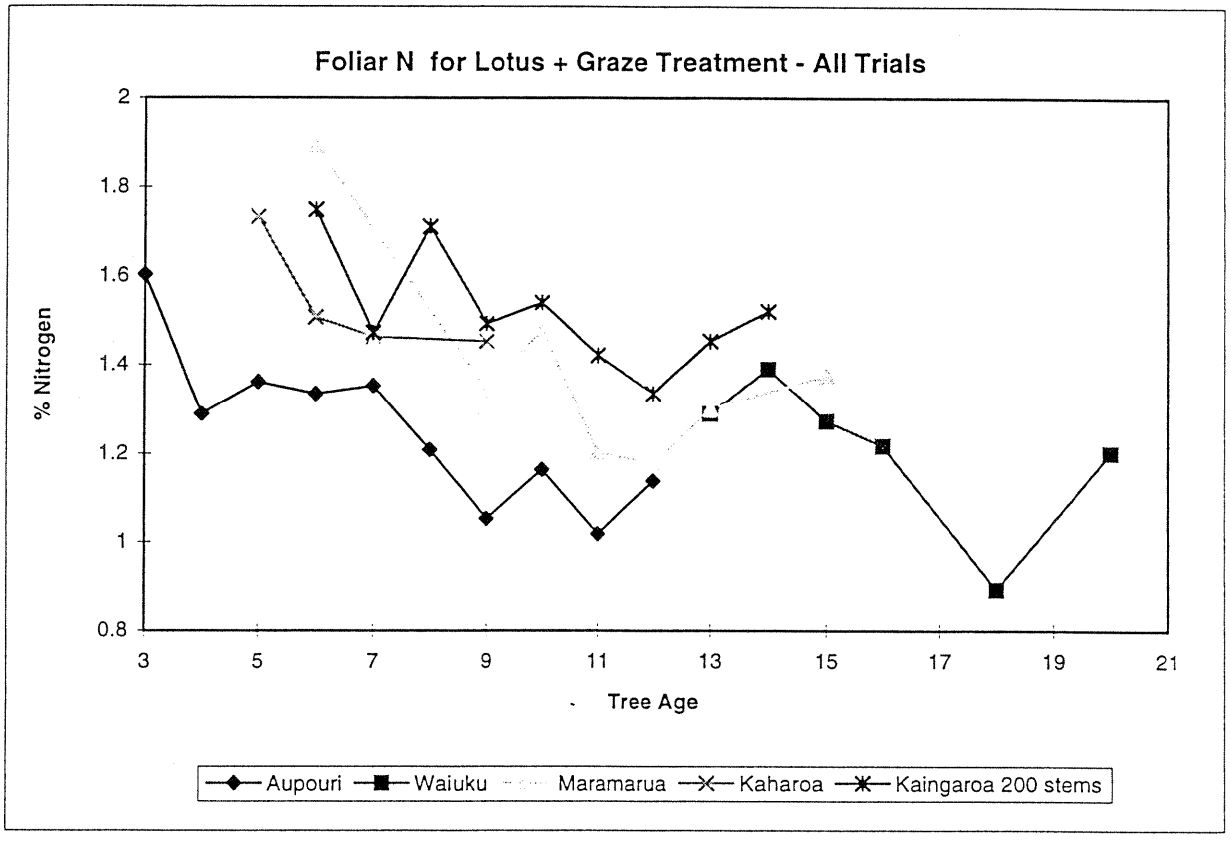


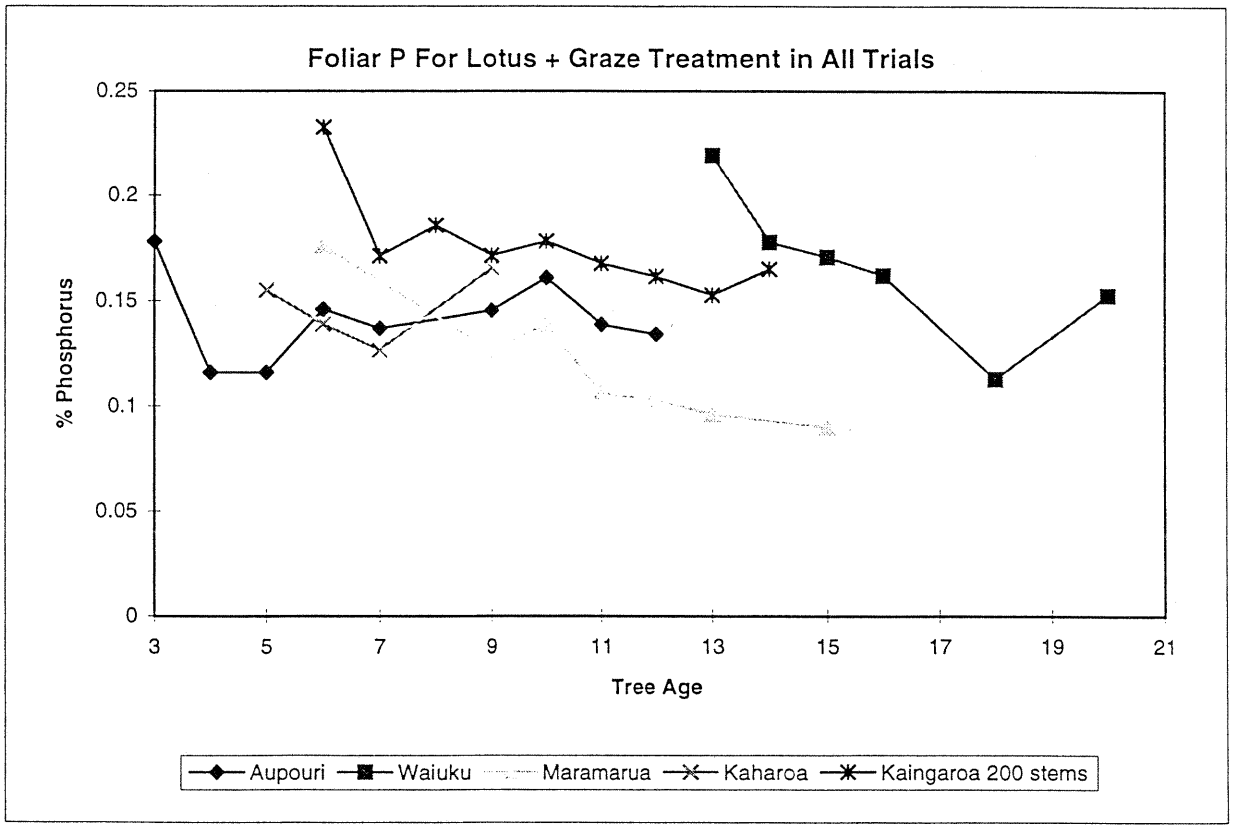
Appendix 6: Foliage analysis of lotus plus grazing treatment at all trials



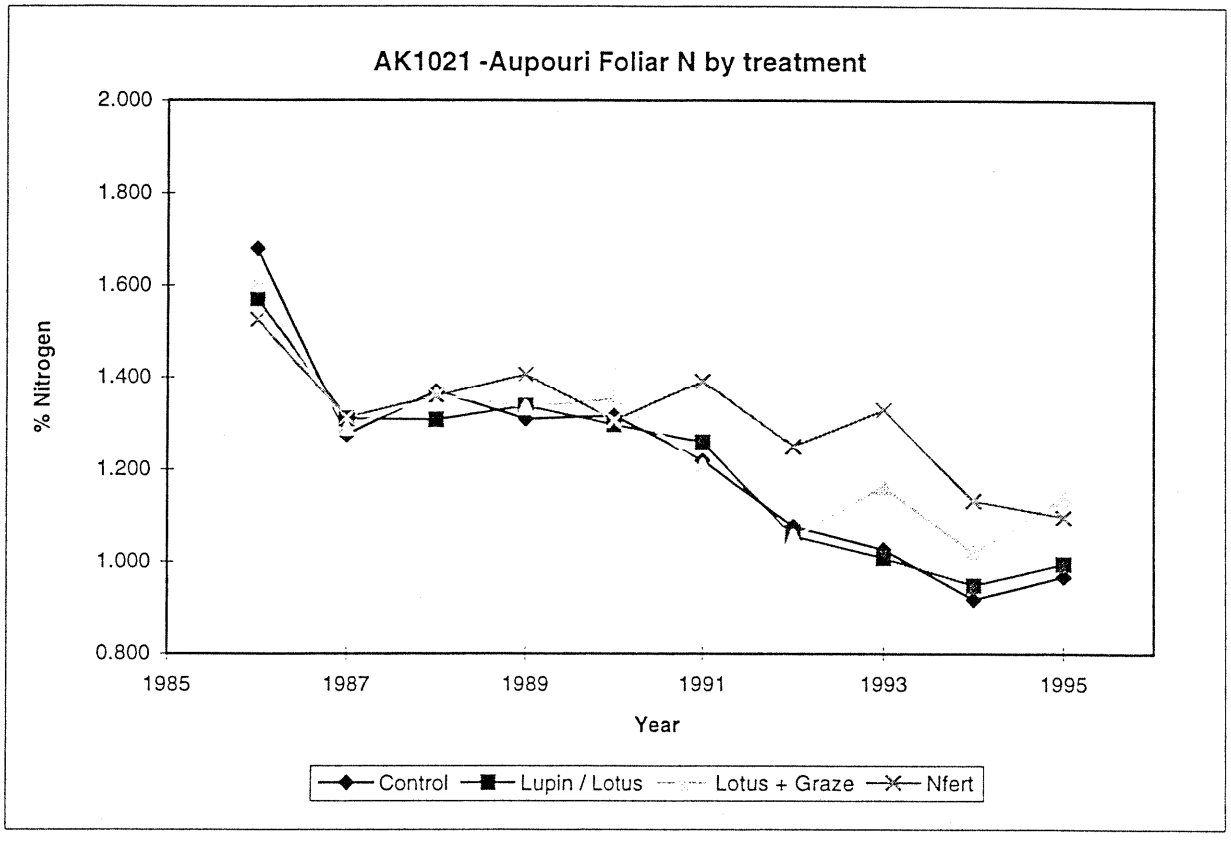


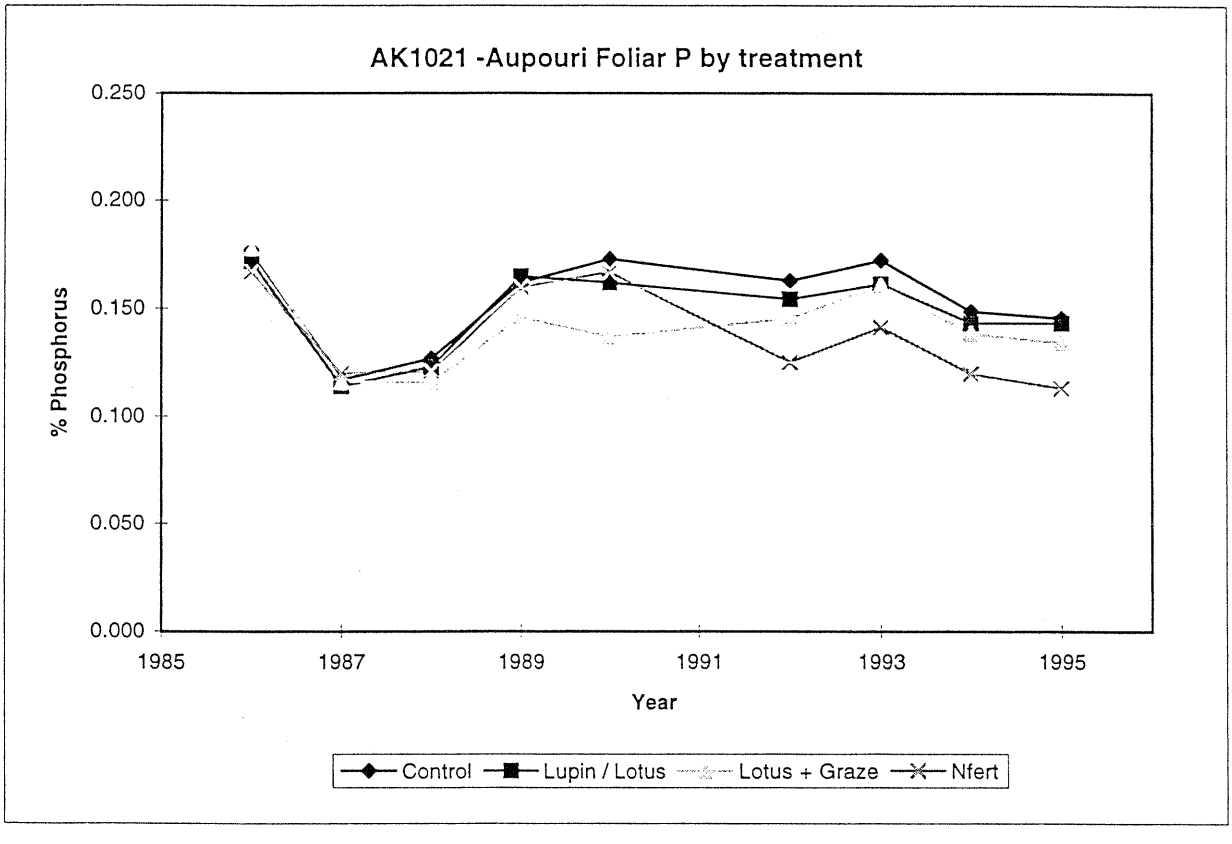
Appendix 7: Foliage analysis of lotus plus grazing treatment against tree age at all trials.



