A COMPARISON OF THE ENERGY AND FORCE REQUIREMENTS OF PRUNING LOPPERS

P. CROSSLAND

Report No. 40 **April 1997**

FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

EXECUTIVE SUMMARY

A COMPARISON OF THE ENERGY AND FORCE REQUIREMENTS OF PRUNING LOPPERS.

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In New Zealand at least 90 000 hectares of pines are pruned each year. The majority of this is done with pruning loppers. If the efficiency of the pruning process was improved, even by as little as 5%, this would create significant savings to forest managers and forest owners. Currently there is very little scientific information available on the relative performance of pruning loppers.

This project analysed the energy and force requirements for six different types of pruning loppers currently available in New Zealand. The loppers tested were Hit 27 loppers, Haumi Big loppers, Haumi Small loppers, Lane Pruners, Wiringi Pruners and Pruneoff loppers.

The loppers were tested on branches collected from a six year old Pinus radiata stand in a universal testing machine. At least 80 tests were made for each set of loppers on a range of different sized branches. There were also tests performed on Douglas fir branches to verify the results from the pine branches.

The study found that there are some significant differences in the energy and force requirements between the different loppers. An example of these differences is shown below. All the values given below relate to cutting a Pinus radiata branch of approximately 50 mm in diameter. However, similar trends in force and energy are apparent regardless of the branch diameter.

Lopper Type	*Energy (Joules)*	*Peak Force (Newtons)*
Haumi Lopper	165	5520
Haumi Pruner	175	6710
Lane Pruners	180	5840
Wiringi	200	7905
Hit 27	220	6620
Pruneoff	235	8015

This project also highlighted some areas of lopper design which require further research. Areas of further research could include the effect of different blade angles, different blade shapes, and pruning technique.

The results show that there are differences between the force and energy requirements of the loppers. By careful selection of the correct pruning loppers the efficiency of the pruning process will be improved.

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Acknowledgments

First I would like to thank my supervisor, Graeme Martin, his help and discussion has been invaluable to the success of this project. I would like to thank The Forest and Farm Plantation Management Cooperative and Mr Mark Dean of the FRI for the initial idea, arranging the supply of pruning tools and financial support. I would like to thank my parents for allowing me to get the branches used for testing from their farm and my father for his help in testing.

The contribution of the following manufacturers/importers through the loan of pruning tools is gratefully acknowledged;

Levin Sawmakers LTD	Pruneoff Lopper
Haumi Traders LTD	Haumi Lopper, Haumi Pruner
Dave Lane	Lane Pruners
Central Saws LTD/Rick Wiringi	Wiringi Pruner
Leighton Hill Co. LTD	Hit 27 Pruner

I would also like to thank Glen Murphy for his help with the Douglas fir tests and the statistical analysis.

1.0 Introduction

In New Zealand at least 90 000 hectares of radiata pine are pruned each year. If the efficiency of pruning was improved this would create significant savings to forest managers and forest owners. Currently the majority of pruning in New Zealand is done with pruning loppers. Pruning loppers remove branches by shearing them off, close to the stem. Frequently contractors modify their own loppers and claim they are much better than loppers direct from the shop. There is very little information available on the relative performance of pruning loppers - particularly with respect to the force and energy requirements.

1.1 Objective

The objective of this project is to compare the energy requirements for some of the pruning loppers currently available in New Zealand, and to attempt to explain why there are differences between the various types.

1.2 Loppers Tested

Six types of loppers were tested and these are shown in Figure 1.2.1.

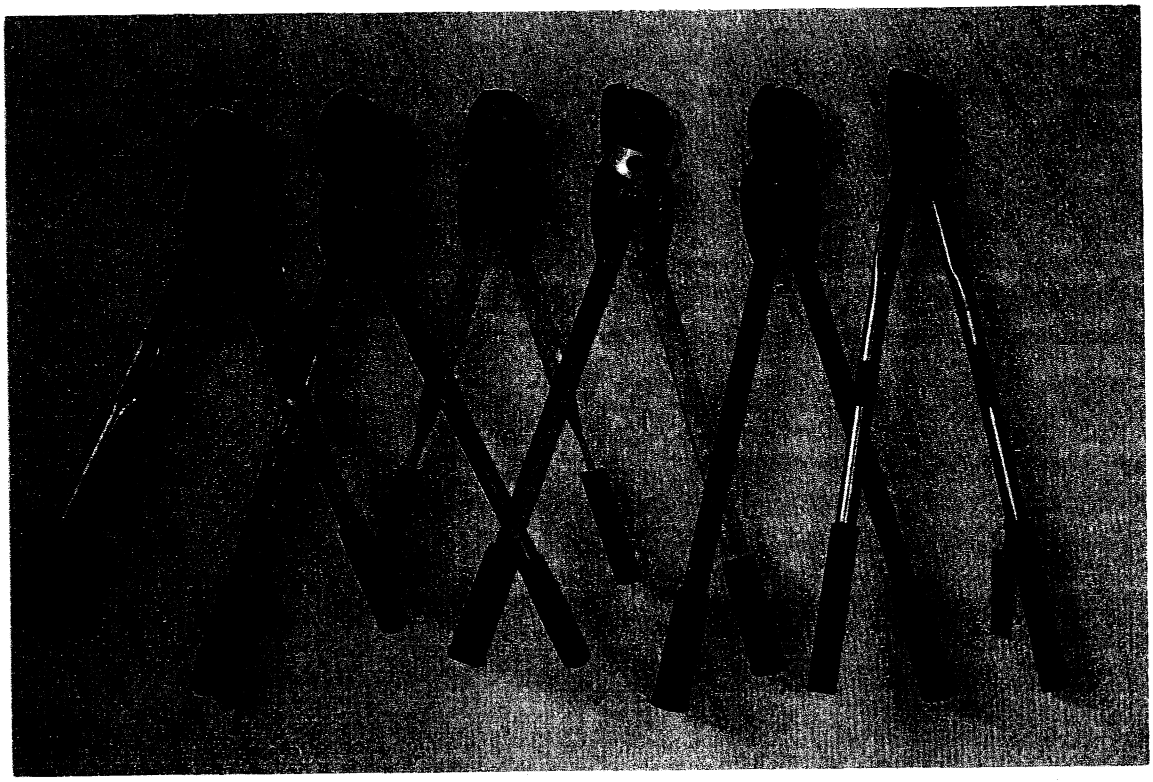


Figure 1.2.1. The pruning loppers analysed in this study. They are from left Haumi Pruner, Haumi Loppers, Lane Pruners, Pruneoff Loppers, Hit 27 loppers and Wiringi pruners.

The loppers have been named according to the information received about them. The Pruneoff loppers, Hit 27 loppers and the Wiringi pruners are called by their correct commercial names. The Haumi Lopper and Haumi Pruner were received from Haumi Traders Limited, Gisborne. The Lane pruners are designed by Dave Lane. There may be other commercial names for the Lane pruners.

The tools were all new and as such were not sharpened or modified in anyway. The tools were June 1996 models. At least one manufacturer, Levin Sawmakers Ltd, has subsequently released a modified design.
The loppers tested were chosen and made available by The New Zealand Forest Research Institute, Rotorua. They were selected as they cover the range of tools commonly used for pruning in the New Zealand forest industry.

A summary of the characteristics of the loppers can be found in appendix 2.

1.3 Literature Review

Extensive library searches and discussions with FRI representatives found that very little research has been done in the field of pruning loppers. The information that follows is a summary of the research material found.

One study compared the force requirements of unmodified and modified Hit 27 pruners, unmodified and modified Pruneoff pruners, Porter pruners and Wolf pruners [1]. This study was carried out in 1986 by Peter Hall and Euan Mason, both of FRI. They tested the various pruners on three different sizes of dowel and recorded the peak force required to cut the dowel. Each set of pruners performed 20 cuts at each of the dowel sizes. Their study found that 'careful grinding of the pruner heads reduced the thickness of the blade and markedly increased cutting efficiency.' They found that the modified Hit pruners performed best of all the pruners they tested.

Another similar study by Dick Everts, also of FRI, tested the six most common loppers used in New Zealand in 1984 [2]. They were the Wolf pruners, Long Porter pruners, Short Porter pruners, Hit pruners, Wilkinson pruners and Point Cut pruners. These were tested on both pine branches and dowel, however only twelve cuts were made in total with each set of pruners. This study also measured peak force. This study found the Wolf and Long Porter pruners required the lowest forces.

A study on Radiata Branch Characteristics and Delimbing Forces [3] was done by A.P. Gleason and J.A. Stulen of LIRA, in 1985. This study determined the forces involved in using a static delimber and removing a complete whorl of branches at one time. Another report on The Force and Work to Shear Green Southern Pine Logs at Slow Speed [4] investigated the force requirements of shearing through complete logs with a mechanised felling head. Neither of these reports had much relevance to this study but they gave an insight to testing procedures. The conclusions were also interesting as their studies were related to shearing wood with steel knives/blades.

1.4 Background

Before conclusions can be made about the energy requirements involved in shearing a branch, the actual forces involved in the shearing process should be determined. These are shown in figure 1.4.1.

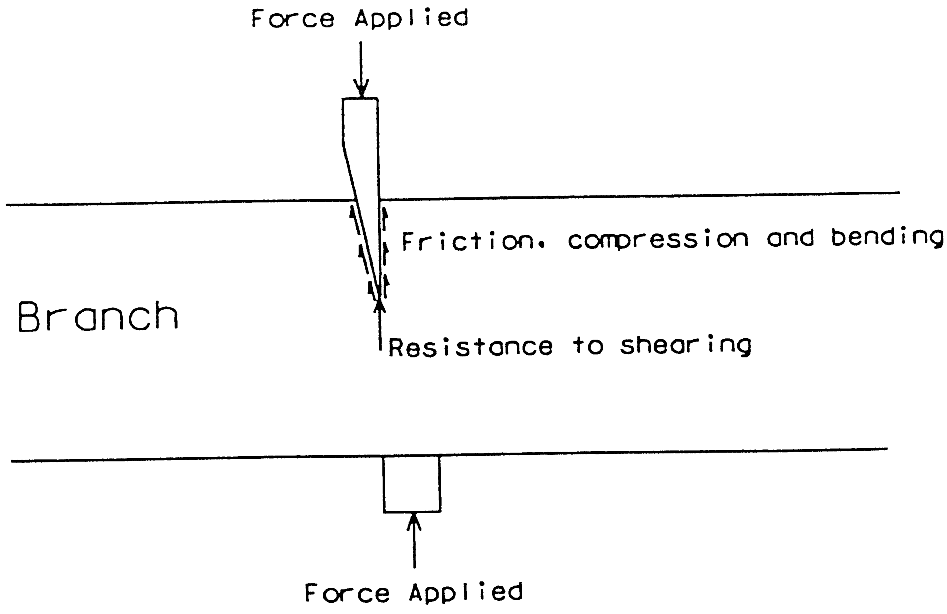


Figure 1.4.1. The forces involved in the shearing process

The force applied is supplied by the user through the handles of the loppers.

The resistance to shearing force comes from the wood. It is dependent on the wood properties and it is the force required to shear the wood cells. This force is also dependent on the shearing edge, as a sharper edge will shear through material easier than a blunt edge.

The friction, bending and compression force results from the cutting blade moving through the wood. The friction component is due to the friction between the branch and the cutting head. The bending and compression forces result from the resistance when the angled blade is forced into the branch causing the branch to either bend or the wood to compress. It would be expected that these forces will increase as the angle of the cutting blade increases and as the roughness of the blade increases. These forces and how they vary with blade angle are shown in figure 1.4.2, below.

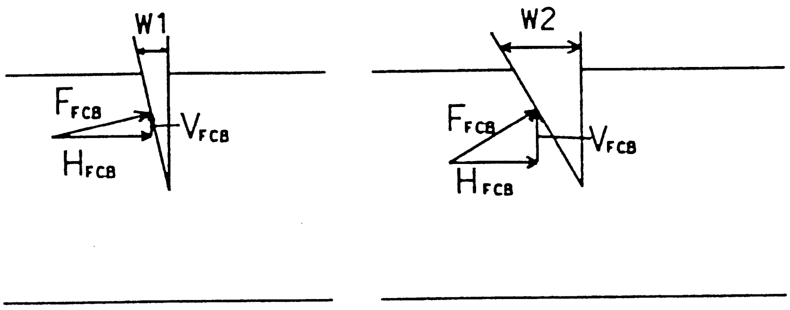


Figure 1.4.2. Friction, bending and compression forces

Figure 1.4.2 shows that the vertical component of the friction, bending and compression forces, V_{FCB}, increases as the blade angle increases. As the vertical component increases so does the force required to continue shearing the branch, therefore it is harder to shear a branch with a large blade angle.

2.0 Testing Procedure

The loppers were tested on branches collected from a 6 year old stand of Pinus radiata, in a computer controlled universal testing machine at Lincoln University. This test rig has a capacity of 130 kN and is two years old. Two sets of loppers were also tested on Douglas fir branches to compare the results found with the pine branches.

The test rig applied and recorded the forces required to cut through the entire branch. The area of the cut was then determined using a planimeter. The total energy and peak force were measured for every cut made.

For testing to proceed the head of the loppers was removed from the handles. The head was then placed in specially made grips which fastened the loppers to the testing machine (see figure 2.0.1).

The testing machine was set up with a program that closed the loppers at a rate of 400 mm per minute. This program recorded the total energy required to cut the branch, the peak force exerted in cutting the branch and it gave a graphical representation of the force exerted against the vertical displacement of the loppers. The loppers were opened and a branch placed in the jaws. The test was started and the test rig closed the loppers calculating the energy and peak force, refer figure 2.0.1. The cut sample was then numbered. More than one cut was made on each branch. The cuts were spaced at least 50 mm apart along the branch. Each branch had tests taken from it by at least two sets of loppers and no one set of loppers took more than four tests from one particular branch. The branches were used in this way to minimise the effect of non-uniform properties unique to one particular branch and to lessen the number of branches required for testing.

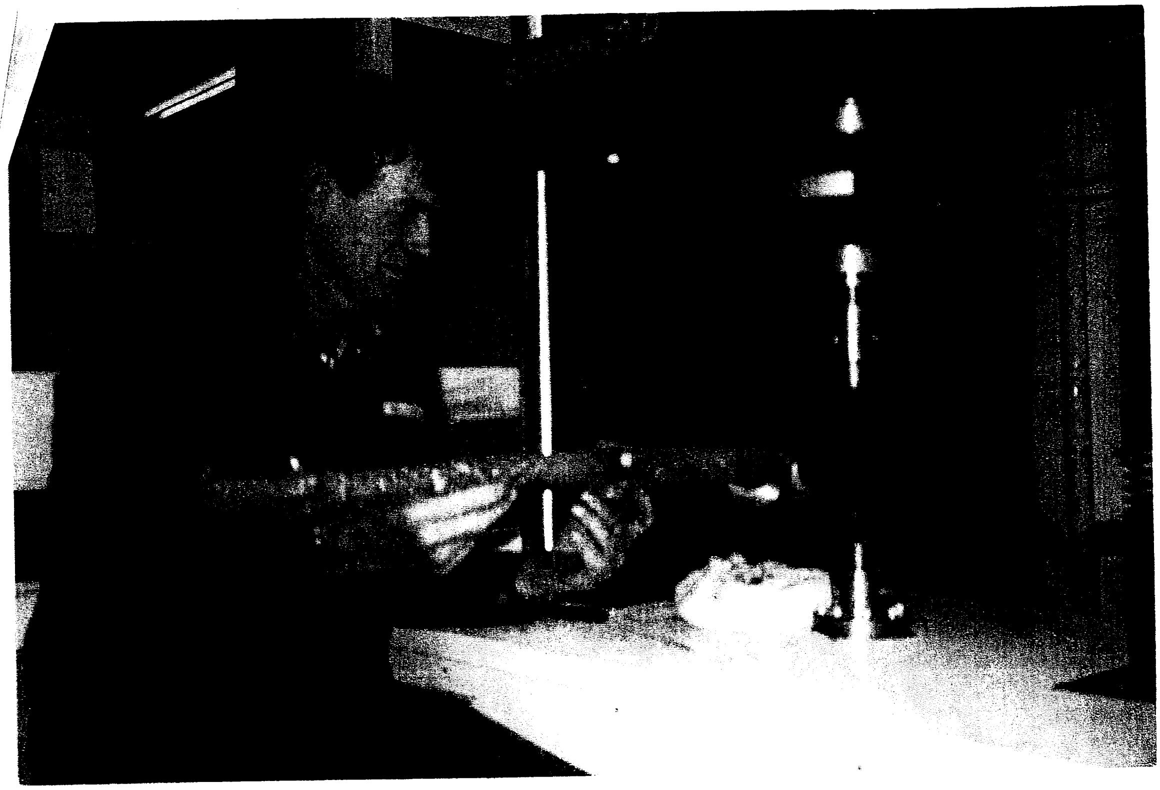


Figure 2.0.1. A test in progress showing the test rig with the loppers attached

Each sample had its area, including bark, calculated twice with a planimeter and the average was taken as the area for the sample, refer figure 2.0.2.

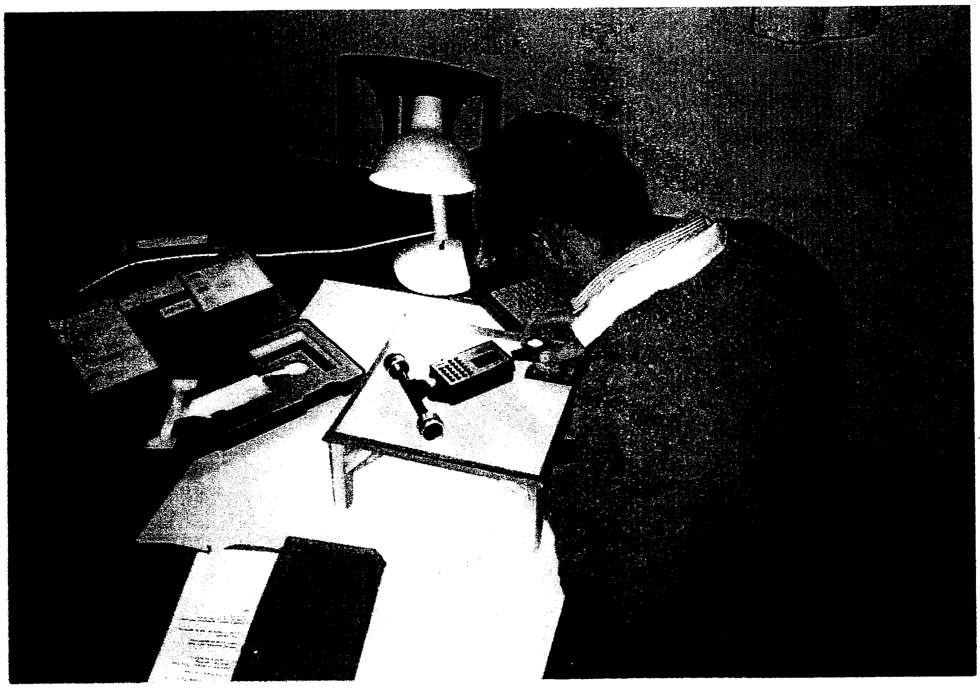


Figure 2.0.2. The author measuring the area using a planimeter.