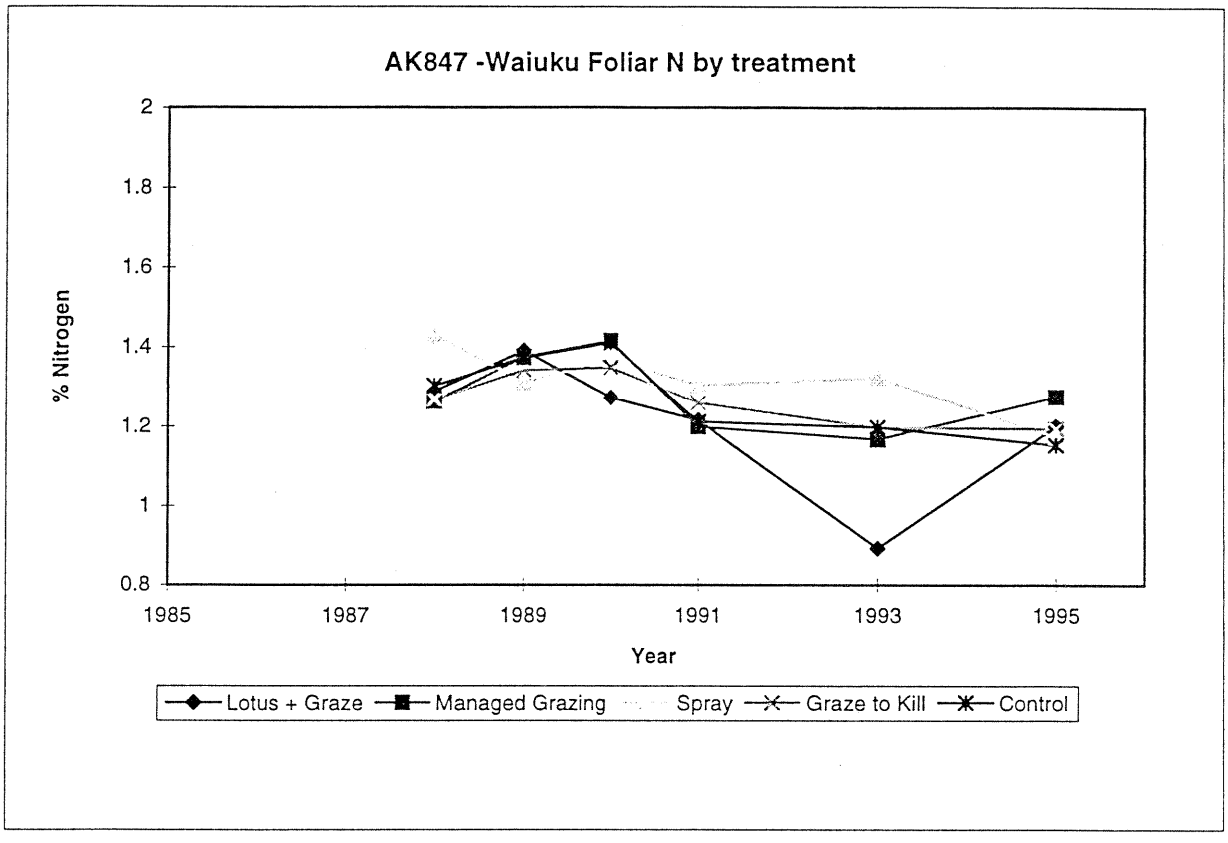


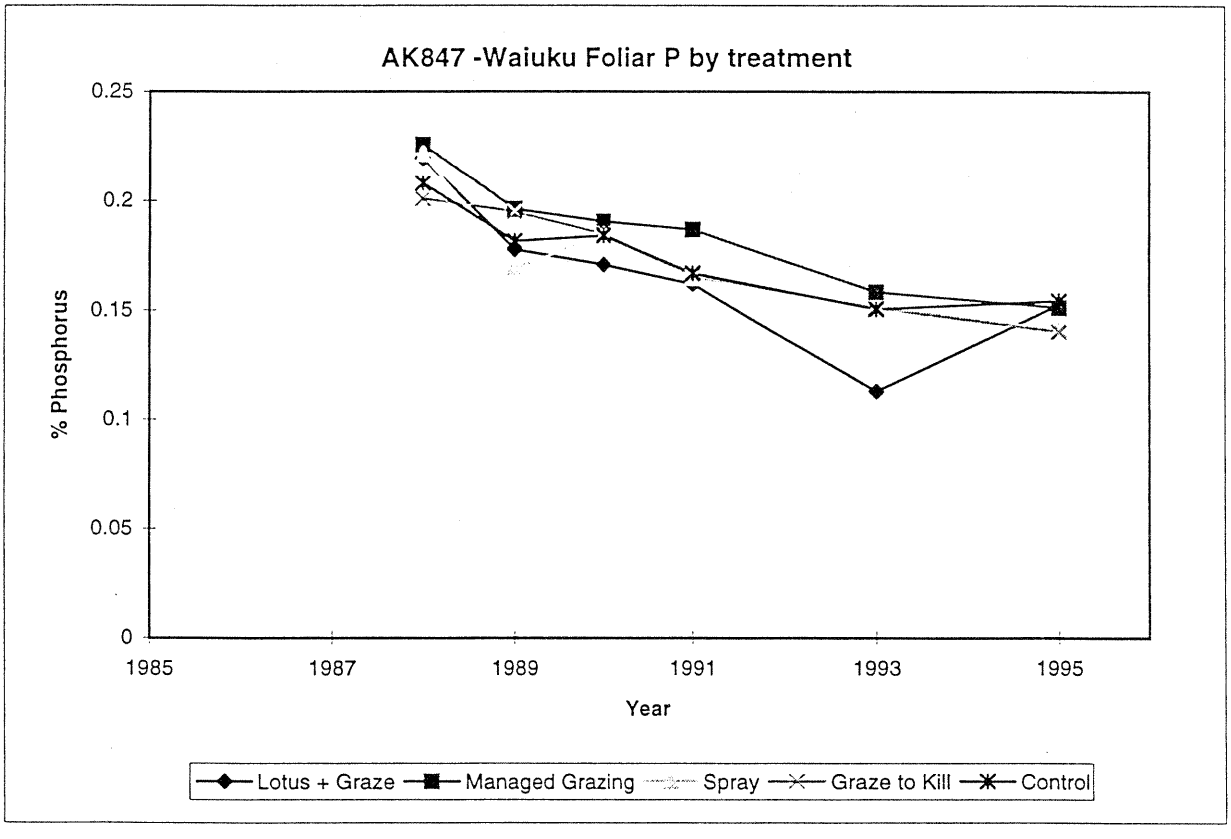
Appendix 8: AK 1021 Foliage Analysis



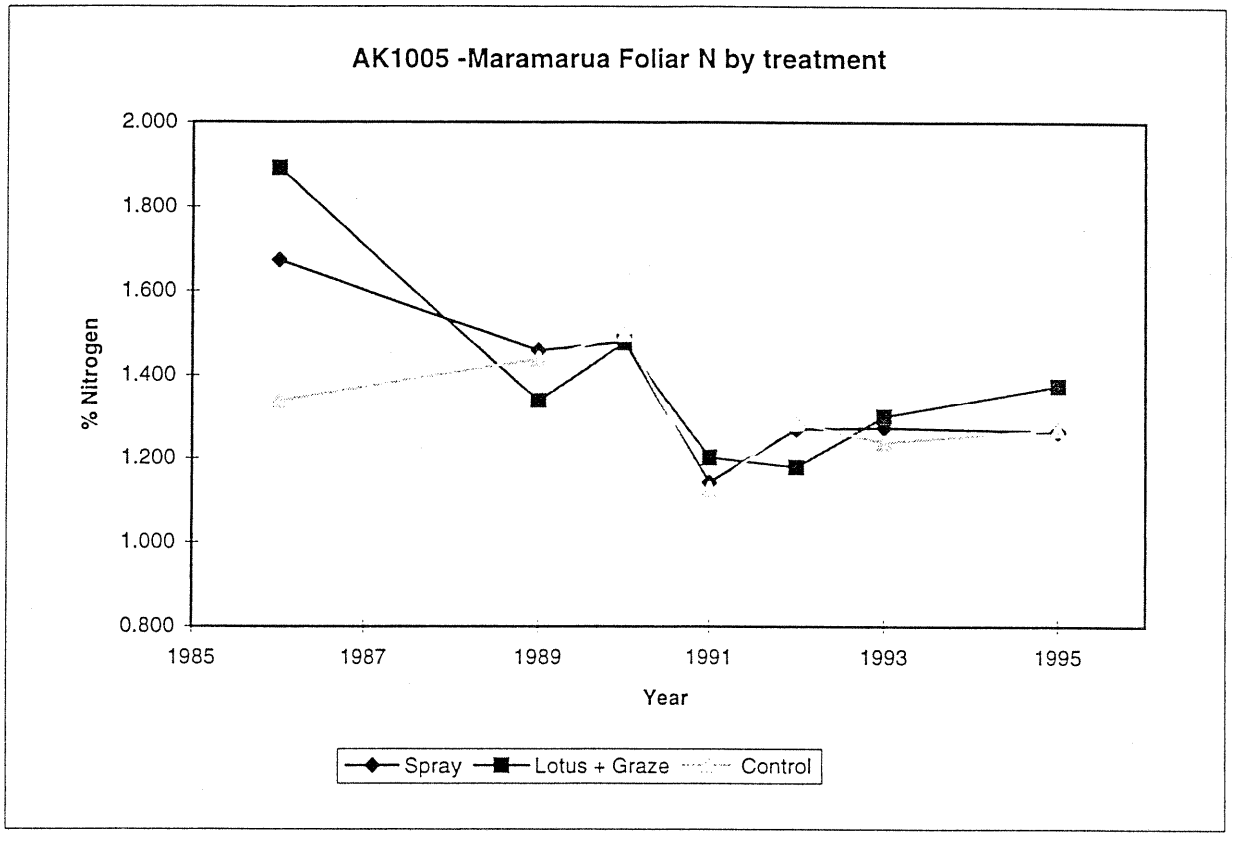


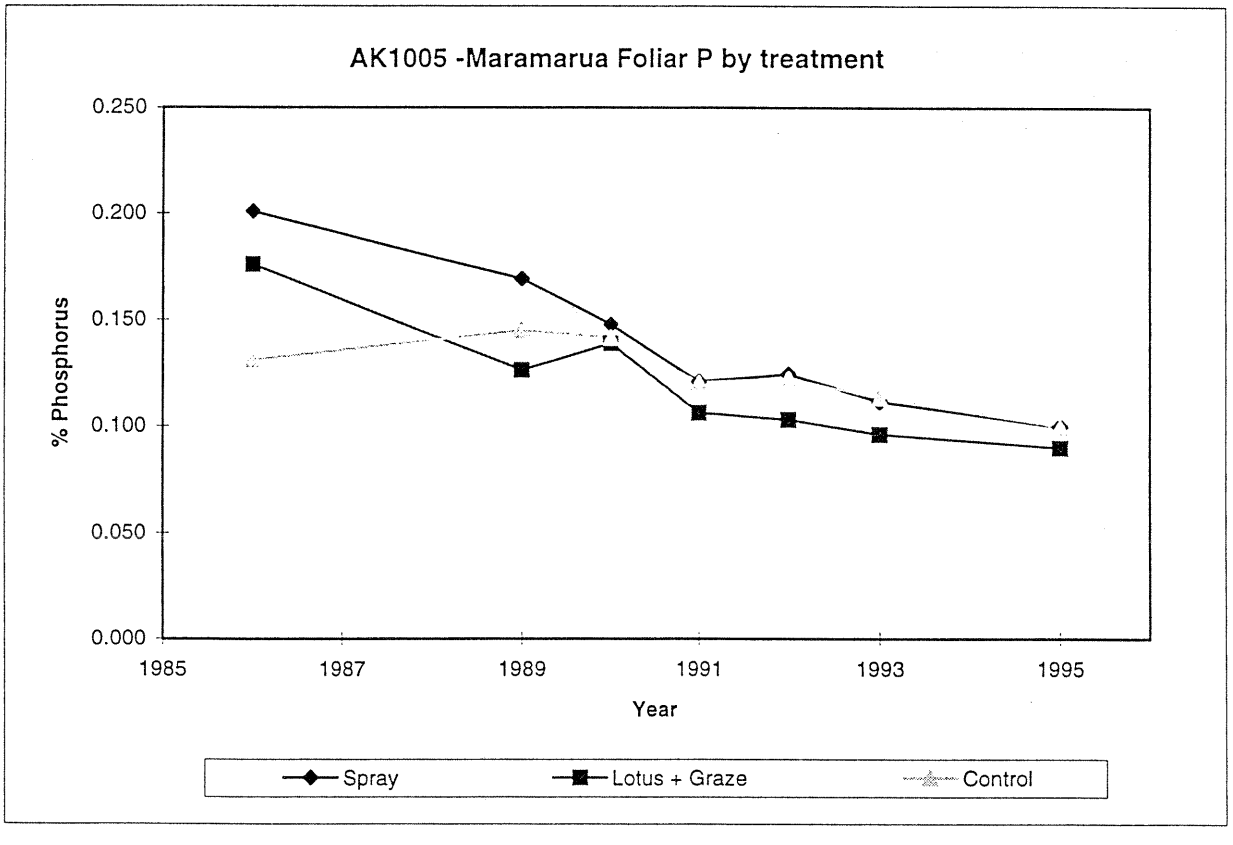
Appendix 9: AK 847 Foliage Analysis



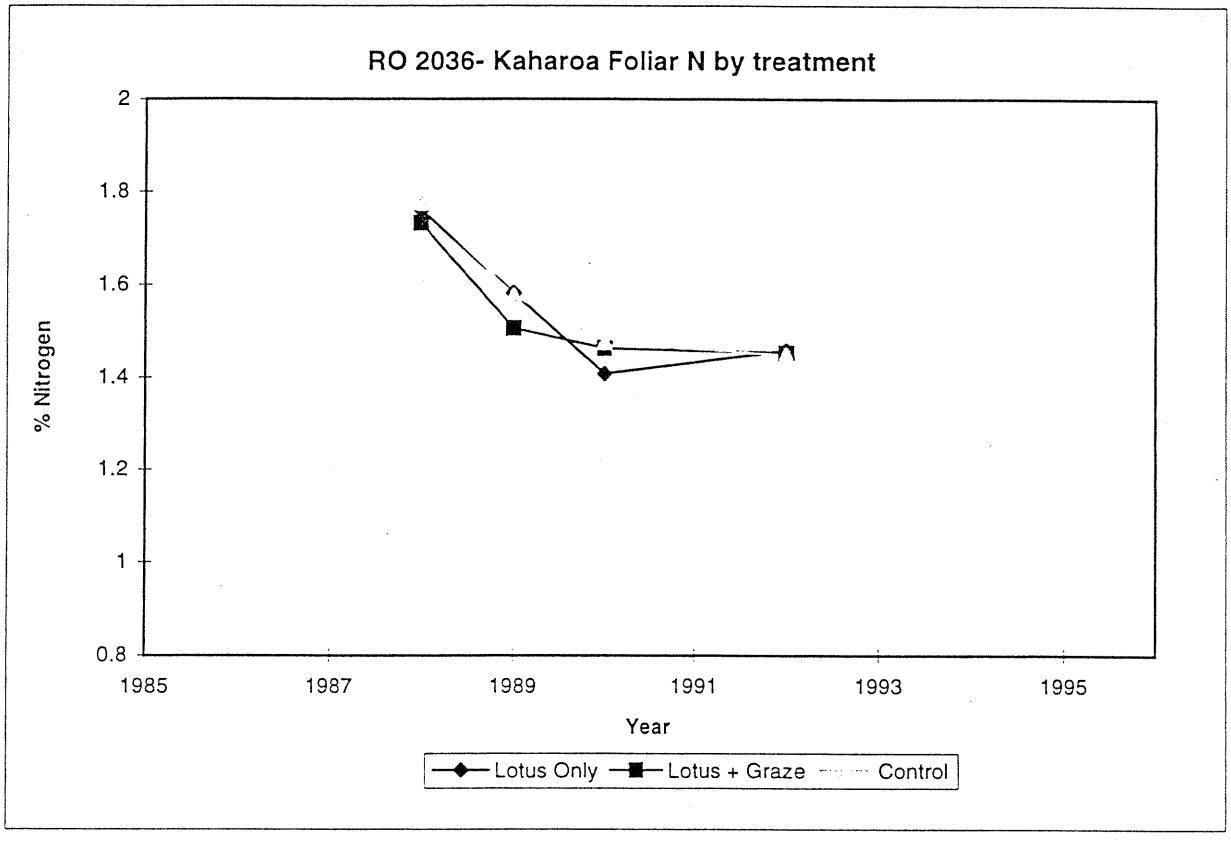


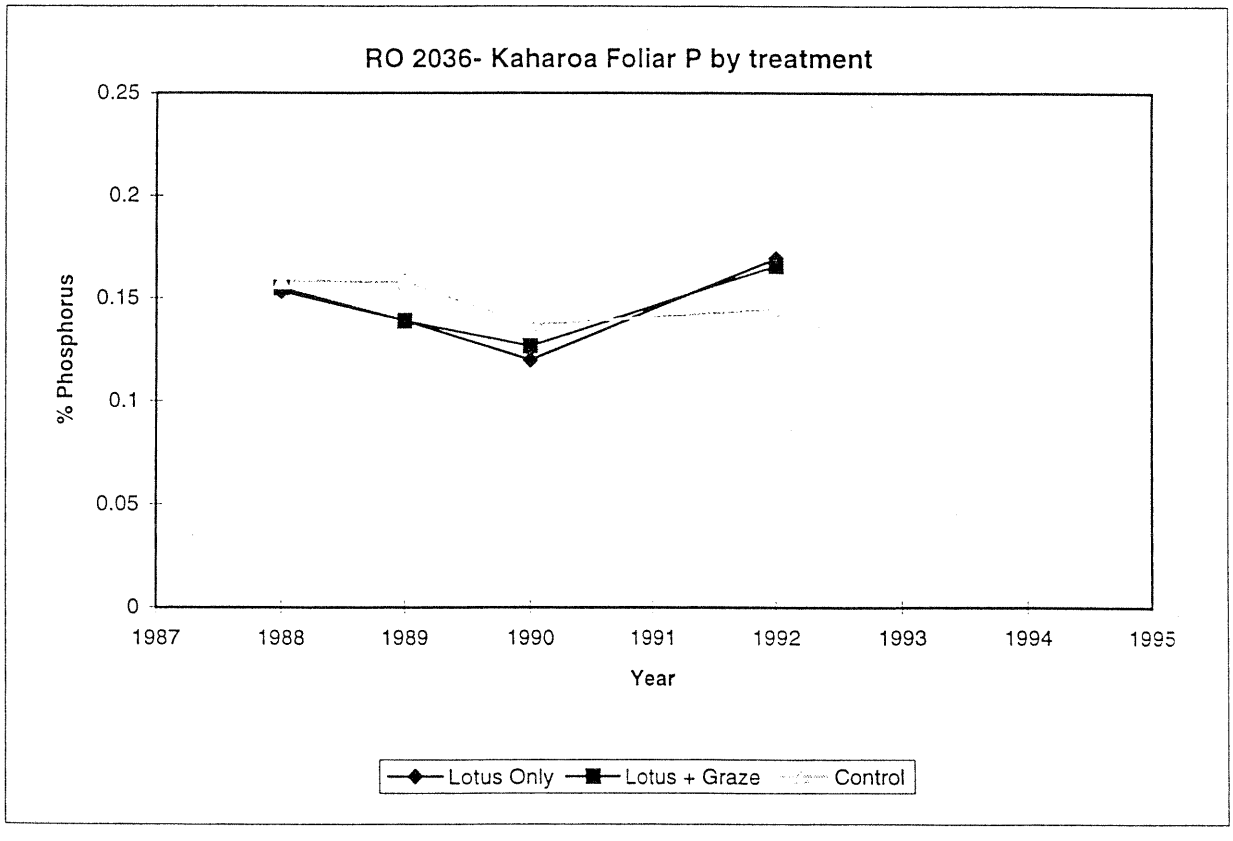
Appendix 10: AK 1005 Foliage Analysis





Appendix 11: RO 2036 Foliage Analysis





Site Management Cooperative Report No. 70
NZ FRI Project Record No. 4737

FOREST OVERSOWING AND GRAZING TRIAL SERIES - PROGRESS REPORT

GG. West and M. G. Dean

SUMMARY

From 1981 to 1985 five major trials were established in Aupouri, Waiuku, Maramarua, Kaharoa, and Kaingaroa forests to quantify the effects on tree growth of oversowing Maku lotus and grazing . Treatments of weed control with grazing or herbicides and the addition of nitrogenous fertiliser have been added at sites where this was appropriate.

Results from these trials to date indicate that :

1) Oversowing with lotus has significantly improved basal area growth on three of the trial sites - Aupouri, Waiuku, and Kaingaroa. At Maramarua and Kaharoa the trial design dos not allow this treatment effect to be analysed.

2) Oversowing with lotus has not improved height growth.

3) The benefits in basal area growth from lotus occurs with and without grazing at Kaingaroa.

4) The benefit in basal area growth from lotus will depend on tree stocking.

5) Competition from pampas grass results in significant losses in tree diameter growth but not height growth.

6) Grazing of pampas will significantly reduce losses in basal area caused by pampas competition.

7) Considerable gains in basal area growth from N fertiliser have been indicated at the Aupouri trial.

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INTRODUCTION

Oversowing forest cutover with grasses and legumes is a potential biological method for weed control and site improvement that is well aligned with the recent ethos of environmental care and sustainable land management. As many forests begin their second and in some cases third rotation weed invasion or weed re-establishment has escalated into a substantial management problem. On these sites the cost of providing effective long term weed control solutions has also escalated . New herbicides have been formulated and these have proved to be very effective for killing most weeds prior to tree planting. However, the period of weed control achieved with herbicides and/or mechanical site preparation techniques is generally only short term. On most sites weeds re-establish and compete with trees, reducing growth (Richardson and West, 1993) and increasing silvicultural costs.

Grazing of plantation forests with livestock in New Zealand has historically been spasmodic and extensive with little benefit to the forest or the grazier. Results indicating substantially improved tree growth when radiata pine is planted onto farm sites suggest that the introduction of a more intensive grazing systems based on forage legumes may provide similar tree growth benefits on traditional forest sites. Lower tree stockings and early pruning and thinning gives greater opportunity for weed growth, with canopy closure generally delayed to age 12-15 years. This also increases the potential understorey forage productivity for livestock grazing. Studies measuring forage yields of Maku lotus and wild grasses in Kaingaroa have recorded annual dry matter production at the level of 3000 - 5000 kg/ha (West et al 1991).