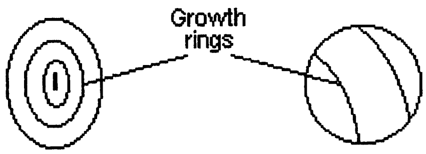
The total energy in Joules, the peak force in Newton's and the area in cm^2 were recorded and then analysed in an Excel spreadsheet.

2.1 The Use of Branches Versus Dowel

Much of the previous research done in this field tested the loppers on water saturated dowel. The reason previous researchers used dowel was to get a constant diameter between tests. They then related the peak force to the diameter.

For this study branches were used instead of dowel. The reasons why are listed below:

- Branches have different properties to dowel as dowel is made from stem wood and branches have different properties to stemwood. Therefore using branches gives the correct representation of properties.
- With branches the full cross-section of growth rings is being cut, rather than a partial cross-section as for dowel.



Branch Dowel

Figure 2.1.1. The cross-section of a branch compared to dowel

- With branches the full gradient of densities that can occur in a branch are being cut. Dowel does not have an equivalent density gradient as it is from stem wood and only contains partial growth rings.
- Different pieces of dowel have different properties. The properties of an individual piece of dowel depends on which part of the stem the piece comes from and these properties are not constant between pieces.
- Using branches incorporates the effect of bark.

- Freshly cut branches have the correct moisture distribution, which may not be so for dowel soaked in water.
- This study compared energy to cut area therefore a constant diameter was not required. However, a continuous range of areas was required which could be achieved with branches.

2.2 Branch Density

Originally it was thought that branch density could be related to the energy required to cut the branch. Discussions with Dr. John Walker, a wood properties expert at the School of Forestry, Canterbury University, revealed that little is known about how the density varies within a branch. This is because up until now most research has concentrated on stem wood, not branches. It is, however, generally accepted that the density does vary throughout the cross-section of the branch due to the formation of compression wood on the underside of the branch. The amount of variation is not known but it is considered to be significant. As a result the density was not included in this study. The density gradient was assumed to be consistent for all the branches tested, as all the branches were obtained from the same area.

2.3 Preliminary Tests

As very little work was found to have been done on this topic, the variability of the results was unknown. This gave great trouble in planning the project as it was unknown if the tests would be repeatable due to the natural variability of wood, how accurate the area determination needed to be or how many samples to test for each set of loppers. In short, due to the lack of information available there was not a starting point to base this study on.

To overcome these problems a sample of branches was tested to give an indication of what to expect. Approximately 40 samples were tested using the Hit 27 loppers. These tests presented an opportunity to refine and finalise the testing procedure and to gain familiarity with the test rig and its associated "Testworks" computer program.

For the preliminary tests the area was determined in three different ways:-

1. The circumference was measured and the area calculated.
2. The largest and the smallest diameters were measured with vernier callipers, these were averaged and the area calculated.
3. A planimeter was used. The edge of the cut was traced around twice and the average taken. This value was taken as the correct area for the sample.

The total energy versus the area were then plotted. From these results a very good correlation was obtained. From the variability in the energy results the accuracy required in measuring the area of each sample could be determined. The variability between the three methods of area determination was surprisingly high, hence the planimeter method was chosen as it is the most accurate.

From the plot of total energy verse planimeter area the required sample size was calculated [8]. It was decided that the required sample size was to be at least 75.

For the preliminary tests the orientation of the branches in the loppers was random. From the close correlation obtained from the results it was assumed that the orientation of the branches in the loppers had no effect on the total energy required to cut the branch. This assumption has been further supported by the rest of the results.

2.4 Branches Used for the Testing

The branches used for testing were obtained from 6 year old Pinus radiata which were planted in a three row shelterbelt in Canterbury. Two rows of Pinus radiata and one row of alternating Cedrus deodara and Eucalyptus nicholii, refer figure 2.4.1. They are planted in a Wakanui silt loam. The branches were selected to provide a range of areas and they were tested the day after they were cut off the trees. Two sets of loppers were usually tested each day and approximately 4 tests would be taken from each branch for each set of loppers tested. This meant that the branches used were common for at least two sets of loppers.

Figure 2.4.1. The shelterbelt from which the branches were obtained.

The Douglas fir branches were obtained from the top six metres from some mature trees in North Canterbury. They were taken from the top six metres to try to represent the age of branches at pruning time.

3.0 Results

Note : The results presented have the branch size represented by the diameter. This was achieved by converting the area of the cut to the diameter of the cut assuming the branch was circular. This conversion was done as it is easier to visualise the size of a branch quantified by diameter than the size of a branch quantified by area.

3.1 Pinus radiata Results

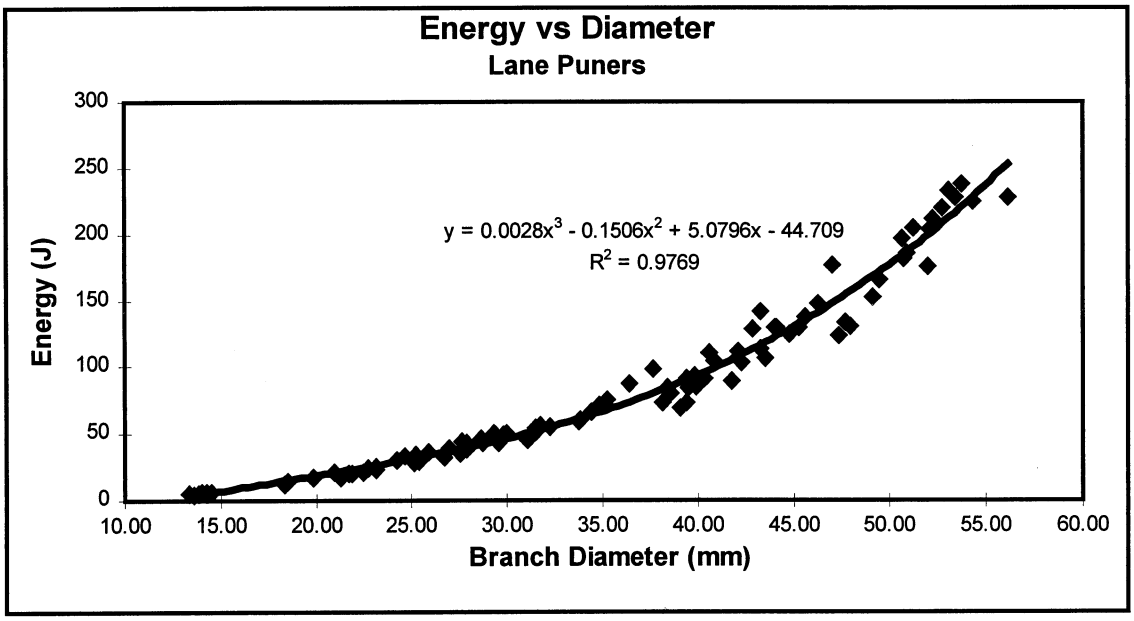


Figure 3.1.1. Typical Energy verse Diameter Graph

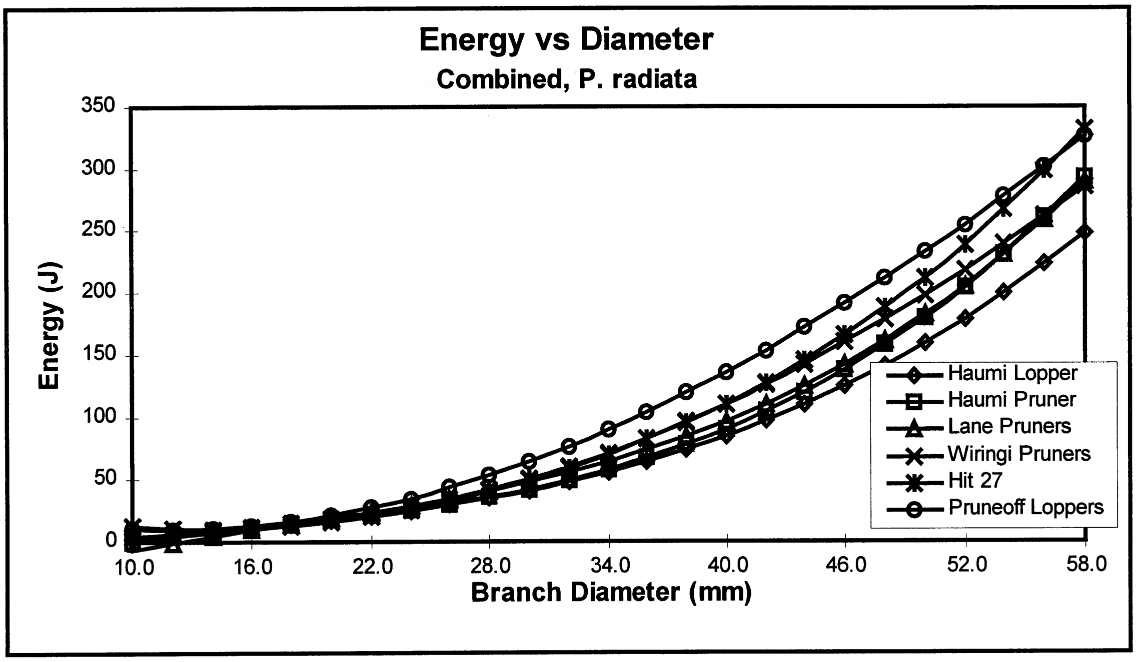


Figure 3.1.2. Energy verse Diameter graph for all loppers

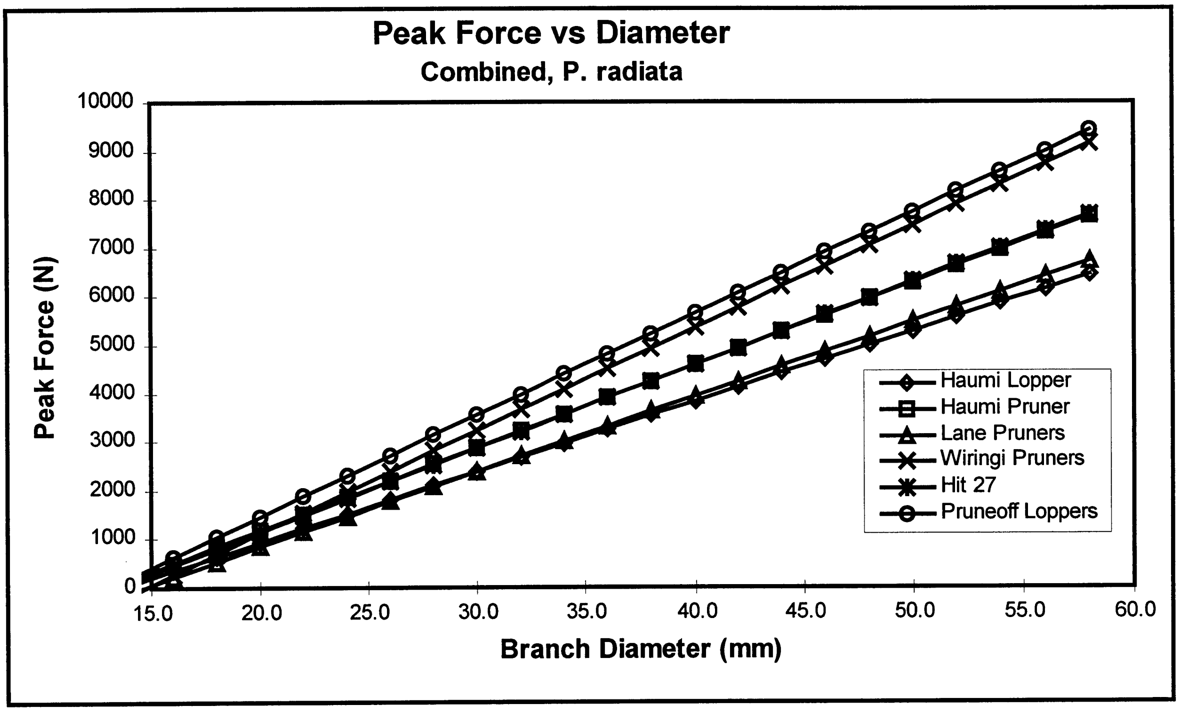


Figure 3.1.3. Peak force verse Diameter graph for all loppers

3.2 Douglas fir results

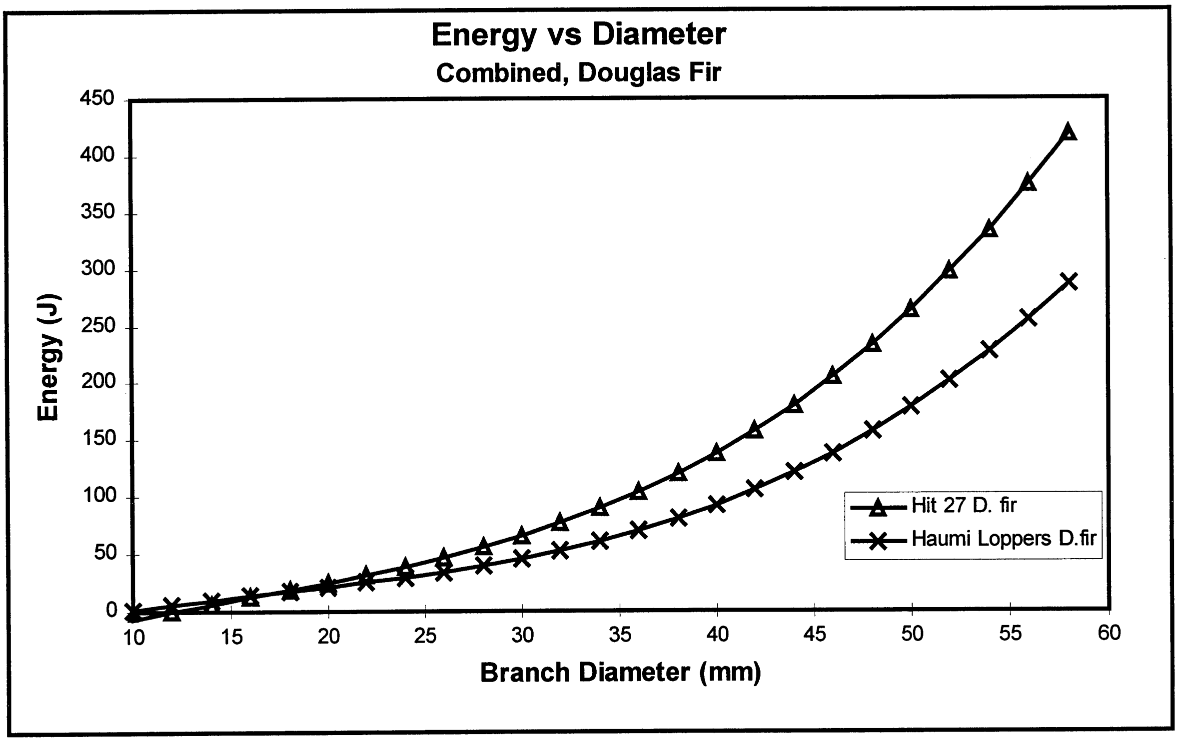


Figure 3.2.1. Energy verse Diameter graph

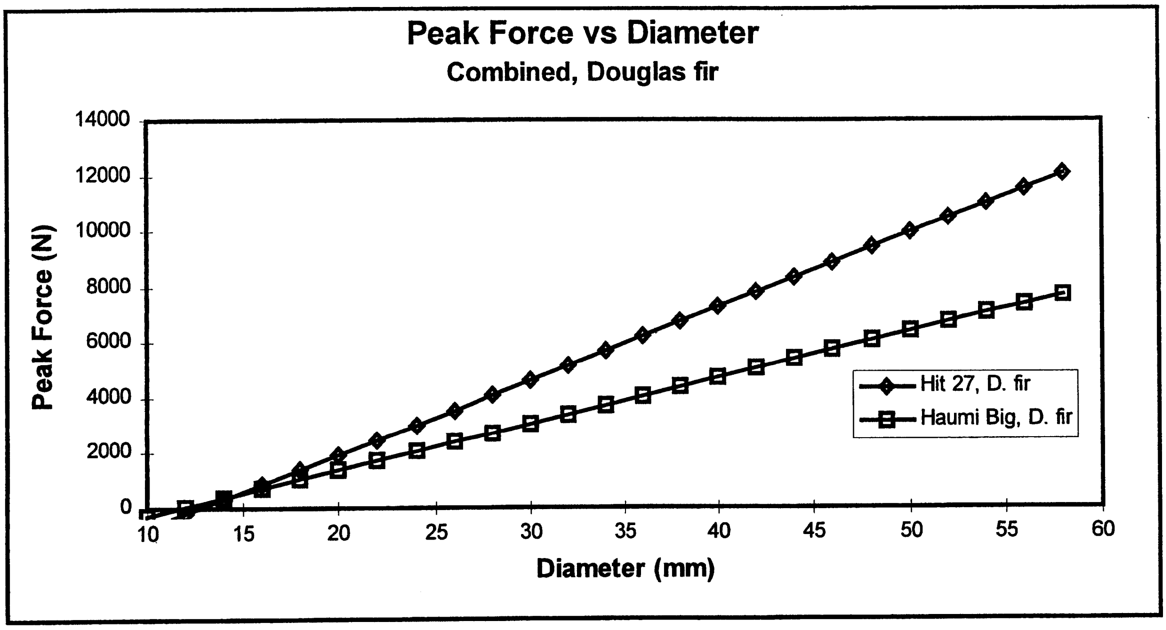


Figure 3.2.2. Peak force verse Diameter graph

3.3 Profiles of the cutting blades

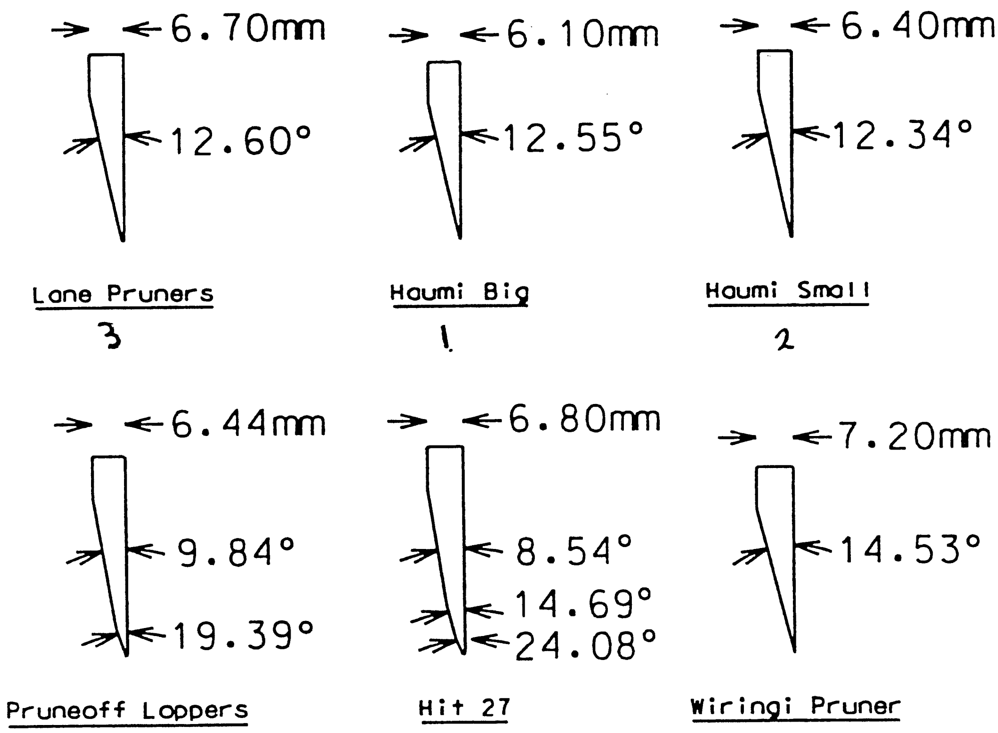


Figure 3.3.1. Profile of the cutting blades

3.4 Comparison of Douglas fir and Pinus radiata results

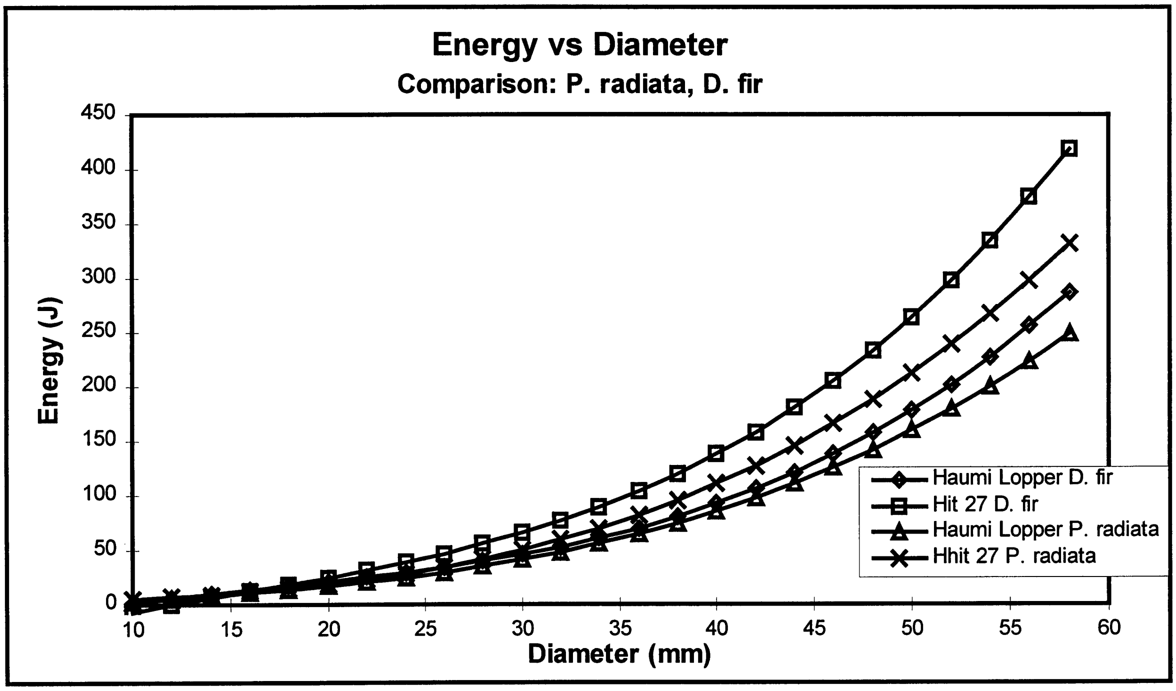


Figure 3.4.1. Comparison of energy requirements between Pinus radiata and Douglas fir

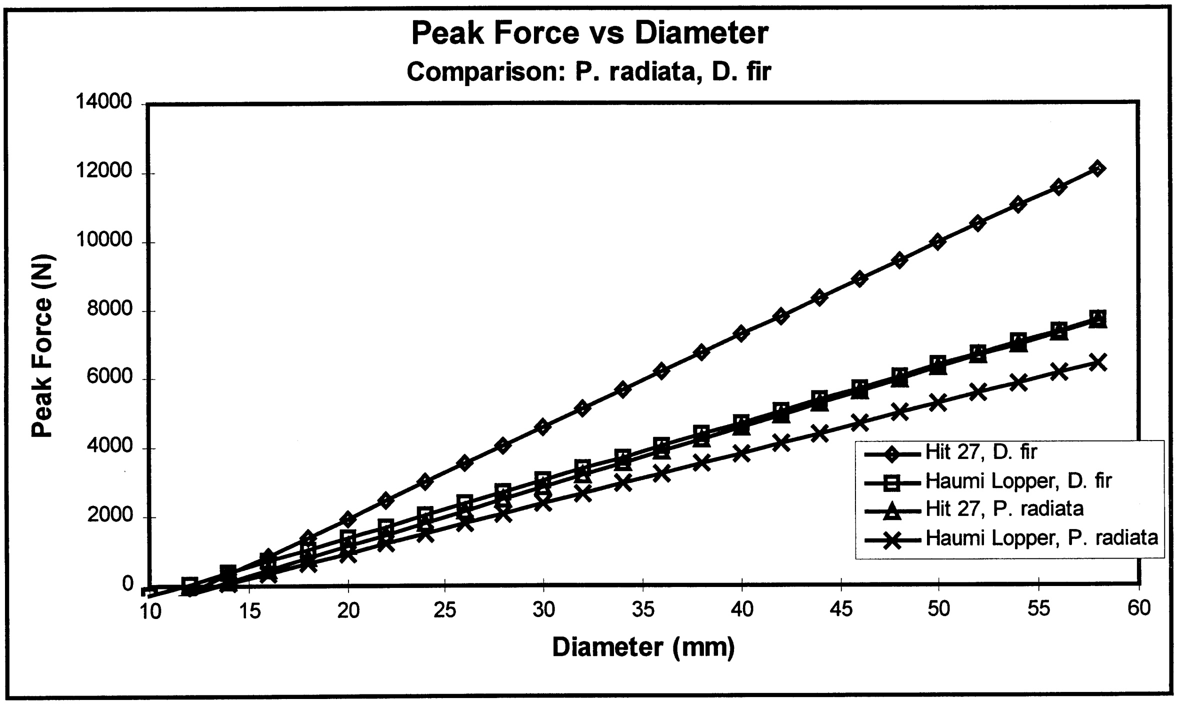


Figure 3.4.2. Comparison of peak force requirements between Pinus radiata and Douglas fir

4.0 Discussion

The lines on the graphs represent the data trends. These trend lines are represented by 3rd order polynomials for the energy results and by straight lines for the peak force results. The type of trend line was chosen to be the type that best represented all of the loppers results for that parameter and explained 92-98% of the variation. More detail about the trendlines can be seen in appendix 3.

The total energy is considered to be the governing parameter as this describes the amount of energy required to cut through the entire branch. The peak force only describes the maximum force applied in cutting through a certain part of the branch.