Several large scale forest grazing schemes implemented in the 1980s have proven that livestock could be grazed in stands from an early tree age to control weeds and managed to improve overall profitability (Breach, 1988; Dale and Todd, 1988; Hansen, 1988). Potential benefits to the tree crop are in the form of reduced weed competition, reduced tending costs (through better access), improved tree growth and decreased fire risk.

From 1981 to 1985 five major trials were established in Aupouri, Waiuku, Maramarua, Kaharoa (NW Mamaku), and Kaingaroa forests to quantify the effects on tree growth of oversowing Maku lotus and grazing . Treatments of weed control with grazing or herbicides and the addition of nitrogenous fertiliser have been added at sites where this was appropriate. Early results from these trials have been reported in West *et al* (1988) , West and Dean (1990), West *et al* (1991), West and Dean (1992), West and van Rossen (1994).

In July 1991 this series of trials became part of the research programme funded by the Site Management Research Cooperative. This report gives progress with the management of these trials and an update of tree growth results.

Description of trials

Table 1 gives the year planted , year of trial establishment, and current age of the trials.

Table 1: Trial description

Location	Year planted	Date established	Current tree age
Aupouri	1983	1985	12
Waiuku	1975	1981	20
Maramarua	1980	1984	15
Kaharoa	1983	1984	12
Kaingaroa	1980	1983	15

Table 2 gives a comparison of treatments covered at each trial

Table 2: Treatments by trial

Treatments	Aupouri	Waiuku	Maramarua	Kaharoa	Kaingaroa
Control	*	*	*	*	*
Herbicide#		*	*		
Graze to kill weeds		*			
Manage graze weeds		*			
Lotus+Graze weeds	*	*	*	*	*
Lotus ungrazed				*	*
Lupin	*				
N fertiliser	*				

* treatment represented in trial
# Total weed control with repeated herbicide applications

AUPOURI TRIAL - AK1021

Trial history and Treatments

This trial has had a stand history similar to most first rotation stands established on coastal sand. One year after Marram grass was established, lupin (*Lupinus arboreus*) was sown and left to grow for three years. Prior to tree planting the lupin was crushed and any regrowth killed with herbicide. Pampas grass (*Cortaderia species*) had become endemic in the south of the forest and was expected to spread north through the trial area. At tree age 2 years the trial was established with treatments aimed at comparing the effects of a range of alternative sources of nitrogen on stand growth. The trial design is a randomised complete block design , see map appendix 1. Treatments were as follows:
1. Control
2. Lupin
3. N fertiliser
4. Lotus + grazing

To encourage legume and tree growth the whole trial area was fertilised at trial establishment with 200 kg/ha of superphosphate. Lupin was resown (at 10 kg seed/ha) in the "Lupin" treatment to encourage regrowth. N fertiliser (Urea) treatment involved two applications/yr (spring and autumn) of 50 kg N/ha every year. To date a total of aprox 800 kgN/ha has been applied. Maku lotus was sown at 5 kg of seed /ha in the "Lotus + Graze" treatment. Grazing of the lotus began in the second year using cattle. Initially the trial received 2 grazings/year with some Marram grass included in the forage consumed. This changed to a single grazing by tree age 8 and since tree age 9 the trial has not been grazed due to a lack of cattle in the local area.

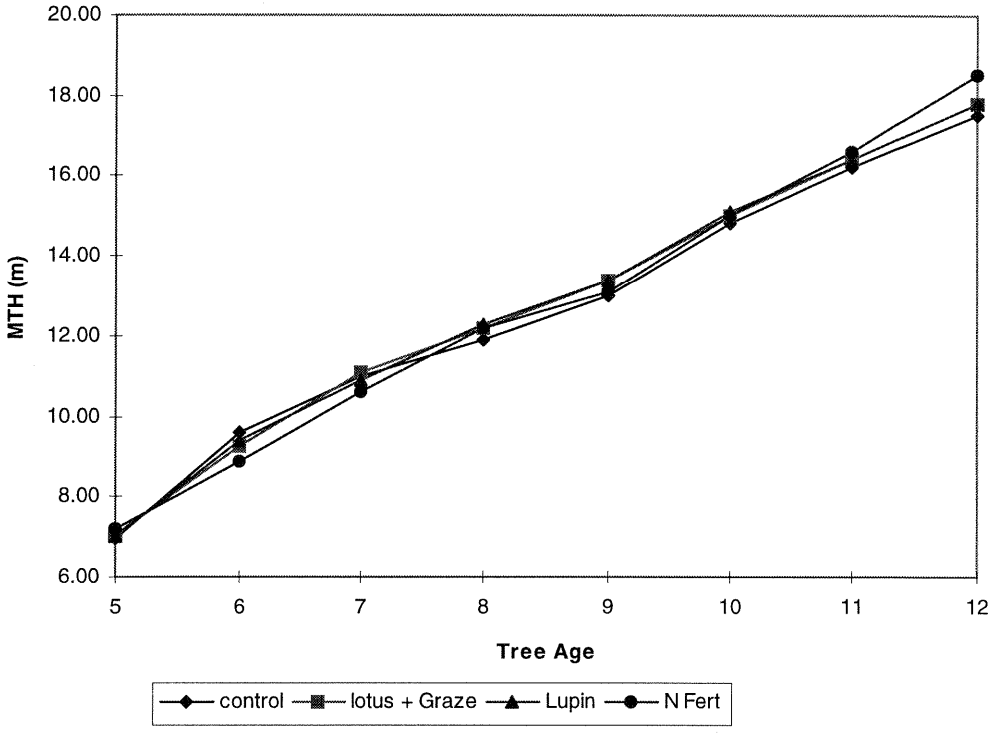
In 1989 the lupin was decimated by the fungus *Colletotrichum gloeosporioides*. To retrieve something from the plots of this treatment, these plots were oversown with Maku lotus in 1990. This proved to be relatively unsuccessful with poor lotus establishment at this late stage in the rotation.

The silvicultural regime in this trial has been the standard forest practice of pruning to 6.0m combined with a production thinning regime. The trial was waste thinned from approx 1300 to 800 stems/ha at age 6. The second thinning has not yet occurred.

Tree Growth

Figure 1 gives height development through time for each treatment.

Figure 1:
Aupouri - Mean Top Height by tree age



Up to age 12 tree height growth has not been influenced by treatments.
Figure 2 gives basal area development through time for each treatment.

Figure 2:
Aupouri - Total Basal Area by Tree age

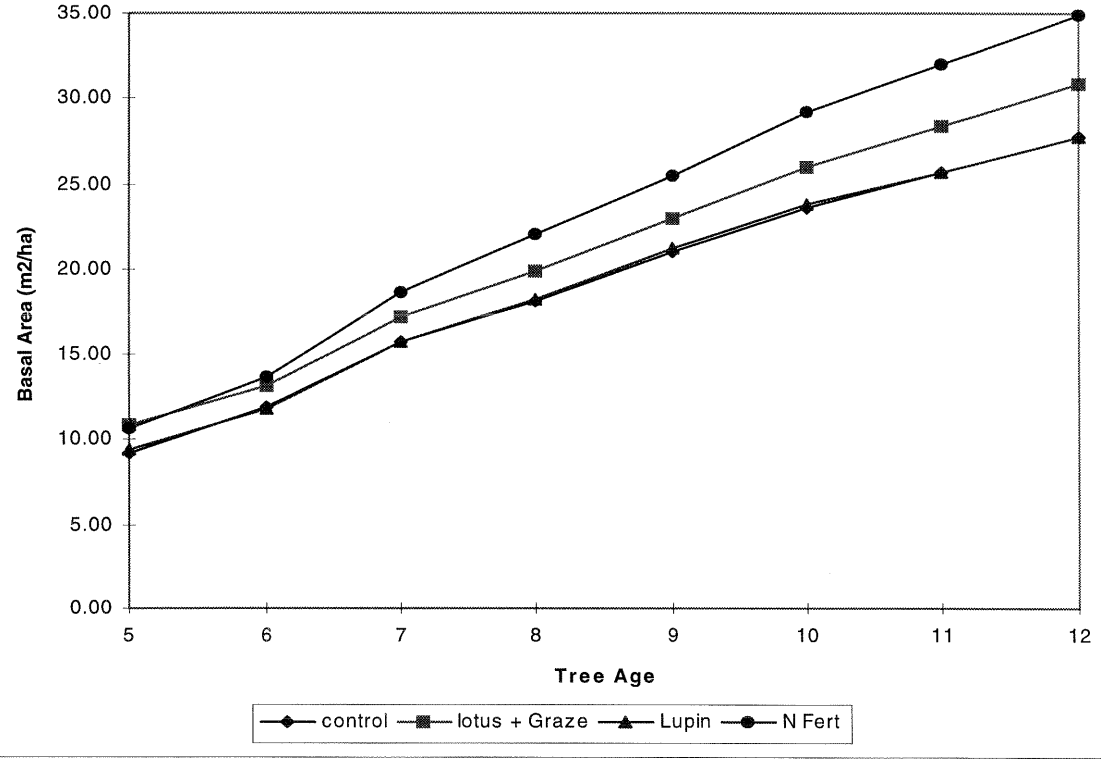
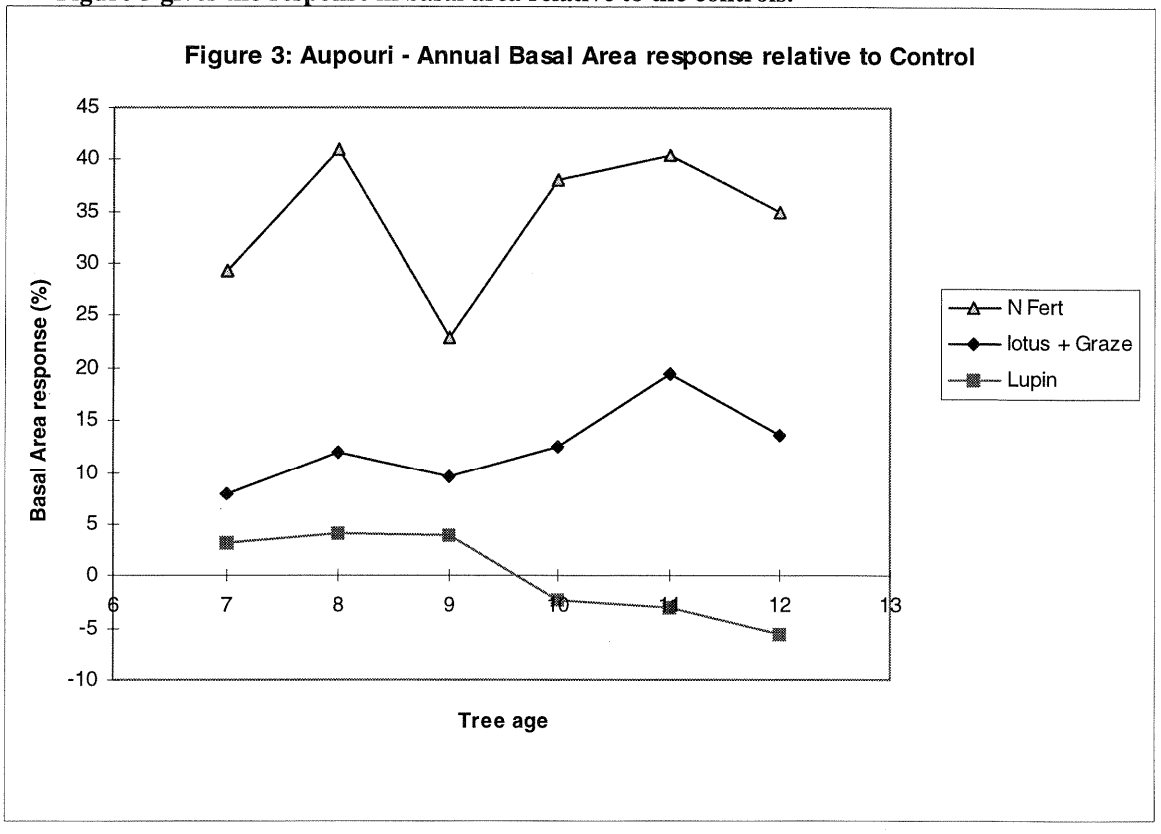


Figure 3 gives the response in basal area relative to the controls.



For the last 6 years, basal area increment for the N fertiliser treatment (100 kg N/ha/yr) has shown a 30% improvement over the control. The lotus + graze treatment has averaged approximately 10% improvement over the same period. This approximately one third of the N fertiliser effect. Because of the early lupin mortality this treatment should be considered the same as the control. Table 3 gives results of analysis of variance of annual basal area increment.

Table 3: Treatments with the same letter are not significantly different - P= 0.05

Tree age	7	8	9	10	11	12
N Fert	A	A	A	A	A	A
lotus + Graze	A	B	A	B	B	B
Lupin	A	B	A	C	C	C
control	A	B	A	C	BC	BC

WAIUKU TRIAL - AK 847

Trial history and Treatments

This trial was established in a second rotation stand growing in coastal iron-sand. By the time of trial establishment (tree age 6) thick pampas grass had developed throughout the stand. Treatments for this trial were developed to quantify the effect of pampas grass on tree growth and to examine alternative strategies for controlling this weed. Treatments in this trial include:

1. Control - Nil treatment resulting in dense pampas understorey.
2. Spray - repeat applications of glyphosate to achieve total weed control.
3. Manage Graze - grazing pampas with cattle 2-3 times a year to maintain a low understorey of pampas for forage.

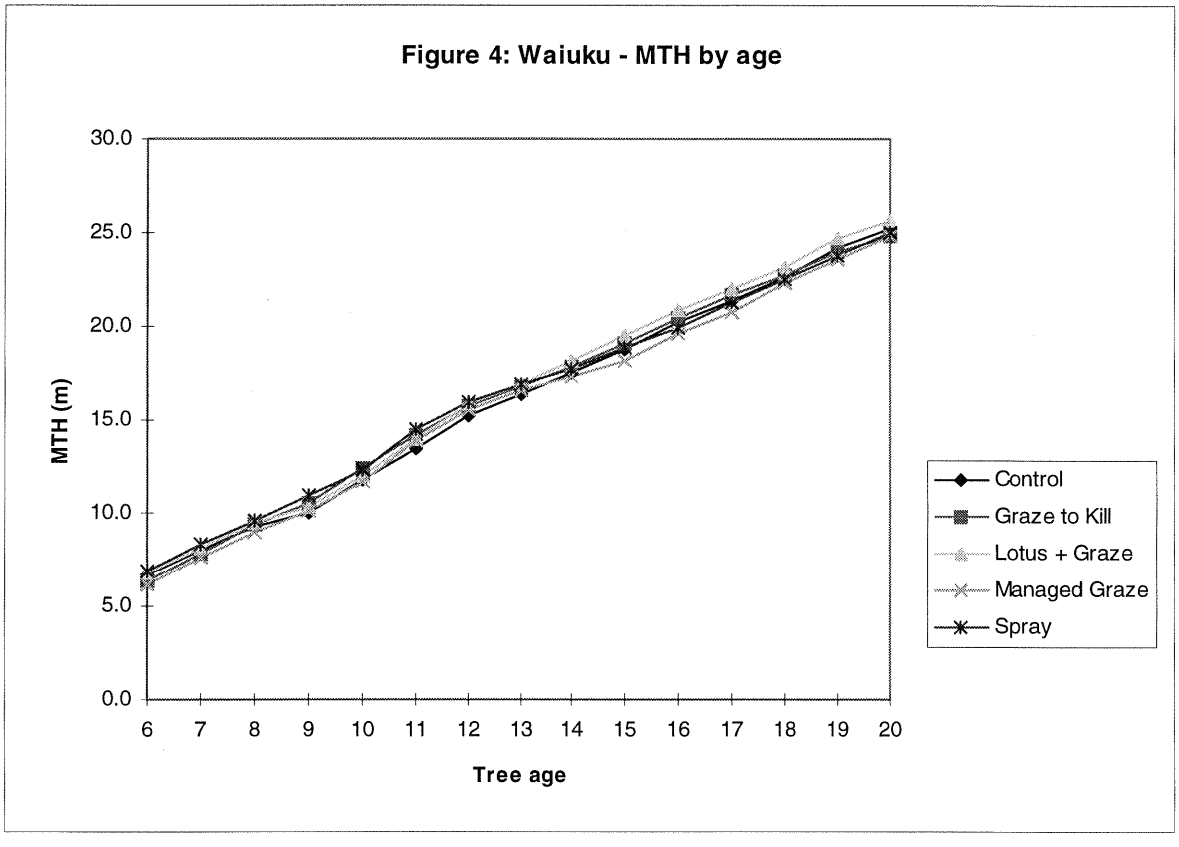
4. Graze to Kill - graze pampas 4-6 times a year to kill plants (Due to light grazing this did not occur for the first 3-4 years)
5. Lotus + Graze - oversow with Maku lotus and graze as in 3 above.

The trial is a randomised complete block design (see map appendix 2)with initial basal area used to identify blocking strata.
Prior to oversowing with lotus, the appropriate plots were grazed with cattle to reduce the ground cover. No fertiliser has been used in the treatments of this trial

The pruning and thinning within the trial has generally followed a direct sawlog regime thinning down to a final crop stocking of 200 stems/ha and pruning to 6.0m by tree age 11 years.

Tree growth

Figure 4 gives height development through time for each treatment.



Height growth at this trial has not been effected by treatments. NB This includes severe competition from pampas in the controls.

Figure 5 gives basal area development through time for each treatment.

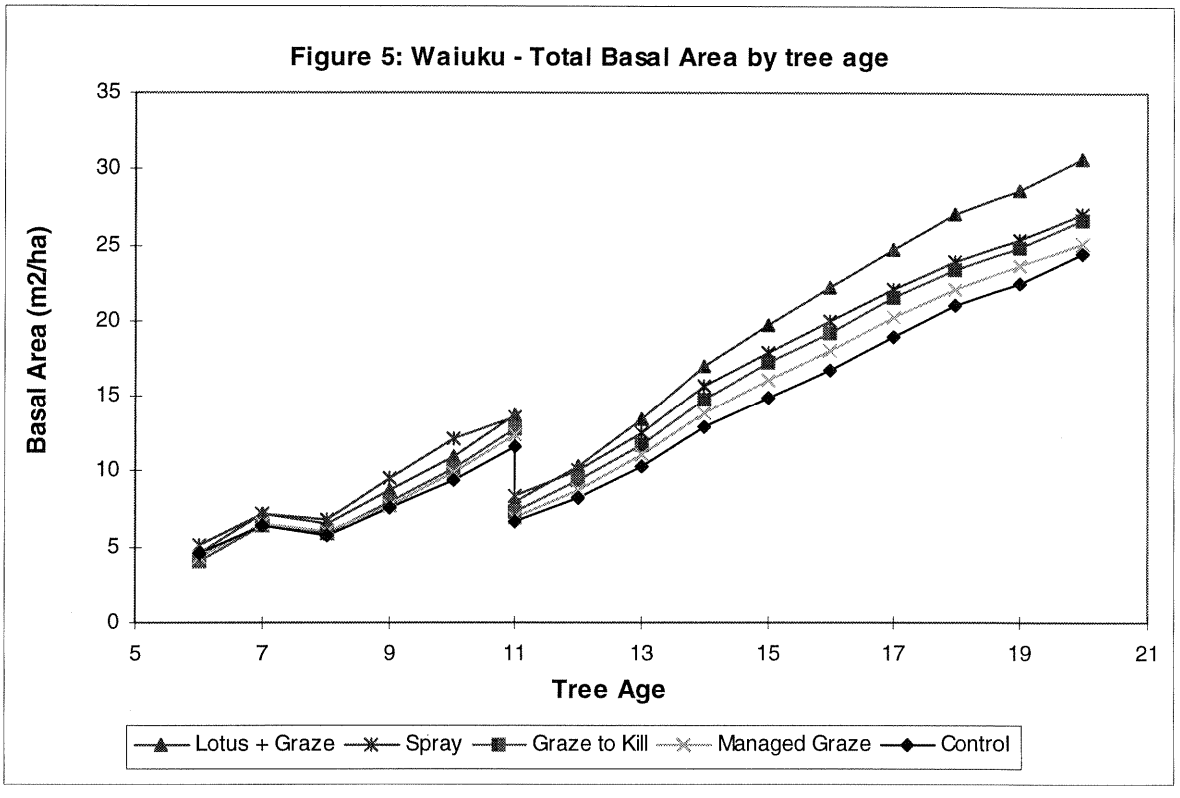
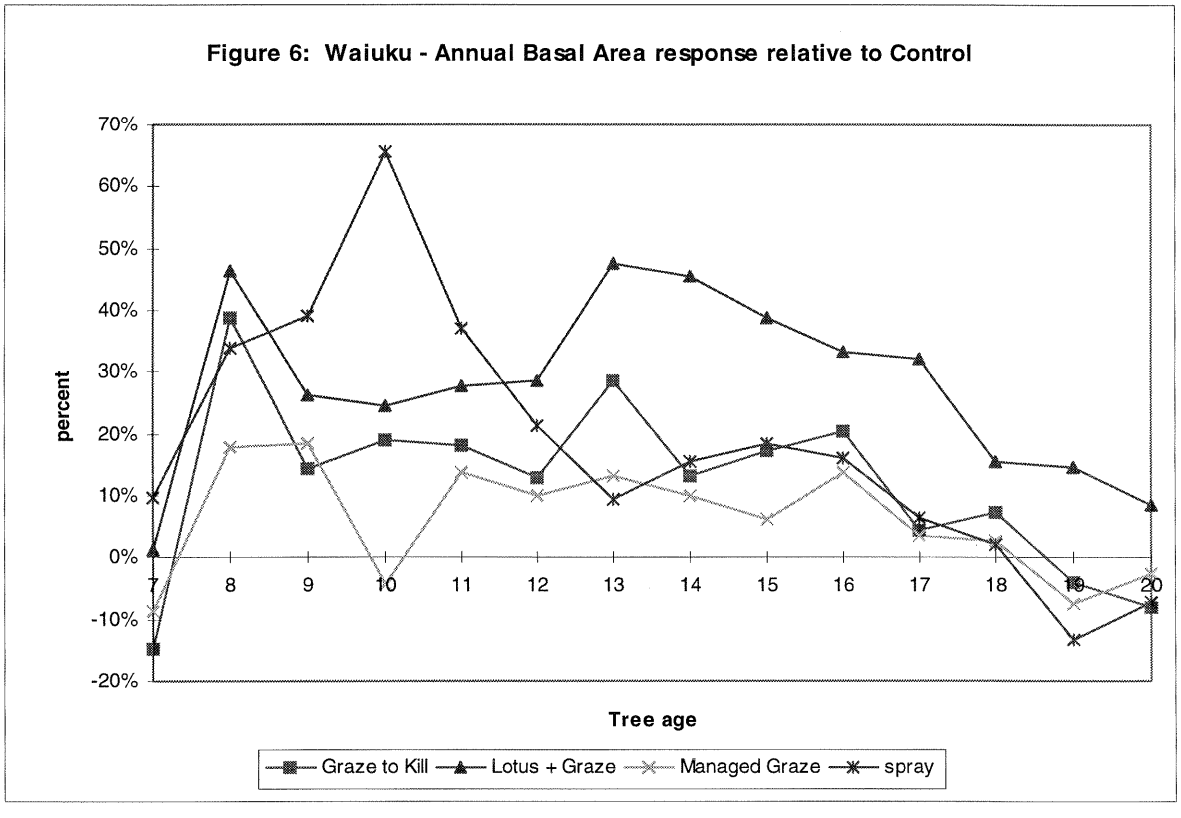


Figure 6 gives the response in basal area relative to the controls.



Relative to the controls basal area growth has been significantly influenced in the first five years by the removal of pampas in the "Spray" treatment (total weed control). Over most of the measurement period the "Lotus + Graze" treatment has also significantly improved basal area growth. A considerable

difference is evident between the "Manage Graze" and "Lotus + Graze" treatments. This difference is expected to be the contribution of lotus to tree growth through N fixation. A small difference between "Graze to kill" and "Manage Graze" is evident but both are significant improvements over the control. Table 4 gives results of analysis of variance of annual basal area increment. Initial basal area has been used to provide covariance adjustment in the initial 7 years of basal area increment.

Table 4: Treatments with the same letter are not significantly different - P= 0.05

Tree age	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lotus + Graze	A	A	B	AB	A	A	A	A	A	A	A	A	A	A
Spray	A	A	A	A	A	C	B	B	A	B	A	B	A	A
Graze to Kill	A	A	B	ABC	AB	B	B	B	A	B	A	B	A	A
Managed Graze	AB	A	B	BC	AB	BC	B	B	A	B	A	B	A	A
control	B	A	B	C	B	C	B	B	A	B	A	AB	A	A

MARAMARUA TRIAL - AK1005

Trial history and Treatments

This trial was established into a second rotation stand with heavy clay soils. At tree age 2, invading pampas was operationally sprayed with Velpar and at tree age three 450 kg/ha of triple superphosphate was applied. At the date of trial establishment (tree age 4) the site was heavily infested with pampas grass . Treatments in this trial were aimed at quantifying the effects on tree growth of grazing pampas grass and oversown lotus. The treatments are as follows:

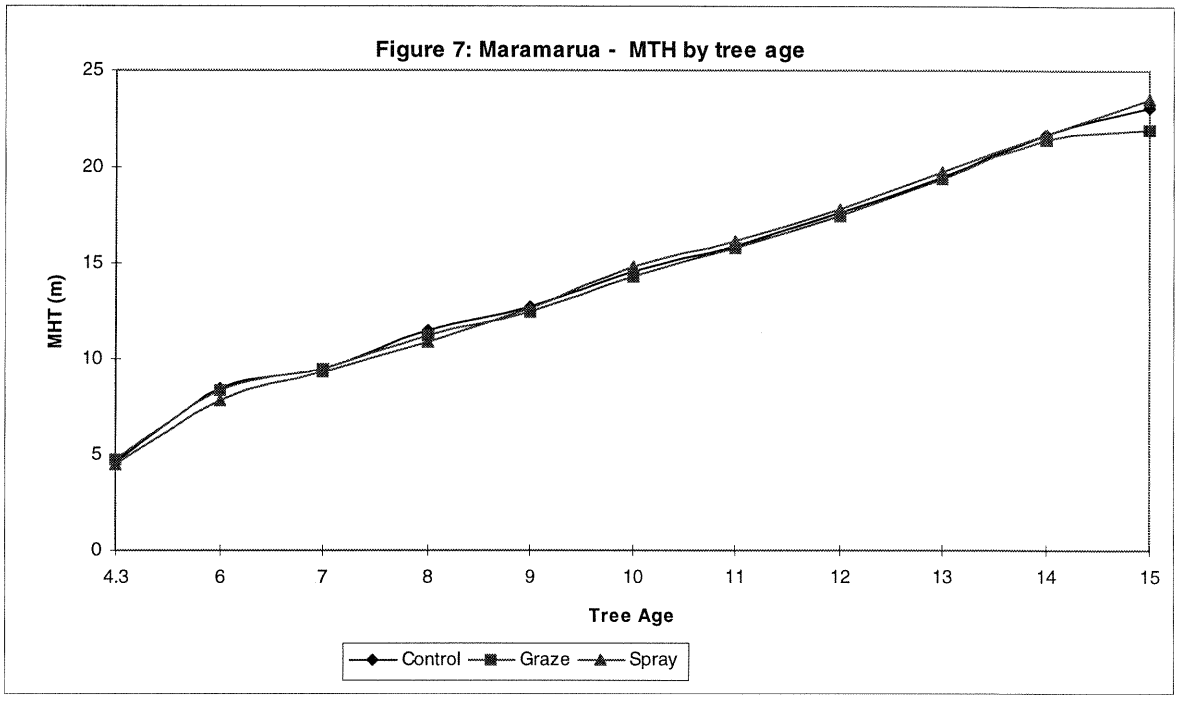
1. Control
2. Spray - repeat applications of herbicide for total weed control
3. Lotus + graze - grazing of pampas and lotus with cattle

The trial is a randomised complete block design (see map appendix 3) with percentage ground cover of pampas grass used to identify blocking strata.

Although repeated applications with glyphosate attempted to achieve total weed control, some woody weeds and Gahnia grass persisted at low intensities. Grazing in the appropriate plots has occurred with cattle as part of the normal rotational grazing of the forest. Grazing has been 3-4 times a year up to tree age 8 and then declined in frequency (due to canopy closure) to where grazing currently occurs only once a year.

The pruning and thinning regime at this trial has generally followed a direct sawlog regime; thinning to a final crop of 250 stems/ha and pruning to 4.3m by tree age 7 years.

Figure 7 gives height development through time for each treatment.



Height growth in this trial has not been influenced by treatments , NB This includes severe competition from pampas grass in the controls.

Figure 8 gives basal area development through time for each treatment.

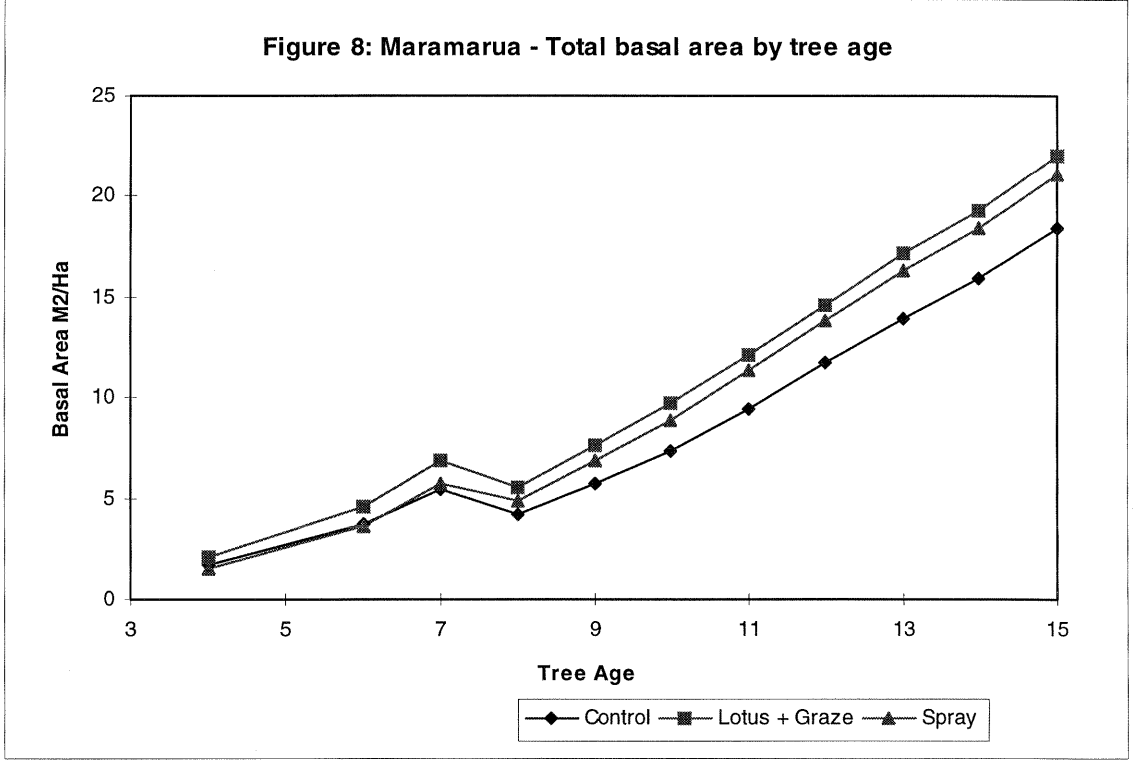
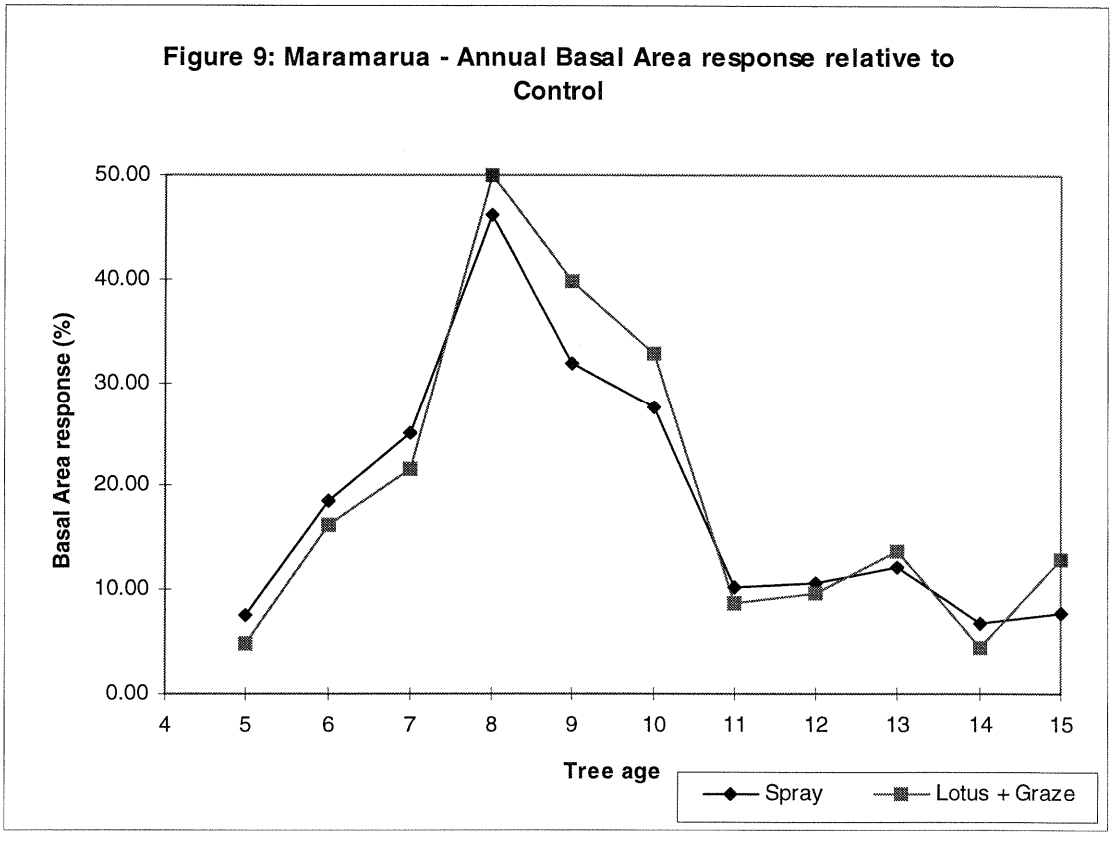


Figure 9 gives the response in basal area relative to the controls.



Relative to the controls annual basal area increment for the "Spray" and "Lotus + Graze" treatments has shown significant improvement. This peaked at age 8 (4 years after trial establishment) and has since declined. The "Lotus + Graze" treatment has indicated little difference from the "Spray" treatment. Initially the "Spray" treatment (no competition) was intended to be equivalent to a grazing only treatment (with no lotus) with any difference between the two treatments being attributable to the lotus. However as indicated by the Waiuku trial this is not the case. The comparison to give the lotus effect is confounded by a number of factors and cannot be used, ie this treatment can only be compared with a treatment of grazing with no lotus. Table 5 gives results of analysis of variance of annual basal area increment. Initial basal area has been used to provide covariance adjustment in the initial three years of basal area increment.

Table 5: Treatments with the same letter are not significantly different - P= 0.05

Tree age	5	6	7	8	9	10	11	12	13	14	15
Lotus + Graze	A	A	A	A	A	A	A	A	A	A	A
Spray	A	A	A	A	A	A	A	A	A	A	A
Control	A	A	B	B	A	A	A	A	A	A	A

For many years a substantial response to treatment is recorded (fig 9) but shown in table 5 as not statistically significant. This is partly due to the small residual degrees of freedom resulting from 3 treatments x 4 replicates. However many years would be significant at P=0.10.

KAHAROA TRIAL- RO2036

Trial history and Treatments

This trial was established in a indigenous cutover site in 1984. The area had been root raked and windrowed removing much of the topsoil. The whole stand had been oversown with lotus by helicopter

in the spring after planting . At age 4 the whole trial area was given an application of superphosphate at 300 kg/ha .