The total energy required to cut through a branch is independent of the length of the handles on a set of loppers. Therefore a measure of the total energy allows comparisons between the different loppers regardless of the length of the handles. The peak force however, does depend on the length of the lever arm about which the force is applied. The length of the lever arm relates to the length of the handles. Therefore peak force comparisons between the loppers can not be made without taking the length of the lever arm into consideration.

The different loppers gave different force verse displacement graphs. The shapes of these graphs often meant that it was meaningless to compare peak force as the peak force of two loppers could be the same but the total energy requirements may be vastly different, refer figure 4.0.1.

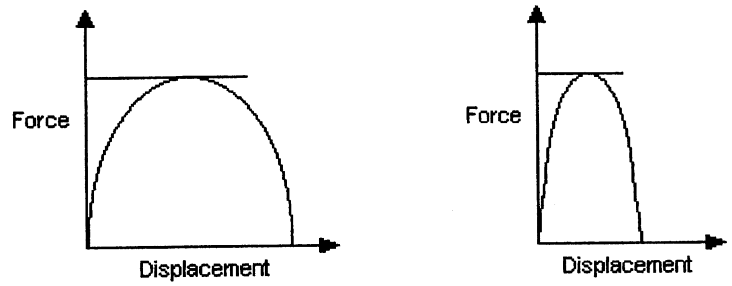


Figure 4.0.1. Two graphs from different loppers, each with the same peak force but vastly different energies. Note: the area under the graph equals the energy used.

Before the peak force could be compared between the loppers it had to be adjusted by multiplying it by the ratio of the length of the lever arm in the test rig to the length about which the branches were cut, refer figure 4.0.2. This gave the maximum force at the cutting point for each set of loppers allowing for meaningful comparisons of peak force values.

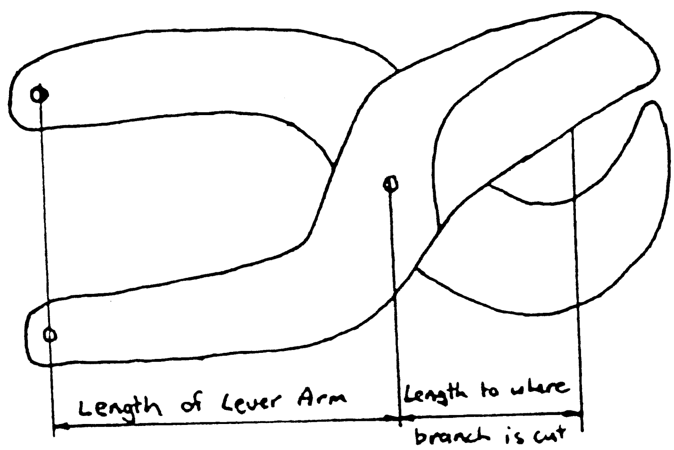


Figure 4.0.2. Length of the lever arm to length about which the branches were cut

$$\text{Ratio} = \frac{\text{Length of the lever arm}}{\text{Length about which the branch is cut}}$$

The conclusions drawn from the results have been made from the regions of the graphs relating to an area cut of 10 cm^2 (approximately 35 mm in diameter) or bigger. The conclusions were made from this region as this relates to a branch that requires a significant effort to shear. Branches any smaller than this do not require any significant effort to remove no matter which type of loppers are being used.