Treatments were as follows:

1. Control
2. Lotus + graze
3. Lotus ungrazed

The trial is a randomised complete block design with four replicates (see map appendix 4). Lotus growth in the first year was slow (due to low soil P) and because the entire area had been sown, control plots had to be created by the killing of emerging lotus plants with herbicide. This proved impossible to achieve. Although repeated applications of a range of herbicides over the first 3-4 years severely reduced the lotus understorey, the lotus re-established each year (probably from rhizomes) and this has confounded the experiment. The only useful comparison this trial can now be used for is to compare the effect of grazing versus no grazing of lotus .

Figure 10 gives height development through time for each treatment.

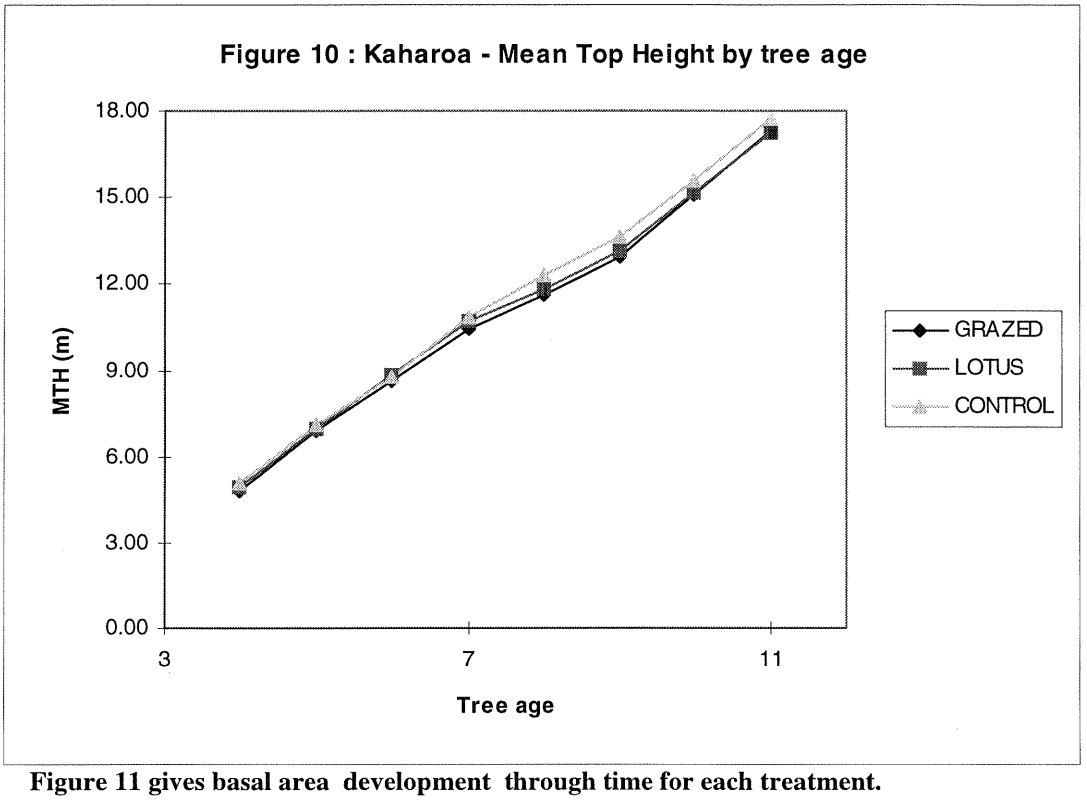
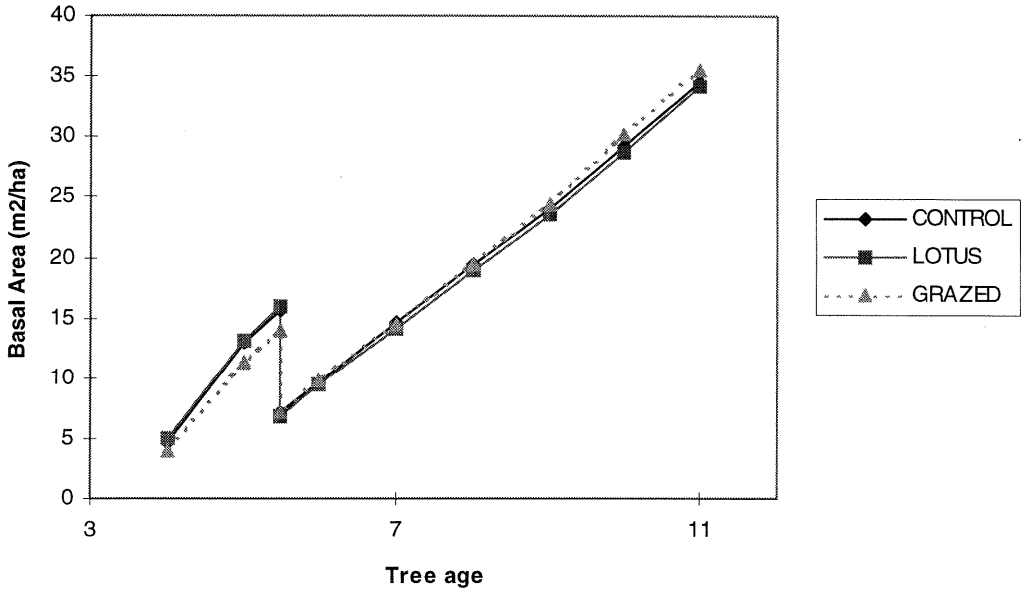


Figure 11 gives basal area development through time for each treatment.

Figure 11 : Kaharoa - Basal Area by Tree age



Treatment effects for this trial are nonsignificant except for year 10 when the increment of the Lotus + grazed plots was better than the other two treatments.

KAINGAROA TRIAL - RO1891

Trial history and Treatments

This trial was established in October 1983 (tree age 3) in a second rotation stand near the half-mile fire break in central Kaingaroa.

The site had been over-sprayed for weed control in the first year after planting (1980) and had remained relatively weed free. Treatments in this trial were aimed at measuring the effect on tree growth of oversowing lotus and grazing with cattle. Because lotus growth was expected to be influenced by tree stocking, a range of tree densities were included. The following treatments were used:

Legume and grazing
1. Cattle grazing of oversown lotus (plus wild grasses and weeds)
2. Oversown lotus, no grazing (at 200 stems/ha only)
3. Control - No oversowing and no cattle grazing

Tree crop
1. Final stocking of 100 stems/ha
2. Final stocking of 200 stems/ha
3. Final stocking of 400 stems/ha

The trial is a randomised complete block design (see map appendix 5) with tree stocking as the main plot treatment and lotus + grazing as a split plot application.

At trial establishment, lotus was oversown at 5 kg seed/ha and superphosphate (with molybdenum and cobalt) applied at 400 kg/ha. After the first year grazing occurred 3 times / year until age 14 when the trial was not grazed. Unfortunately cattle are no longer available from the nearby farm for this treatment.

Figure 12 gives height development through time for each treatment.

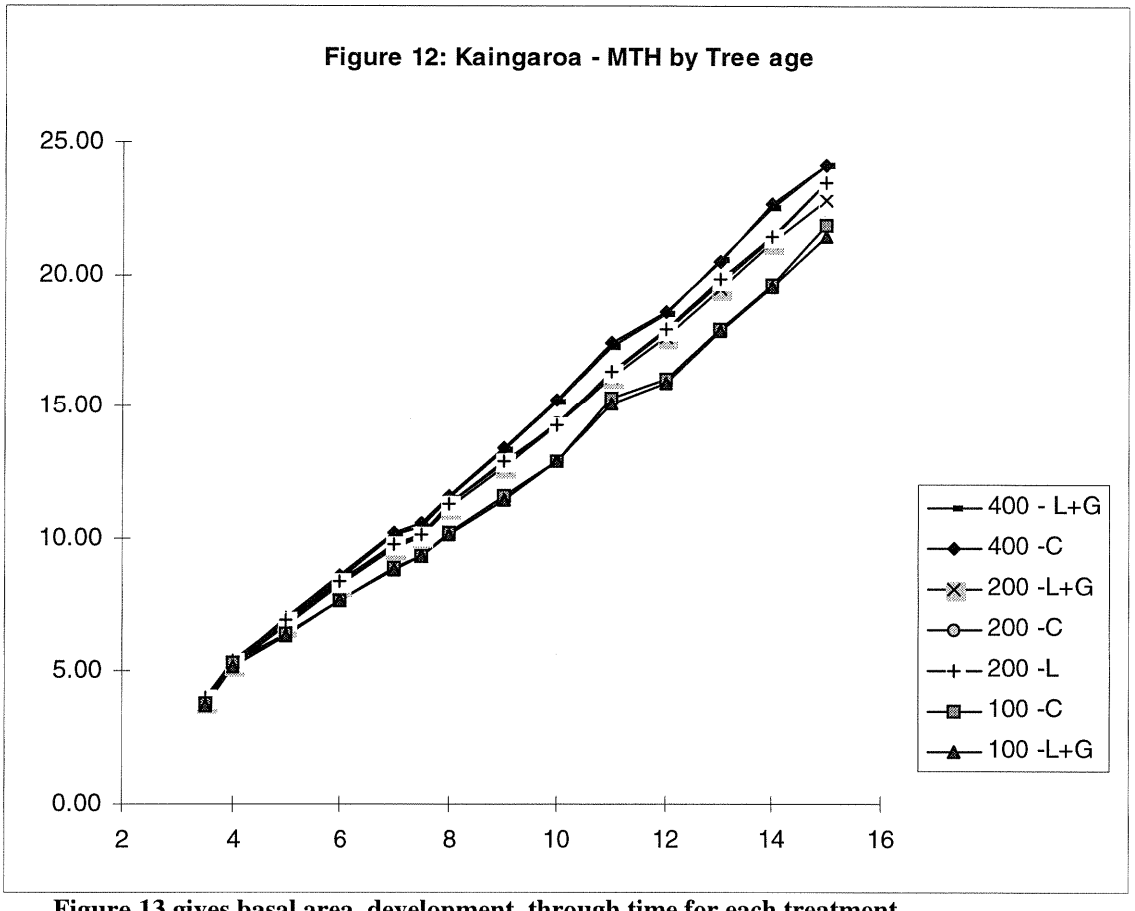
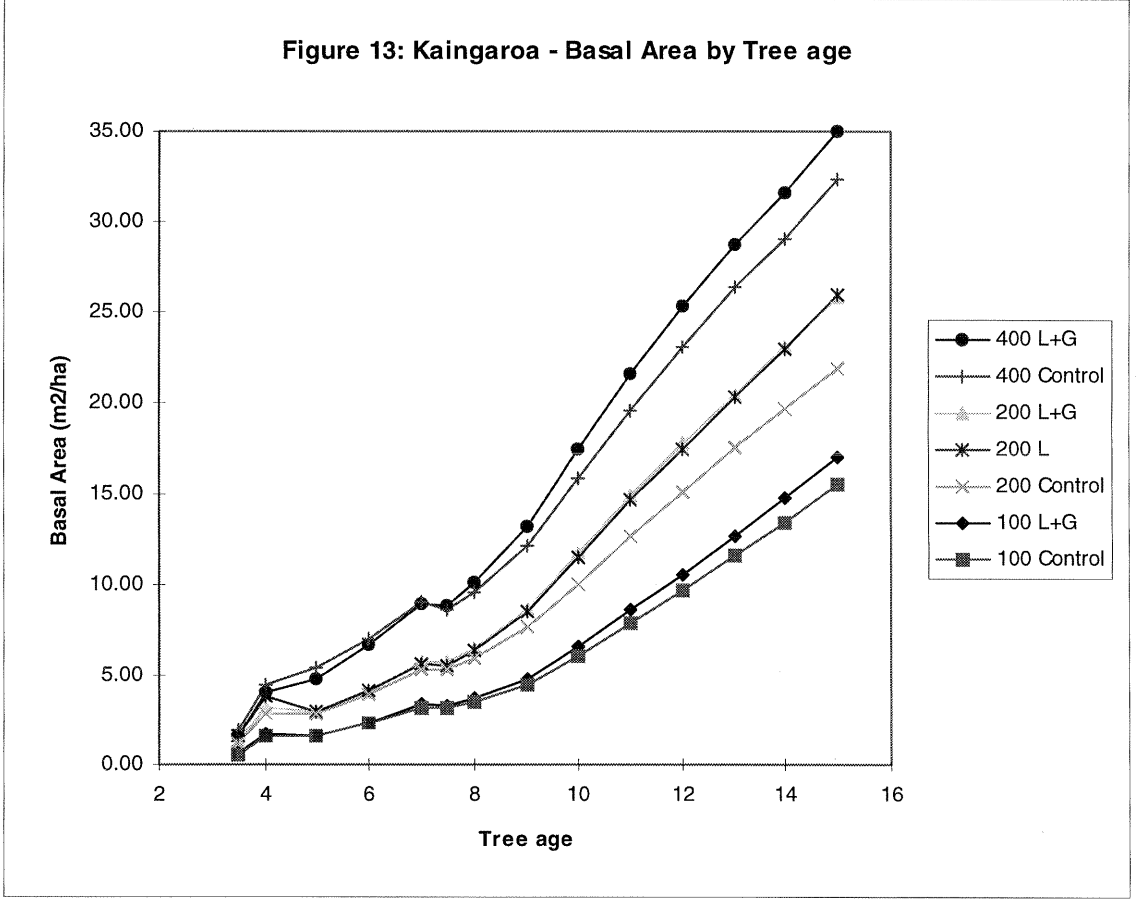


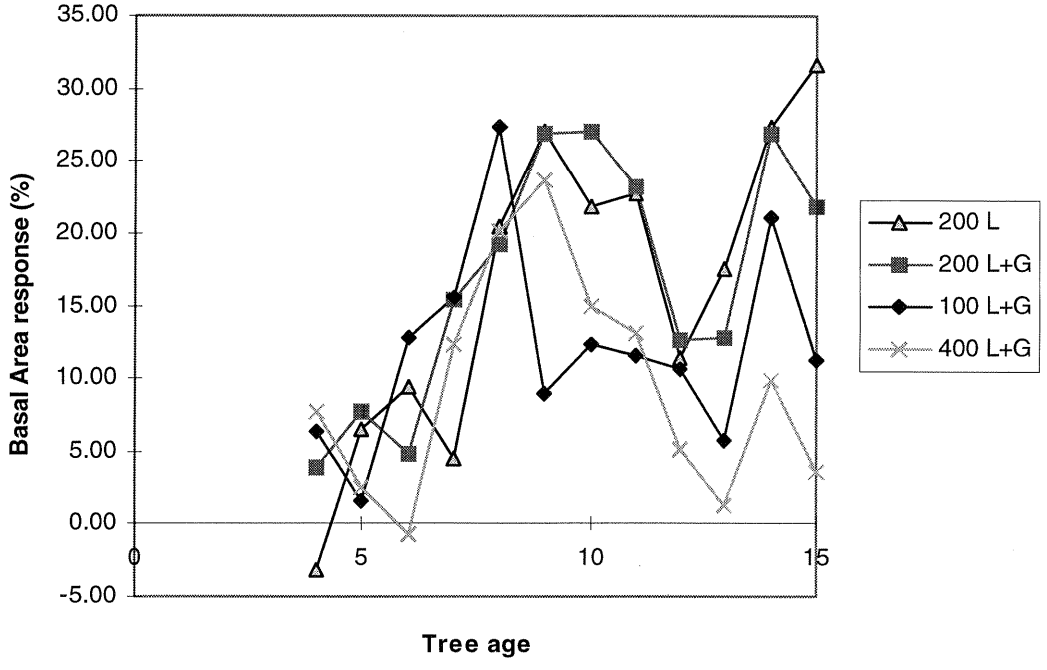
Figure 13 gives basal area development through time for each treatment.



Height growth in this trial has not been affected by the lotus + graze treatment. However, height growth has been considerably affected by tree stocking. This phenomenon has been reported by Maclaren *et al* (1995), with lower height growth often being recorded on sites where trees are grown at stockings below 400 stems/ha.

Figure 14 gives the response in basal area relative to the controls.

Figure 14: Annual Basal Area relative to the Control



Basal area response to lotus + grazing has rapidly increased over the first 5 years after oversowing. Response has generally peaked at 27% improvement (for tree age 8-10) , then declined for several years before improving again (years 14-15). The response to the ungrazed lotus treatment (200 stems/ha only) has been very similar.

The response to lotus has been influenced by tree stocking with the 100 and 400 stockings showing less improvement than the 200 stocking. At age 15 the total accumulated basal area difference between the lotus plots and controls, at 200 stems/ha, is now 3.5 m2/ha (a 17.5 % improvement)

Table 6 gives results of analysis of variance of annual basal area increment. Initial basal area has been used to provide covariance adjustment in the initial two years of basal area increment.

Table 6: Treatments with the same letter are not significantly different - P= 0.05

		Tree age											
Treatment	Stocking	4	5	6	7	8	9	10	11	12	13	14	15
Lotus + Graze	100	A	A	A	A	A	A	A	A	A	A	A	A
Control	100	A	A	A	A	A	A	A	A	A	A	A	A
Lotus + Graze	200	A	A	A	A	A	A	A	A	A	A	A	AB
Lotus only	200	A	A	A	A	A	A	A	A	A	A	A	A
Control	200	A	A	A	A	B	B	B	B	A	A	B	B
Lotus + Graze	400	A	A	A	A	A	A	A	A	A	A	A	A
Control	400	A	A	A	A	B	B	B	B	A	A	A	A

DISCUSSION

On all five sites of the trial series a positive basal area response has been indicated from the oversowing of lotus however at the Maramarua and Kaharoa trials these effects are confounded and not statistically significant. At Kaingaroa and Waiuku the response is substantial and indicates an improvement in growth of at least 10% (merchantable volume) (West and van Rossen, 1994). At Kaingaroa the response to lotus is still persisting at the last measurement (age 15). This is unexpected as the green crown in the 200 stocking is beginning to rise (now 8.1m) indicating canopy closure. Height growth has not been influenced by lotus oversowing or from severe weed competition from pampas grass.

The removal of pampas grass competition at the Waiuku and Maramarua trials has provided substantial improvements in basal area growth. The use of cattle grazing to achieve this has been very successful particularly when combined with oversowing lotus.

Foliage samples have been taken and analysed annually (or biennially over the last three/four years) for N and P. Results from the foliage analysis are given in appendices 6 to 12. Using the Lotus + Graze treatment as a standard, appendix 6 compares foliar N and P for all five trial sites for each year. Appendix 7 makes the same comparison by tree age. Appendix 8 to 12 give individual trial results and compares the effects of treatments.

These results help to provide some explanation of the tree growth responses. For the Lotus and Graze treatment (appendix 7) P levels at Aupouri, Kaharoa, and Maramarua have been noticeably low through the early stages of stand growth and this has probably restricted lotus growth and hence N fixation. At the Aupouri trial, foliar N levels have been noticeably improved by the N fertiliser treatment over the last five years. However, the significant tree growth response to legumes at Waiuku and Kaingaroa has not been reflected in foliar N levels.

More detail on this data, including statistical analysis, will be provided in a final and more formal publication. Data on ground cover achieved with lotus and biomass of weeds will also be included.

CONCLUSIONS

Results from these trials to date indicate that :

1) Oversowing with lotus has significantly improved basal area growth on three of the trial sites - Aupouri, Waiuku, and Kaingaroa. At Maramarua and Kaharoa the trial design dos not allow this treatment effect to be analysed.

2) Oversowing with lotus has not improved height growth.

3) The benefits in basal area growth from lotus occurs with and without grazing at Kaingaroa.

4) The benefit in basal area growth from lotus will depend on tree stocking.

5) Competition from pampas grass results in significant losses in tree diameter growth but not height growth.

6) Grazing of pampas will significantly reduce losses in basal area caused by pampas competition.

7) Considerable gains in basal area growth from N fertiliser have been indicated at the Aupouri trial.

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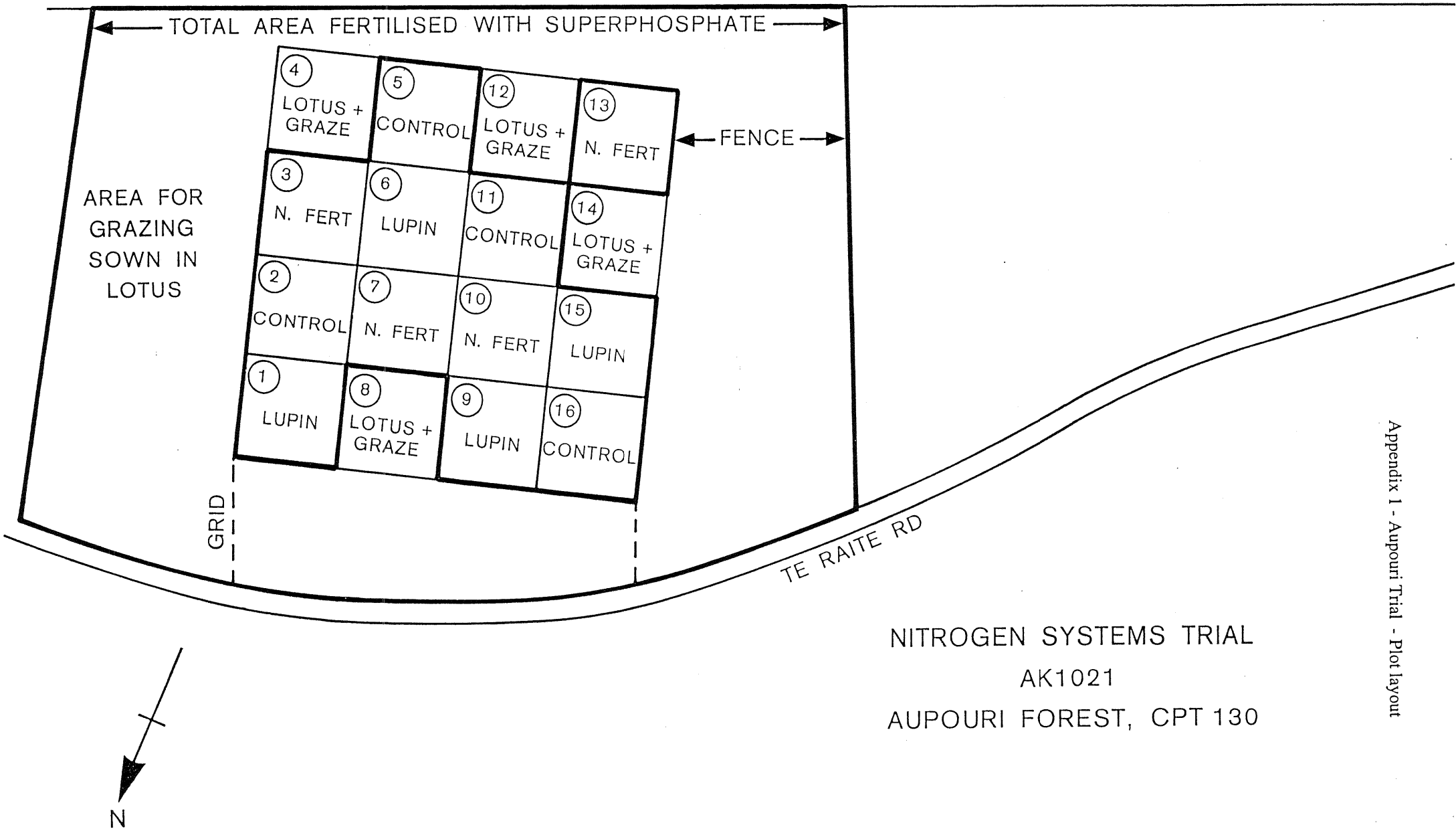