The size of the branches tested was limited to the size of branch that could fit into all the jaws of the loppers. Some very large branches (~ 67 mm diameter) were tested with the Haumi Lopper and Hit 27 loppers. These tests gave energy values that corresponded very closely with a continuation of the above curve, refer Appendix 5. Unfortunately such tests could not be performed for all the sets of loppers, as the large branches would not fit in their jaws. Therefore, it is assumed that the trends shown in the graphs would continue on as shown. However, as the loppers were tested at their maximum branch sizes, it is assumed that the values at approximately 60 mm diameter are the maximum energy requirements when used for cutting Pinus radiata. This is assumed as it is physically impossible to cut branches much larger than 60 mm with one cut. If larger cuts can be made then it is expected the energy required will relate to a continuation of the trendline on the graph.

4.1 Energy Results

From the Energy verse Area graph for Pinus radiata it can be seen that the energy required to cut entirely through the branch increases as the area to be cut increases. There are clearly different amounts of energy required between the various sets of loppers. Between some loppers these energy differences are significant, however the differences are not as significant between all the sets of loppers. For small branches, where the energy required to cut by all types of loppers is low, the operator may not find the differences noticeable, however for larger cuts, ie. cuts greater than 45 mm in diameter, the operator will notice a difference between the different sets of loppers.

The graph shows that when cutting large branches, which is the hardest work, the Haumi Lopper requires the least amount of energy to operate. The Haumi pruner and the Lane pruners were the next best and these performed approximately the same. The Wiringi pruners required the fourth lowest amount of energy throughout but performed about the same as the Haumi pruner and Lane pruners at the largest cuts, approximately 60 mm. The Hit 27 loppers required the second highest amount of energy. The Pruneoff loppers required the highest amount of energy to cut branches. At the largest cuts, approximately 60 mm, the energy required by the Pruneoff loppers coincided with the energy required by the Hit 27 loppers.

Ranking the loppers in order of energy efficiency, first being the most energy efficient, gives:

Ranking	*Lopper*	*Energy required compared to the Haumi Lopper (%)*
First	Haumi Lopper	100
Second	Haumi Pruner Lane Pruners	110
Fourth	Wiringi Pruners	120
Fifth	Hit 27 Loppers	130
Sixth	Pruneoff Loppers	140

Table 4.1.1. A comparison of the energy requirements of the loppers tested.

4.2 Peak Force Results

The graph of Peak Force verse Area shows that as the area increases the peak force also increases. It also shows that there are some significant differences between the peak force requirements of the various loppers.

Ranking the Peak force requirements (first requiring the lowest peak force) of the various loppers gives:

Ranking	*Lopper*	*Peak Force required compared to the Haumi Lopper (%)*
First	Haumi Lopper	100
Second	Lane Pruners	110
Third	Hit 27 Loppers Haumi Pruner	125
Fifth	Wiringi Pruners Pruneoff Loppers	145

Table 4.2.1 . A comparison of the peak force requirements of the loppers tested.

4.3 Effect of the Blade Profile

Comparing the energy required to the angle of the cutting blade suggests that as the blade angle increases so does the energy required to cut through a branch. From the Hit 27 and Pruneoff results it appears that the energy is determined from the average angle of the bottom 5 - 8 mm of the blade. The results also suggest that the loppers with a single blade angle perform better than the loppers in which the blade angle changes.

4.4 Douglas Fir Results

The tests done on the Douglas fir branches were carried out to determine if they would confirm the trends found for the pine branches. Only the Haumi Lopper and the Hit 27 loppers were tested on Douglas fir, as these two sets of loppers show similar curves but with significantly different energy requirements. The results from the Douglas fir tests confirm that the Hit 27 loppers require significantly more energy and a higher peak force to cut through a branch than if the Haumi Lopper was to cut through the same branch.

4.5 Statistical Analysis

The energy results from all the tests, including the Douglas fir tests, were entered into the statistical analysis program, "Minitab," refer appendix 8. This was done to confirm the statistical relevance of the results. This analysis was only done for the energy results as they are considered to be the governing parameter when comparing loppers. The results of these tests are shown in Appendix 8.

4.6 Practical use of the Loppers

The Haumi Loppers were good to use as they cut the branches easily, cleanly and close to the stem. They handled big branches easily and were not limited by branch size in the six year old pines they pruned. Due to the length of the handles it was sometimes awkward to remove the first few branches, but once these were removed there was no difficulty in using the loppers. When the loppers are closed the end of the cutting blade sticks out approximately 15 mm past the anvil. This sharp edge is a potential hazard as it could injure the individual using the loppers or damage property. As the maximum cut to be made by a set of loppers is limited by the shape of the anvil it is unnecessary for the blade to protrude past the end of the anvil.

The Haumi Pruners were very good for cutting branches up to approximately 45 mm in diameter. These loppers could cut bigger branches but due to their short handles and blade configuration it required some extra effort. Due to the size of the loppers they were easy to manoeuvre, especially when removing the initial branches. They cut the branches cleanly and close to the stem. As with the Haumi Lopper these also have the sharp end of the blade sticking out past the anvil which may be a safety hazard.

The Lane pruners performed similarly to the Haumi pruners in the field tests. The twist in the flat steel handles (refer to a picture of the loppers) provided some dampening as the loppers were closed. This reduced the jarring felt from the loppers being closed abruptly. The cutting blade on the Lane pruners did not project past the anvil.

The Wiringi pruners cut the branches easily, cleanly and close to the stem. They could handle the full range of diameters tested but required some extra effort for branches over 50 mm in diameter. The major fault found whilst using the Wiringi pruners was that the tubular aluminium handles were not rigid enough. This means that the operators knuckles would get knocked together between the handles as the pruners closed fully. This can cause great discomfort for the pruner and could lead to long term knuckle damage if it happened repeatedly. The Wiringi pruners also have some of the sharp blade extending out beyond the anvil. This could be a safety hazard as well as damaging to property.

The Pruneoff loppers required a noticeably higher effort than the other tools tested on branches greater than 25 mm in diameter. The shape of the anvil on the Pruneoff lopper restricted the branch size to approximately 60 mm. The quality of the cut was not as consistently high as many of the other loppers tested. Due to the length of the handles they were sometimes awkward to manoeuvre in order to remove the first few branches, but once these were removed there was no difficulty in manoeuvring the loppers. The cutting blade of the Pruneoff loppers also sticks out past the anvil, causing safety hazard however the blade is not as sharp as many of the other loppers, so comparatively, it creates less of a hazard.

The Hit 27 loppers could cut some very big branches but required a lot of effort to do so. As with the Pruneoff loppers the quality of the cut was not as consistently high as the other loppers and due to the length of the handles they were sometimes awkward to manoeuvre in order to remove the first few branches. Again the cutting blade of the Hit 27 loppers sticks out past the anvil, however this section of the Hit 27 blade is blunt and may not cause a hazard.

4.7 Limitations of This Study

Because the force requirements were measured using a static test rig this study has not been able to quantify the effect of technique on cutting efficiency of the tools tested. Specifically the effect of colling the blade around the branch and away from the tree in a knife type action as compared to the scissor action created by the test rig has not been quantified. Manufacturers such as R. Wiringi claim that the correct pruning technique is critical in order to best utilise the design of the pruning tool (R. Wiringi pers com).

Despite relatively small differences in the total weight and dimensions of the tools the balance of each tool is quite different. These differences may have ergonomic implications for the operator.

Because of the relative stability of the test rig any deflection or twisting of the blade due to metallurgy or thinness of the blade was minimised. Therefore this study was unable to measure the durability of the tools tested. A study involving field use of the tools would be more likely to highlight any differences.

5.0 Future Research

From the discussion and research into this project several questions have been raised about the design of pruning loppers. These questions are outside the boundary of this project and require future research. A summary of these questions and the future research is presented below:

- There could be more research into determining the proportion of the resisting forces ie. determine the proportion of the resistance to shearing force, the friction force, the compression force and the bending forces. This would give conclusions about the optimum blade profile and roughness.
- Determine the effect of different blade shapes

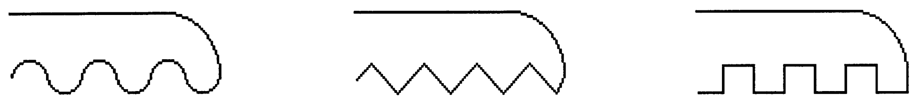


Figure 5.0.1. Different blade shapes which could be investigated

- Determine the effect of different blade profiles

Figure 5.0.2. Different blade profiles which could be investigated

- Investigate blade thickness to determine the optimum thickness, ie. the thickness which requires the least energy but doesn't break.
- Investigate the sharpness of the blade
- Investigate why a twisting action when pruning, is easier. Refer appendix 10.

The results from this study provide a useful set of base data for further research to continue on from.

6.0 Conclusion

The energy and force requirements of six common types of pruning loppers was evaluated. The loppers were tested on a universal testing machine. From the results there are clearly different energy and force requirements required by the different loppers. These differences have been summarised below in table 6.0.1 and table 6..0.2.

Ranking	*Lopper*	*Energy required compared to the Haumi Lopper (%)*
First	Haumi Lopper	100
Second	Haumi Pruner Lane Pruners	110
Fourth	Wiringi Pruners	120
Fifth	Hit 27 Loppers	130
Sixth	Pruneoff Loppers	140

Table 6.0.1. A comparison of the energy requirements of the loppers tested.

Ranking	*Lopper*	*Peak Force required compared to the Haumi Lopper (%)*
First	Haumi Lopper	100
Second	Lane Pruners	110
Third	Hit 27 Loppers Haumi Pruner	125
Fifth	Wiringi Pruners Pruneoff Loppers	145

Table 6.0.2. A comparison of the peak force requirements of the loppers tested.

The total energy is considered to be the governing parameter, when comparing loppers, as this describes the amount energy required to cut through the entire branch. The peak force only describes the maximum force applied in cutting through a certain part of the branch and is dependent on pruning technique, and the length of the lopper handles.

The results suggest that as the blade angle increases so do the energy and force requirements.

This project has presented results and a method of testing which further research can be based on. This project has raised many questions about the energy and force requirements of pruning loppers and has given an insight into the possible design characteristics which could be considered for developing improved pruning loppers.

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Appendix 1 - Preliminary Test Results

This appendix contains the results and a summary of the conclusions drawn from the preliminary tests. For the preliminary tests approximately 40 samples of Pinus radiata were tested with Hit 27 loppers. These tests were done to aid with the planning of the project. The findings and workings of these tests are also included in the appendix.

Hit 27 lopers (new)
Tested on 6 year old pine branches at the Lincoln testing rig.
Test rig file: July

Sample	Vernier Measurement (diam.) B (mm)	D (mm)	Average	Circumference (cm)	Planimeter area (cm^2) Run 1	Run 2	Average	Energy (Joules)	Peak Force (N)	Break load (N)	Area (cm^2) Vernier	Circumference	Planimeter results Average		Vernier % Of Planimeter	Circ. %
1	33.5	32.2	32.85	10.4	7.8	8.0	7.90	67.5	1430	671	8.48	8.61	7.90		107.2836	108.9506
2	32.7	31.7	32.20	10.3	7.7	7.9	7.80	60.5	1300	585	8.14	8.44	7.80		104.4016	108.2356
3	33.4	32.2	32.80	10.4	8.0	7.8	7.90	78.1	1820	520	8.45	8.61	7.90		106.9573	108.9506
4	31.5	30.3	30.90	9.8	7.3	7.4	7.35	65.0	1473	650	7.50	7.64	7.35		102.028	103.9812
5	30.6	29.3	29.95	9.6	6.8	6.8	6.80	55.0	1365	607	7.05	7.33	6.80		103.6035	107.8509
6	30.3	28.7	29.50	9.5	6.4	6.5	6.45	50.9	1343	650	6.83	7.18	6.45		105.9679	111.3468
7	29.5	28.7	29.10	9.3	6.2	6.1	6.15	46.5	1235	760	6.65	6.88	6.15		108.1436	111.9131
8	29.7	28.1	28.90	9.2	6.2	6.4	6.30	42.0	1148	585	6.56	6.74	6.30		104.1226	106.9117
9	28.9	28.0	28.45	9.1	6.0	5.9	5.95	39.7	1061	693	6.36	6.59	5.95		106.8409	110.7531
10	31.8	30.4	31.10	9.9	7.2	7.1	7.15	66.8	1603	823	7.60	7.80	7.15		106.2441	109.0823
11	30.6	30.3	30.45	9.9	7.1	7.3	7.20	59.2	1451	650	7.28	7.80	7.20		101.1421	108.3248
12	31.3	31.0	31.15	9.9	7.4	7.4	7.40	55.5	1408	520	7.62	7.80	7.40		102.9851	105.3971
13	29.2	27.4	28.30	9.1	6.3	6.1	6.20	46.4	1235	715	6.29	6.59	6.20		101.4544	106.2873
14	28.6	26.2	27.40	8.8	5.5	5.8	5.65	38.4	1148	693	5.90	6.16	5.65		104.362	109.0704
15	28.2	27.5	27.85	8.9	5.8	5.8	5.80	40.3	1018	823	6.09	6.30	5.80		105.0297	108.6781
16	32.8	32.8	32.80	10.4	8.3	8.3	8.30	67.3	1581	585	8.45	8.61	8.30		101.8027	103.7
17	32.4	30.9	31.65	10.2	7.7	7.7	7.70	59.9	1481	628	7.87	8.28	7.70		102.1755	107.5226
18	32.4	30.7	31.55	10.1	7.4	7.3	7.35	56.6	1343	520	7.82	8.12	7.35		106.3656	110.4449
19	31.0	29.5	30.25	9.8	7.0	7.2	7.10	50.3	1170	585	7.19	7.64	7.10		101.2237	107.6425
20	30.3	30.5	30.40	9.7	7.1	7.0	7.05	46.5	1126	500	7.26	7.49	7.05		102.9551	106.2049
21	30.0	28.9	29.45	9.4	6.4	6.6	6.50	42.3	1126	542	6.81	7.03	6.50		104.7966	108.1764
22	40.6	38.1	39.35	12.5	11.6	11.5	11.55	109.0	2036	520	12.16	12.43	11.55		105.2925	107.6535
23	38.4	37.6	38.00	12.1	10.7	10.8	10.75	97.6	1971	671	11.34	11.65	10.75		105.4991	108.3808
24	38.1	36.8	37.45	12.0	10.7	10.7	10.70	86.7	1776	563	11.02	11.46	10.70		102.9461	107.0949
25	38.1	36.7	37.40	11.9	10.5	10.5	10.50	78.9	1560	520	10.99	11.27	10.50		104.627	107.3235
26	38.2	36.0	37.10	12.2	10.4	10.3	10.35	72.1	1495	607	10.81	11.84	10.35		104.4473	114.4378
27	38.5	36.8	37.65	11.9	10.4	10.5	10.45	71.8	1473	498	11.13	11.27	10.45		106.5378	107.837
28	23.9	22.7	23.30	7.4	4.1	4.1	4.10	28.4	1083	845	4.26	4.36	4.10		103.9963	106.2844
29	23.3	21.7	22.50	7.3	3.6	3.8	3.70	22.8	736	542	3.98	4.24	3.70		107.4616	114.6131
30	22.0	22.7	22.35	7.2	3.7	3.7	3.70	22.1	758	693	3.92	4.13	3.70		106.0335	111.4945
31	35.0	33.3	34.15	10.9	8.9	8.8	8.85				9.16	9.45	8.85		103.4971	106.8316
32	32.4	33.3	32.85	10.5	7.9	8.1	8.00	65.0	1451	585	8.48	8.77	8.00		105.9426	109.6677
33	31.7	33.0	32.35	10.2	7.8	7.7	7.75	61.7	1451	542	8.22	8.28	7.75		106.0564	106.8289
34	35.5	33.8	34.65	11.1	9.2	9.1	9.15	76.7	1711	542	9.43	9.80	9.15		103.0565	107.1556
35	31.9	31.5	31.70	10.1	7.6	7.5	7.55	63.8	1408	607	7.89	8.12	7.55		104.5349	107.5192
36	31.0	30.8	30.90	9.9	7.1	7.2	7.15	53.0	1278	628	7.50	7.80	7.15		104.882	109.0823
37	30.3	30.8	30.55	9.7	7.1	6.9	7.00	47.0	1148	650	7.33	7.49	7.00		104.7163	106.9635
38	34.2	33.2	33.70	10.8	8.6	8.6	8.60	68.1	1581	498	8.92	9.28	8.60		103.7173	107.9293
39	34.2	32.8	33.50	10.7	8.5	8.4	8.45	64.3	1560	500	8.81	9.11	8.45		104.3092	107.8204

Std.dev = 18.546
Variance = 343.94
Mean = 58.5

DETERMINATION OF THE SAMPLE SIZE

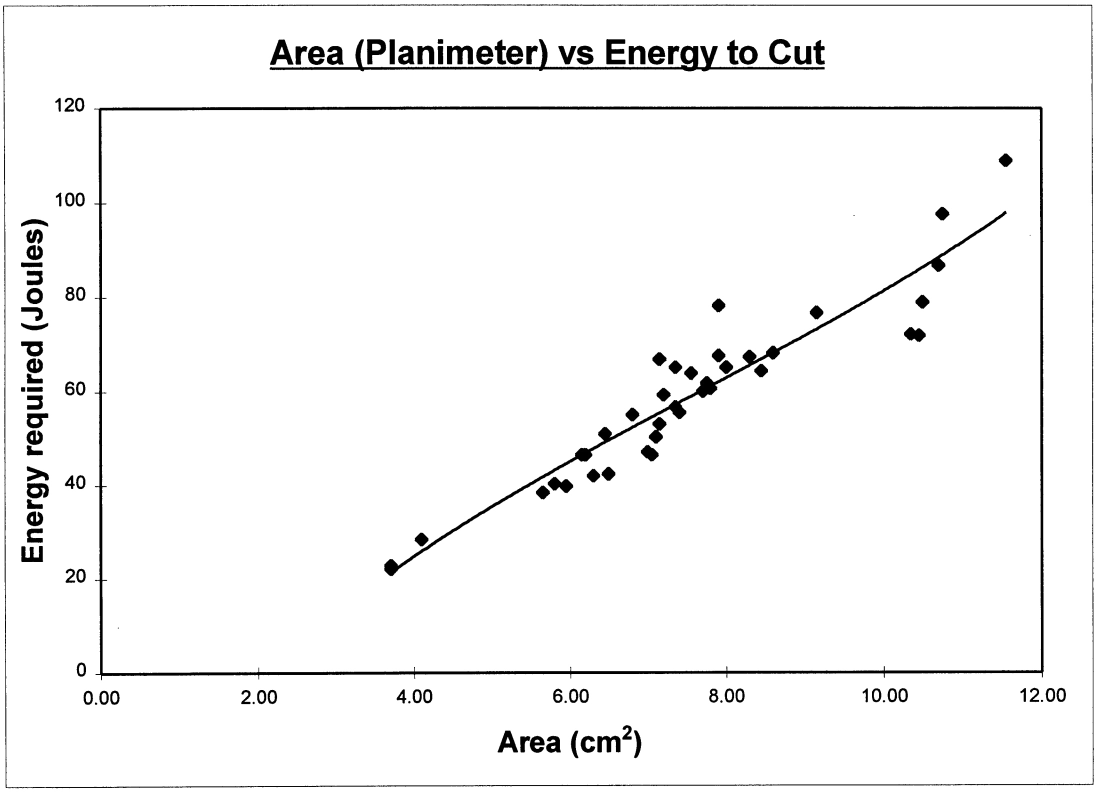
$$n = \frac{t^2 s^2}{E^2}$$ *Sample Size Equation*

where
- n = sample size
- t = level of probability of t distribution
- s^2 = variance
- E = error at specified significance level