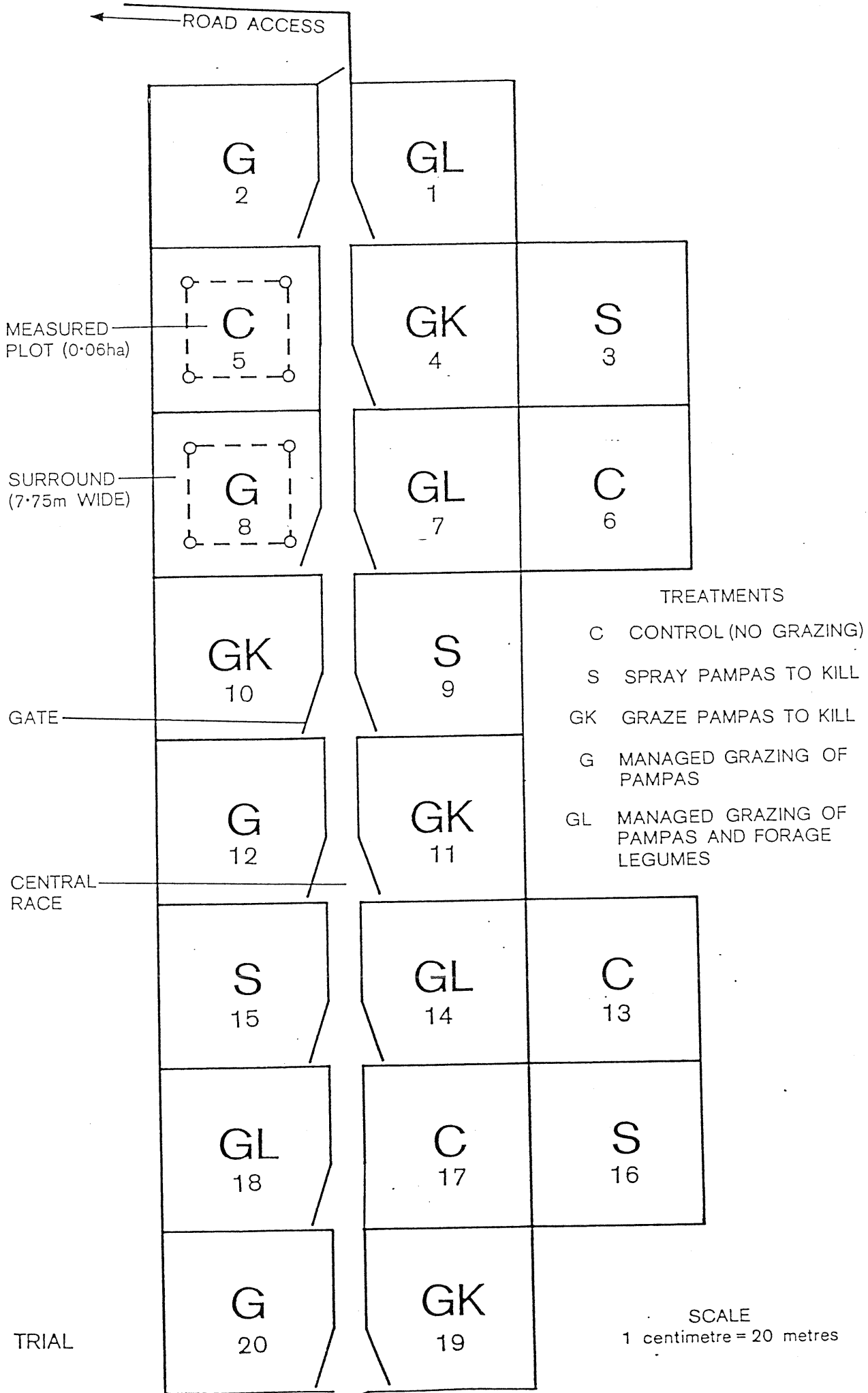
NITROGEN SYSTEMS TRIAL

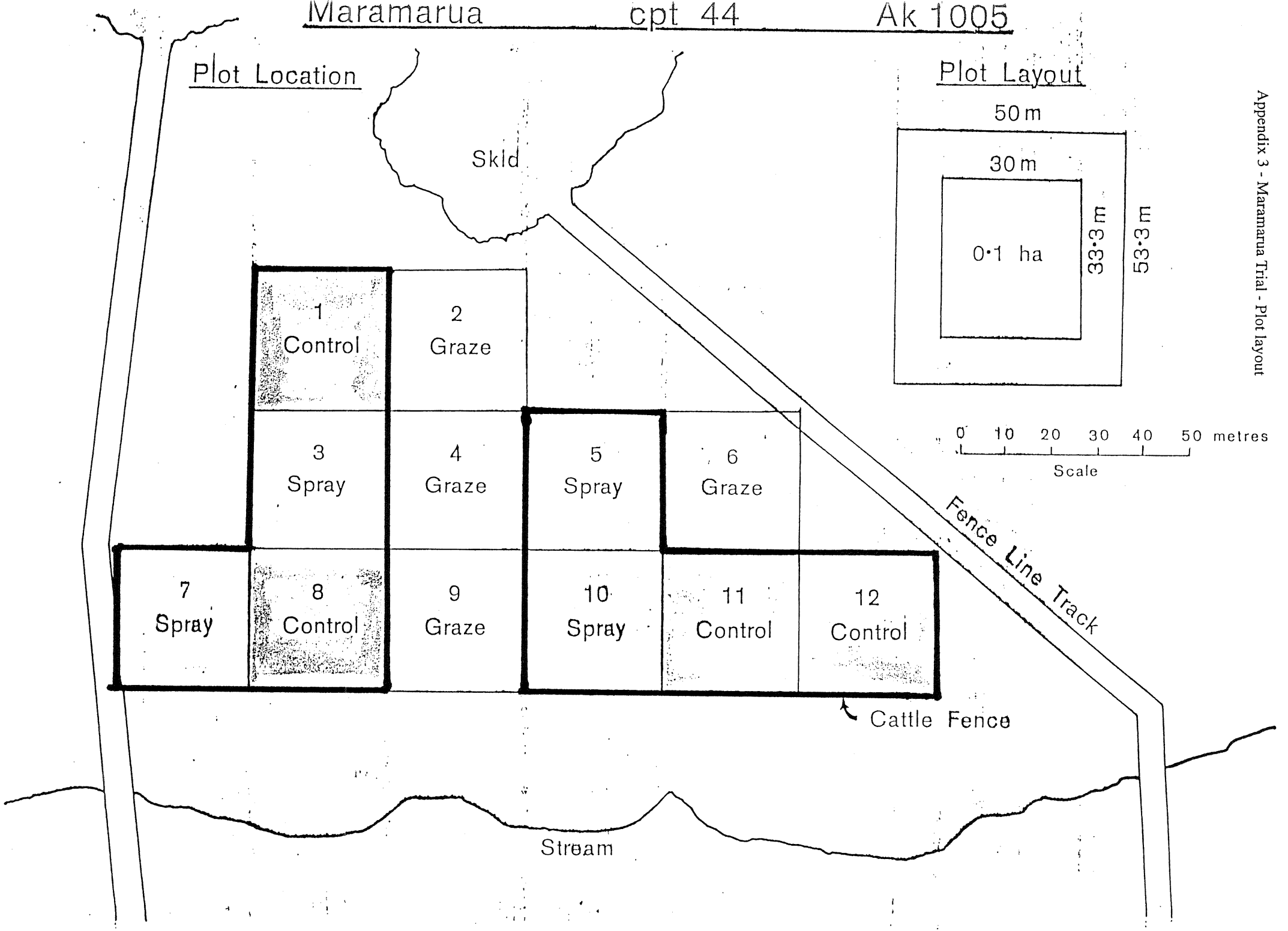
AK1021

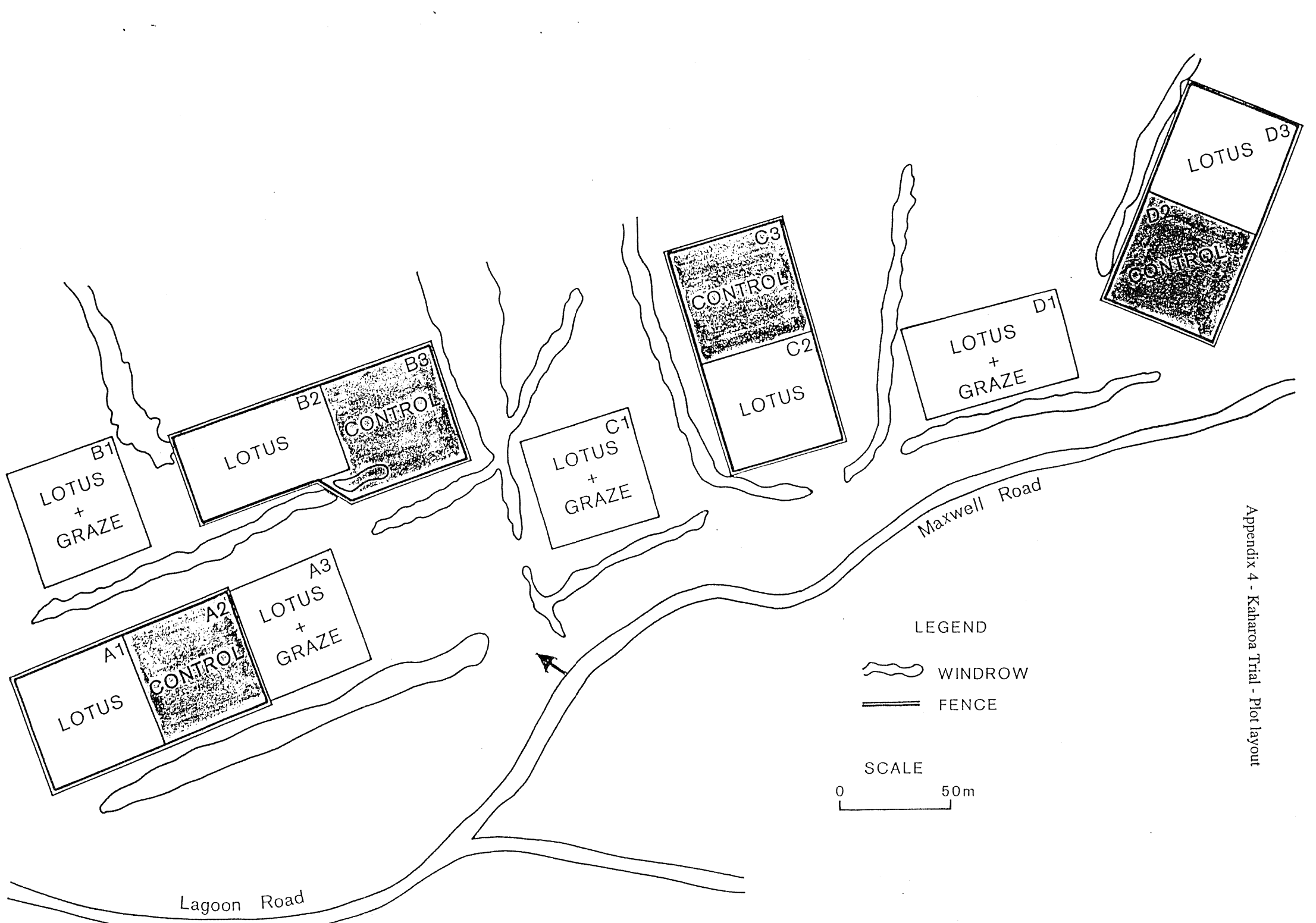
AUPOURI FOREST, CPT 130

Appendix 1 - Aupouri Trial - Plot layout

Appendix 2 - Waiuku Trial - Plot layout

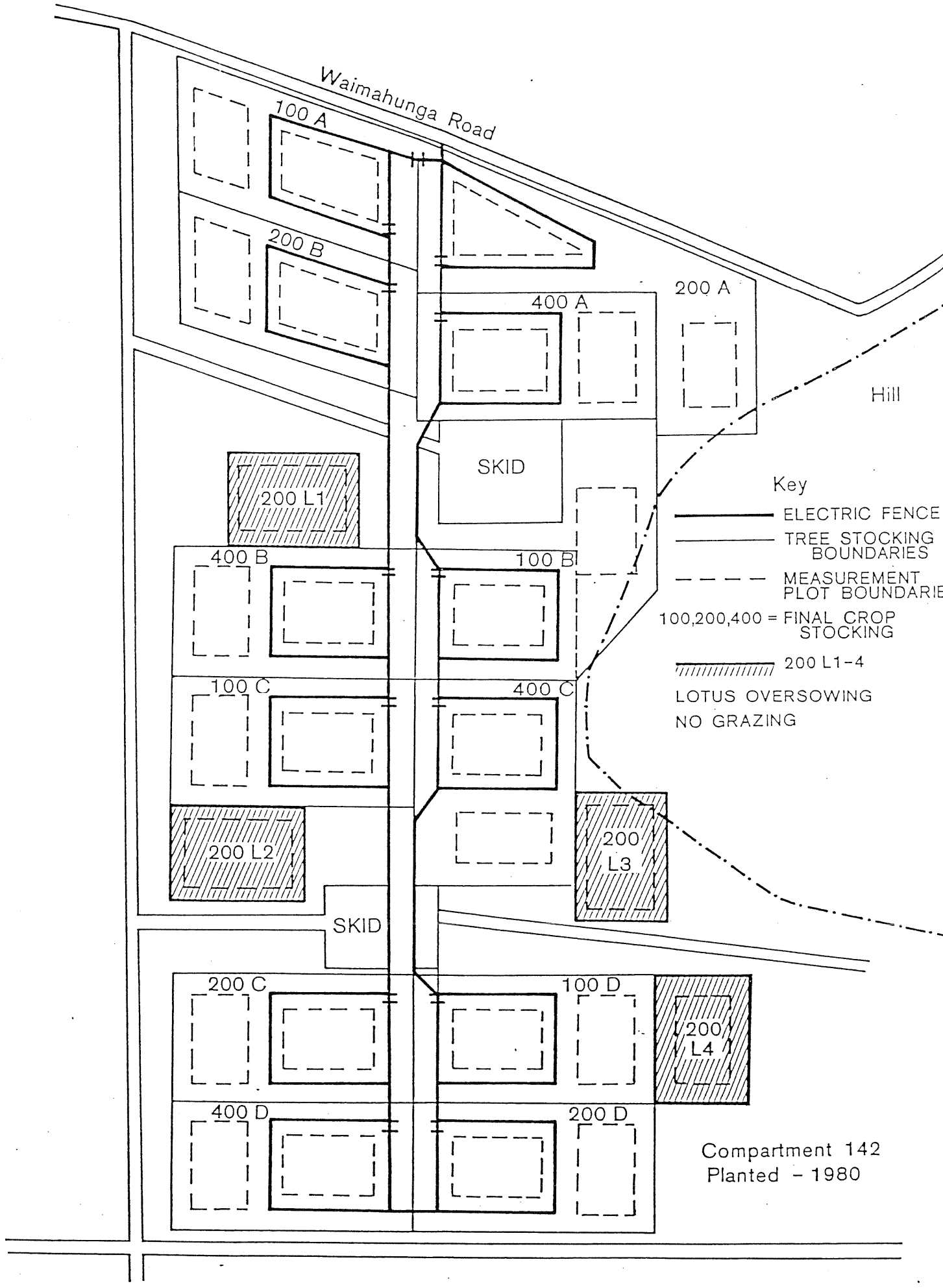



Maramarua cpt 44 Ak 1005
Plot Location
Skid
Plot Layout
50 m
30 m
0·1 ha
33·3 m
53·3 m
0 10 20 30 40 50 metres
Scale
1 Control
2 Graze
3 Spray
4 Graze
5 Spray
6 Graze
7 Spray
8 Control
9 Graze
10 Spray
11 Control
12 Control
Fence Line Track
Cattle Fence
Stream

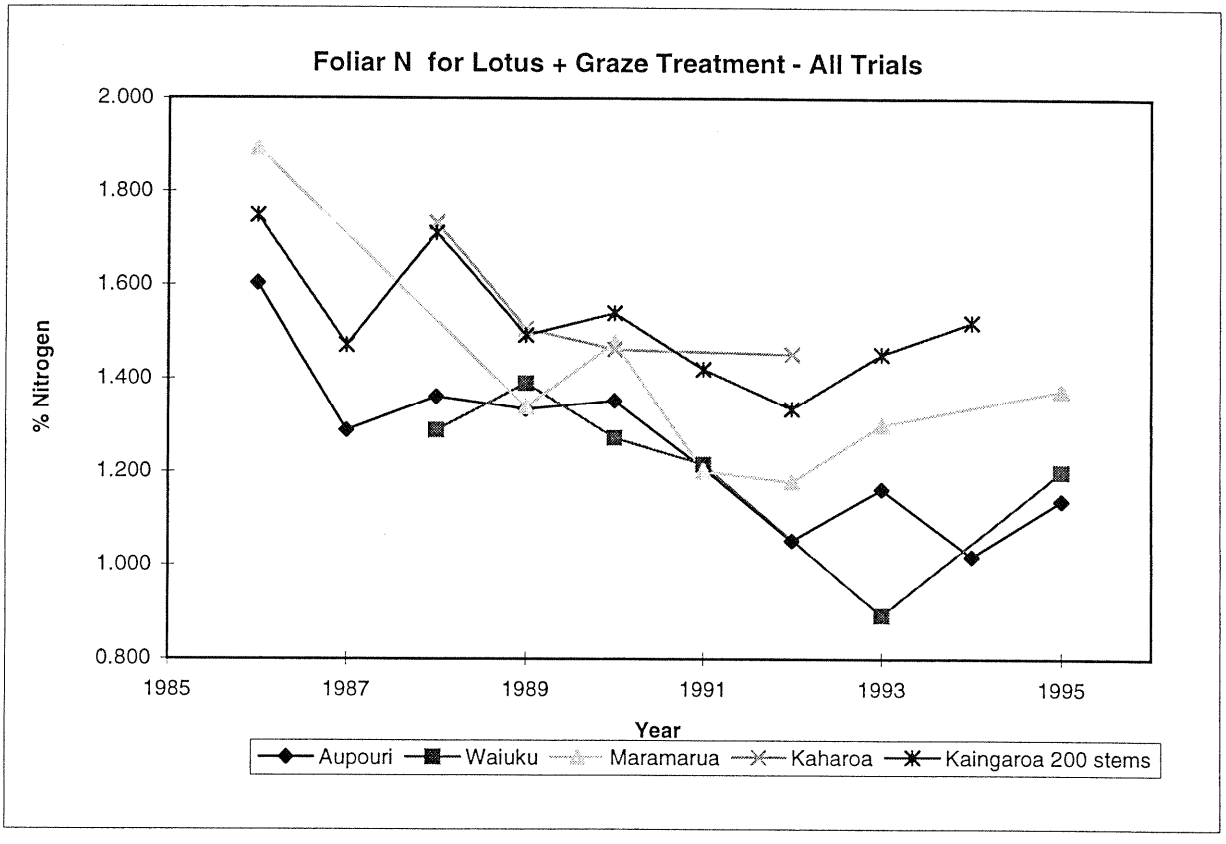


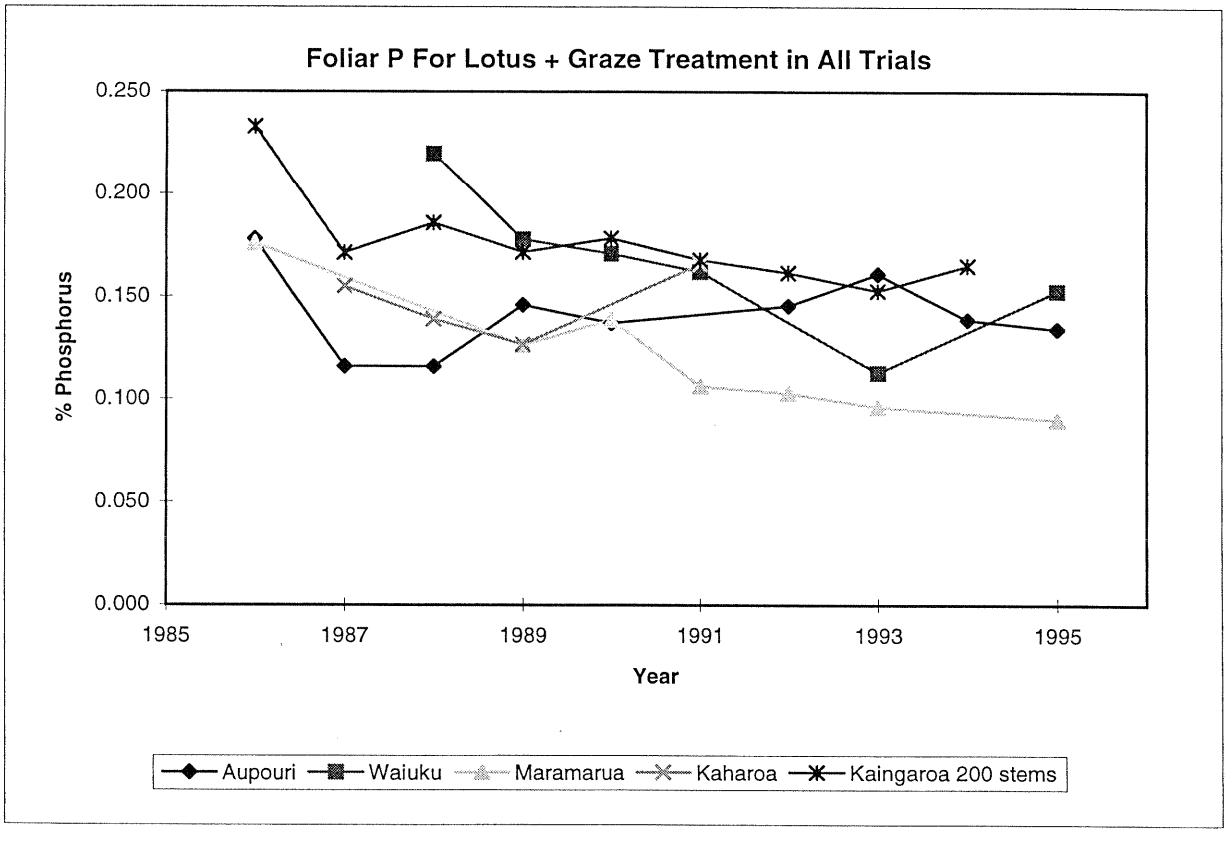
Appendix 4 - Kaharoa Trial - Plot layout

Appendix 5 - Kaingaroa Trial - Plot layout

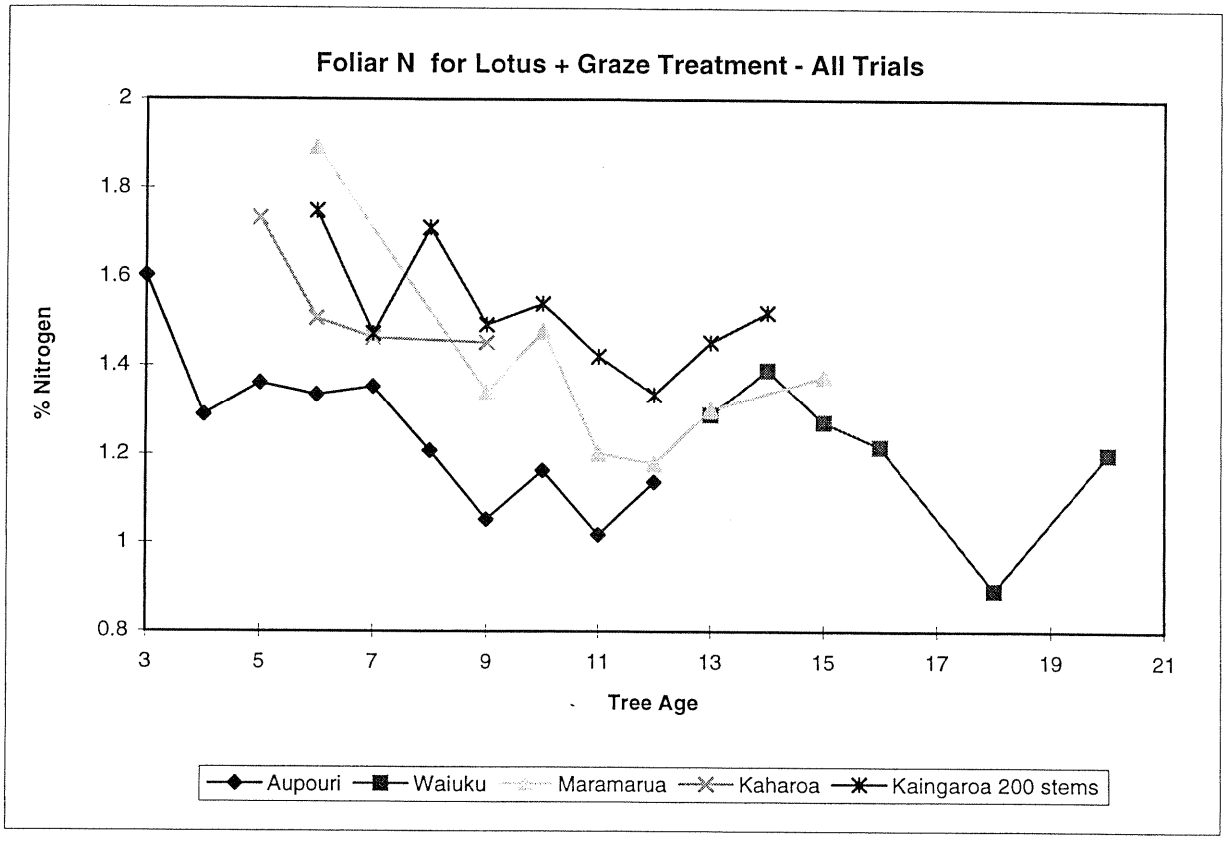


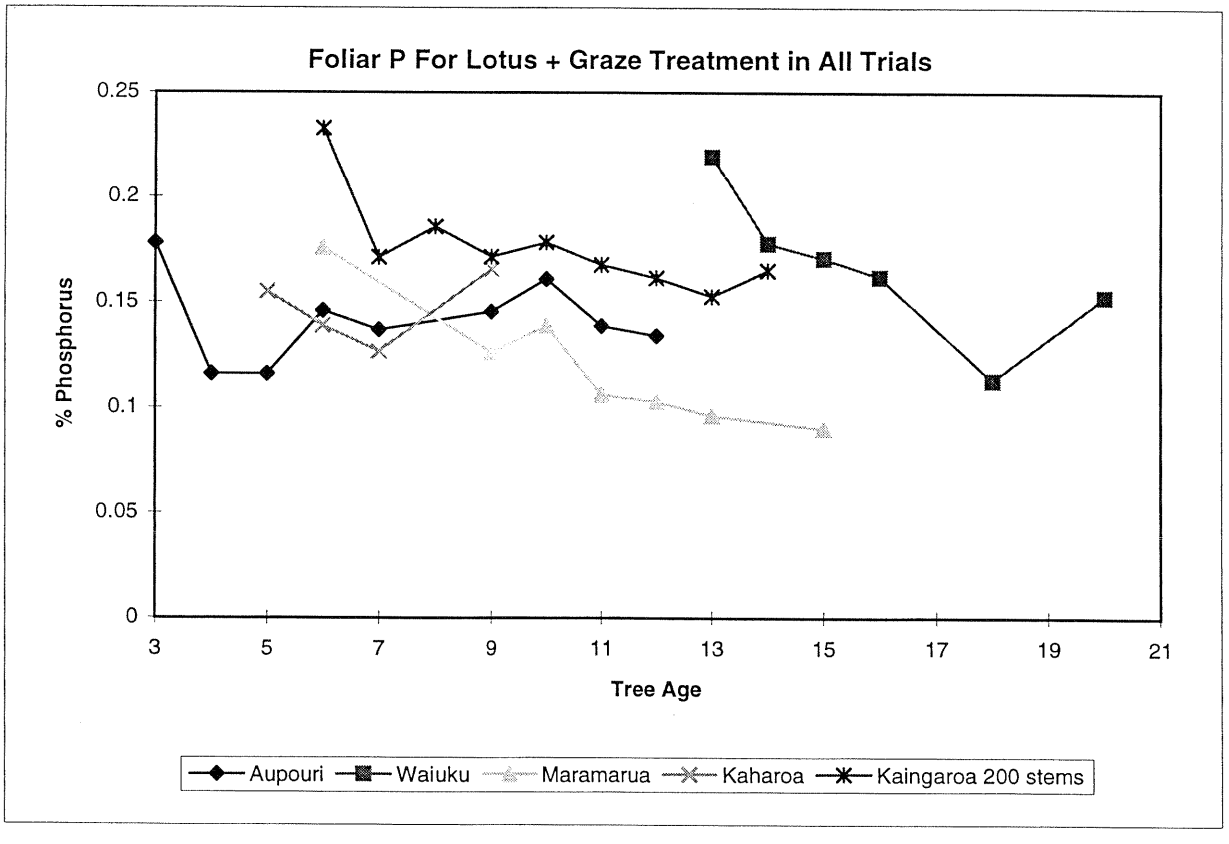
Appendix 6: Foliage analysis of lotus plus grazing treatment at all trials



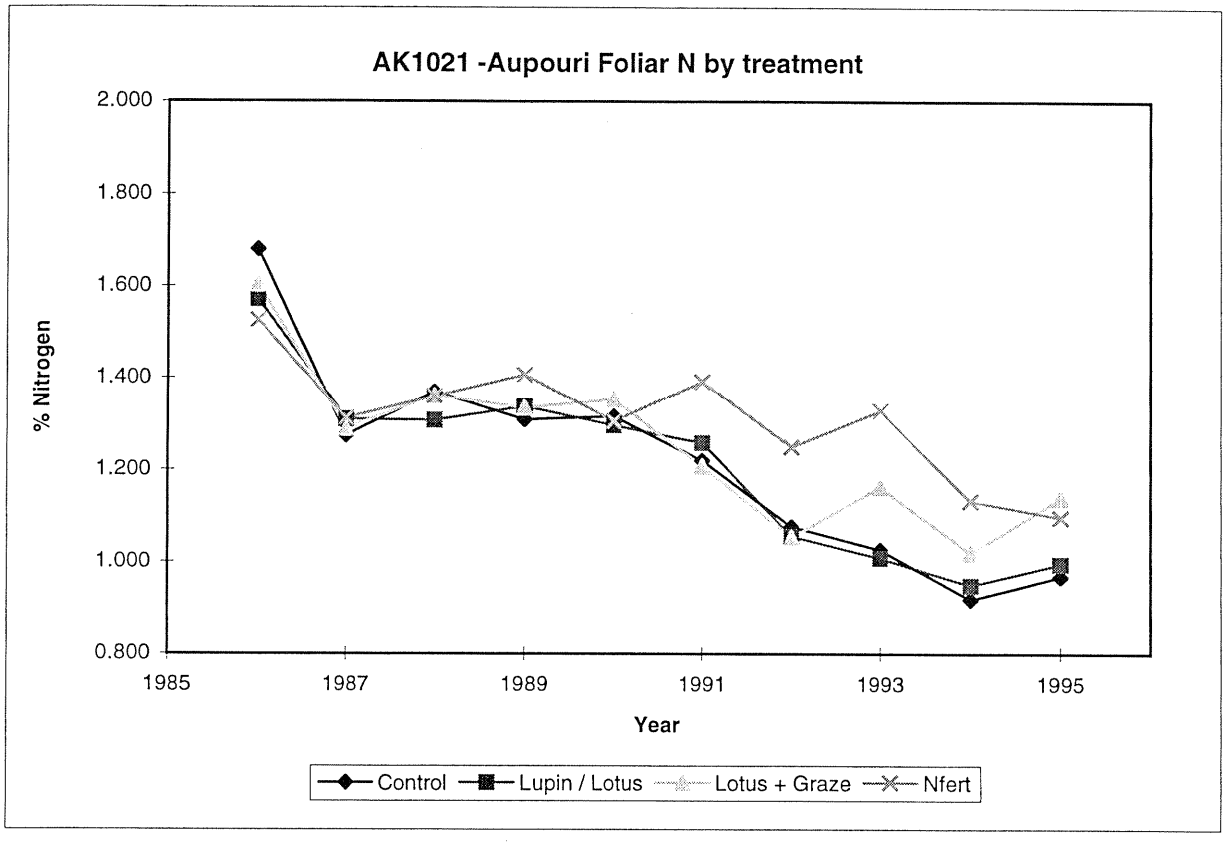


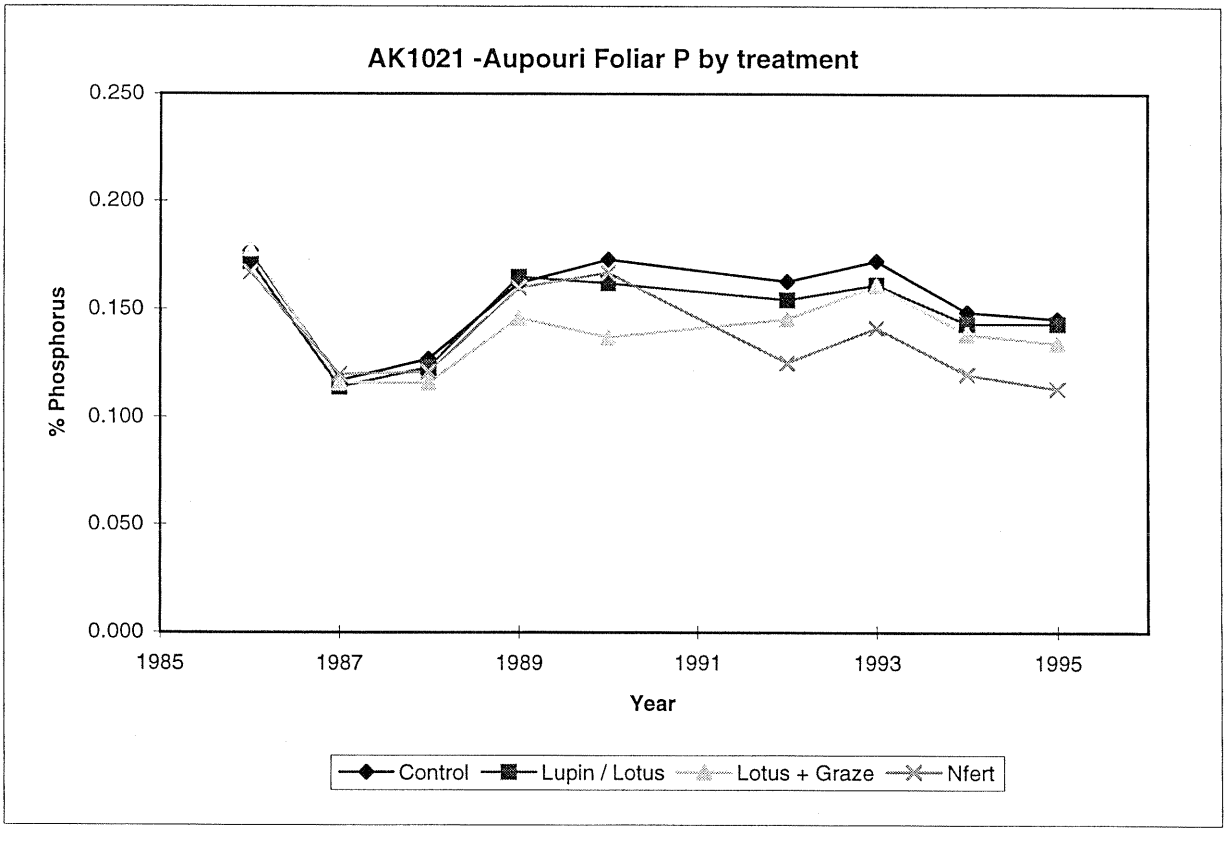
Appendix 7: Foliage analysis of lotus plus grazing treatment against tree age at all trials.



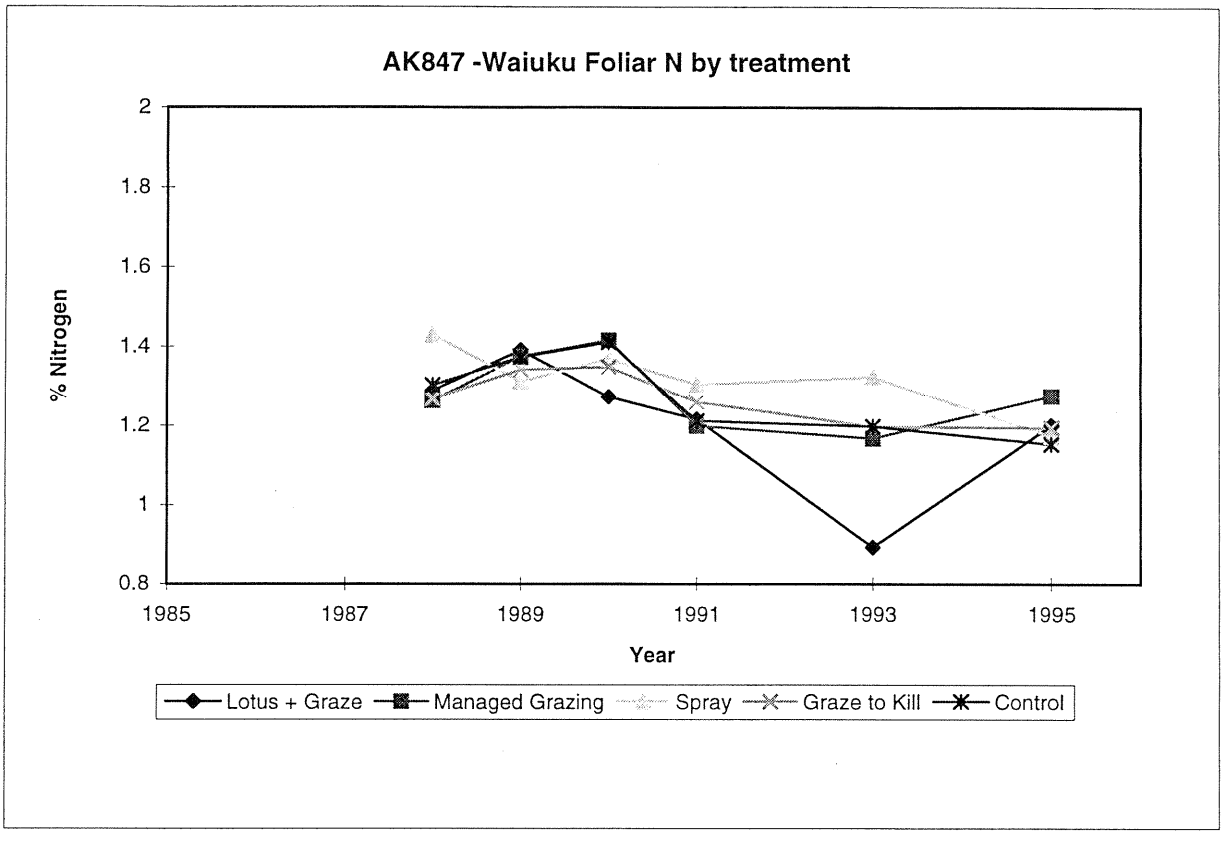


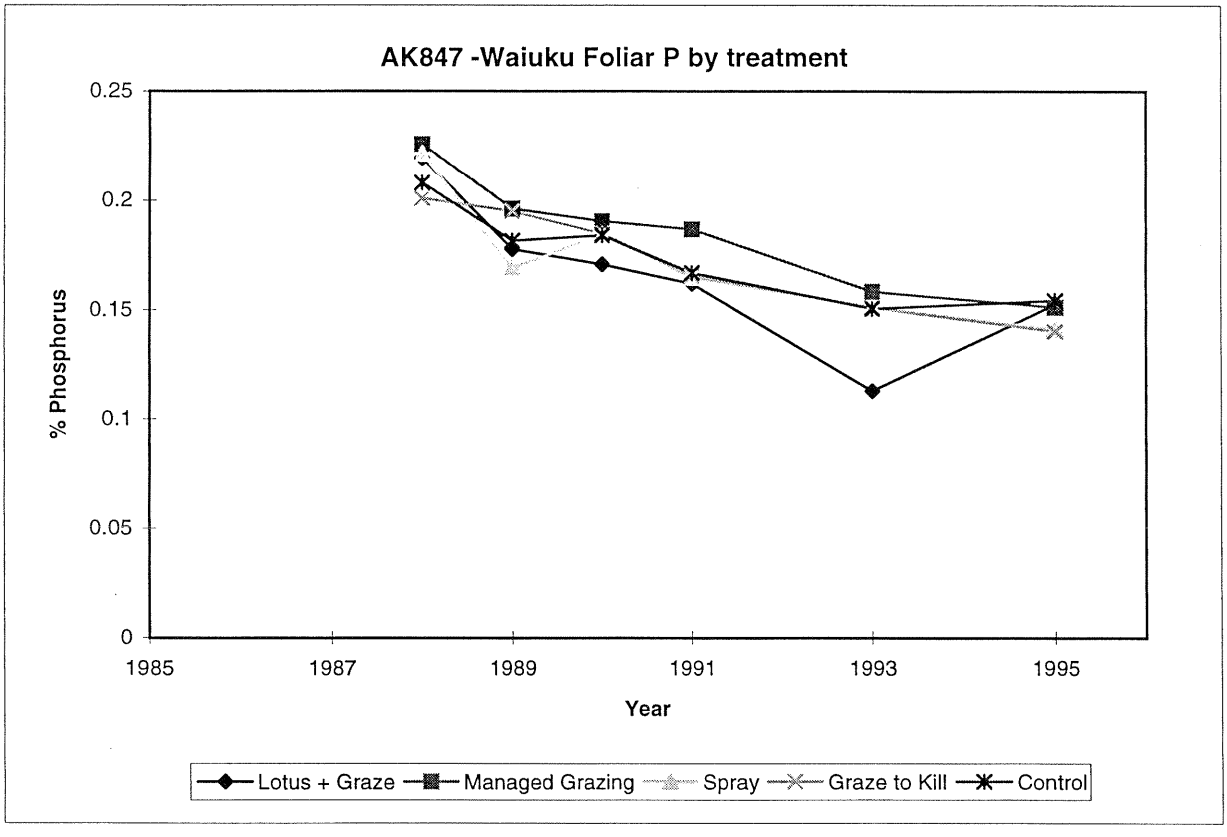
Appendix 8: AK 1021 Foliage Analysis



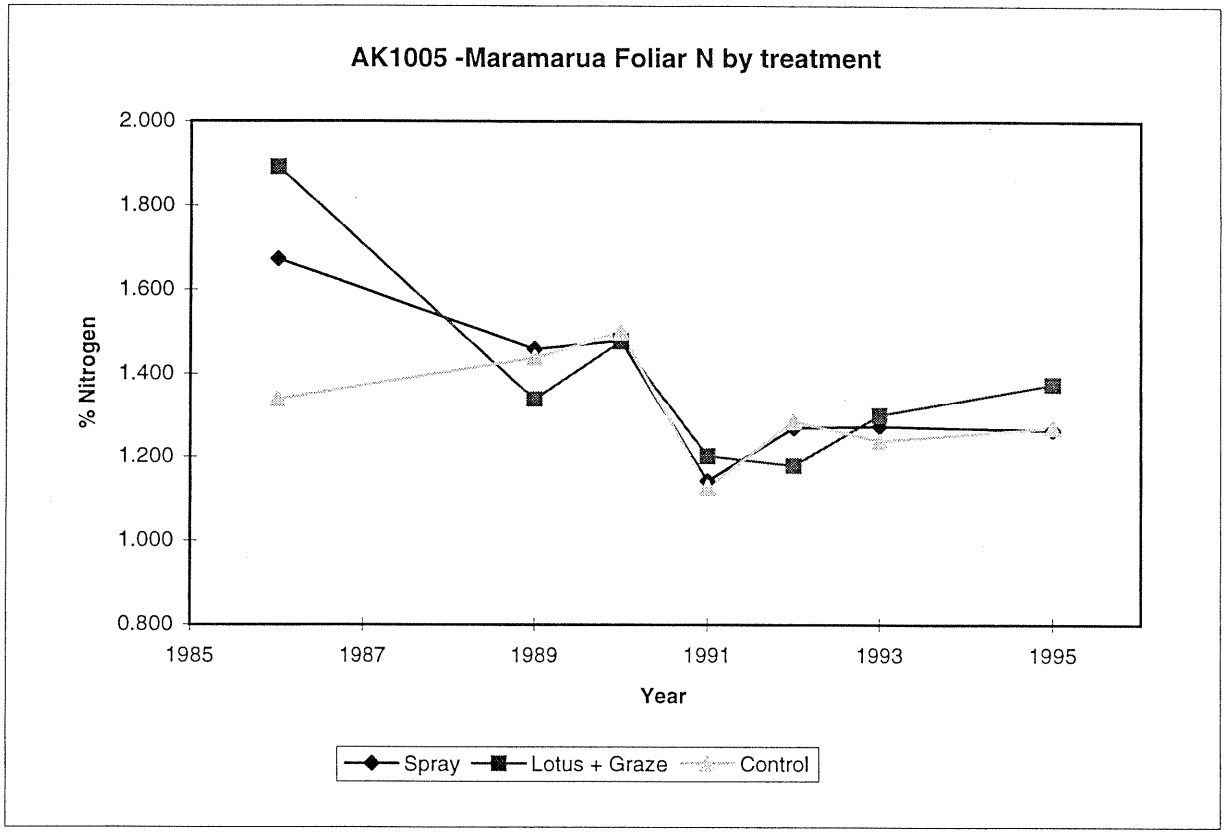


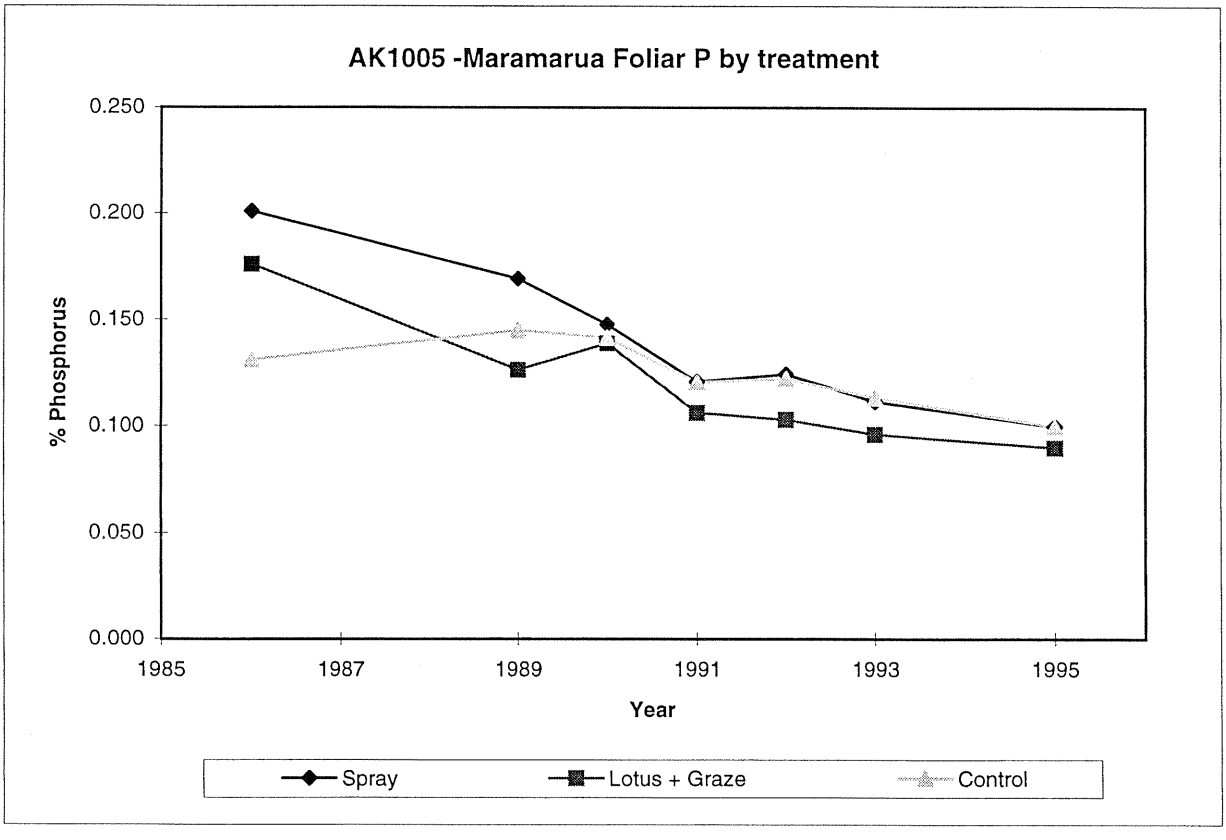
Appendix 9: AK 847 Foliage Analysis





Appendix 10: AK 1005 Foliage Analysis





Appendix 11: RO 2036 Foliage Analysis