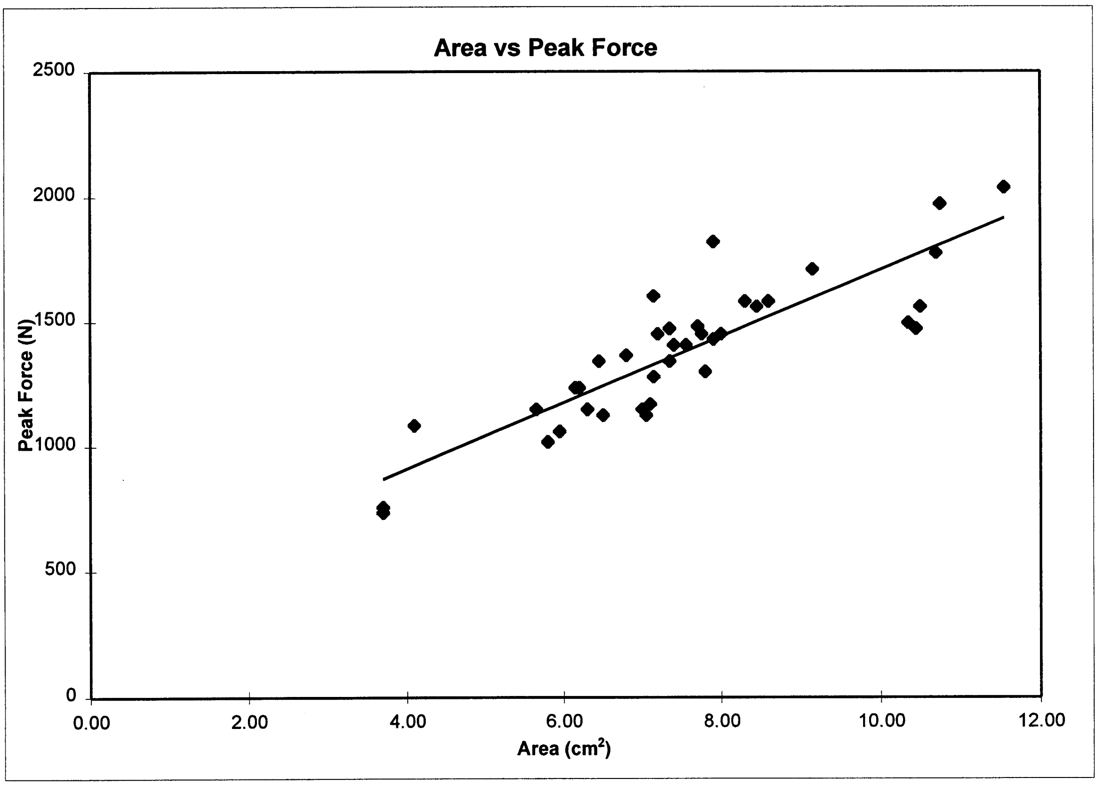
All of the data used in the equation above was obtained from the spread sheet on the previous page.

Level of significance = 10%		
s^2	=	343.94
t	=	2.39
mean	=	58.5
E	=	5.85
n	=	58

On the basis of the results from the preliminary tests a sample size of 58 has been calculated. To ensure accuracy in the results for each set of loppers a sample size of 75 was chosen.



Area (Planimeter) vs Energy to Cut
Energy required (Joules)
Area (cm²)
0
20
40
60
80
100
120
0.00
2.00
4.00
6.00
8.00
10.00
12.00

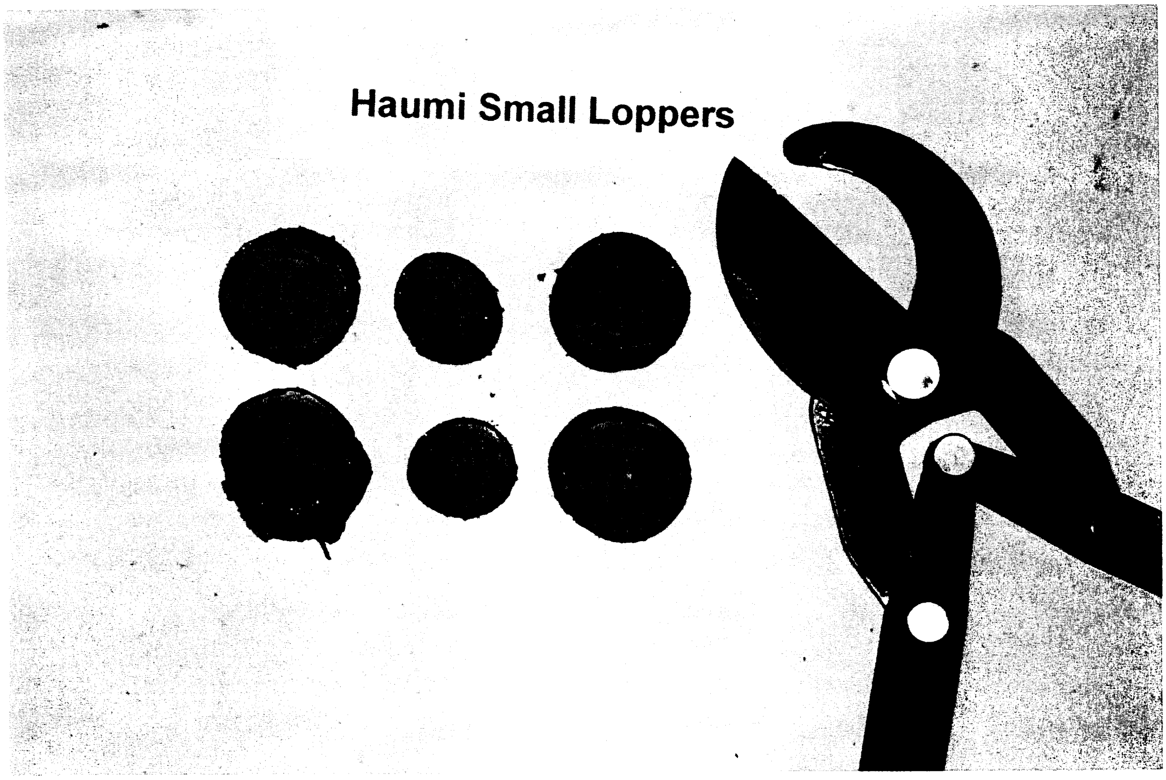


Area vs Peak Force
Peak Force (N)
Area (cm²)
0
500
1000
1500
2000
2500
0.00
2.00
4.00
6.00
8.00
10.00
12.00

Appendix 2 - Summary of the Loppers Tested

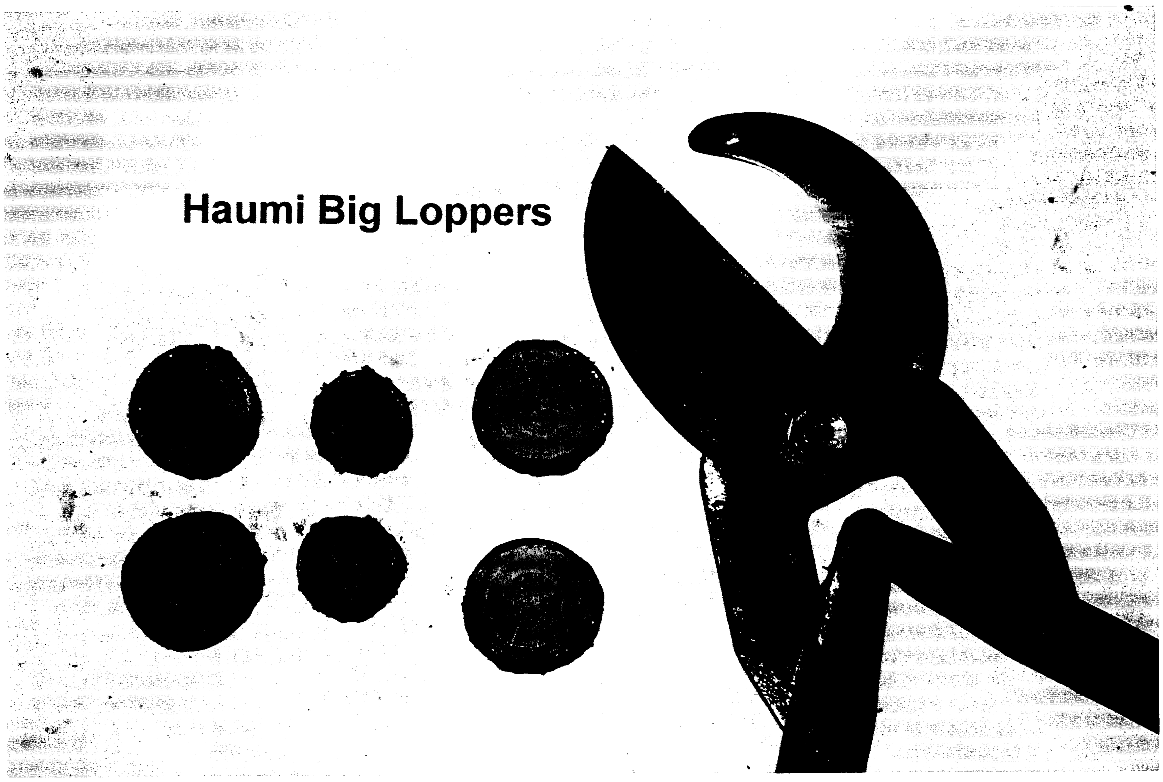
This appendix is a summary of the loppers tested. It includes a photograph of each lopper and a close up of their cutting heads. It also describes each set of loppers in terms of size, weight, maximum branch size.

Haumi Small



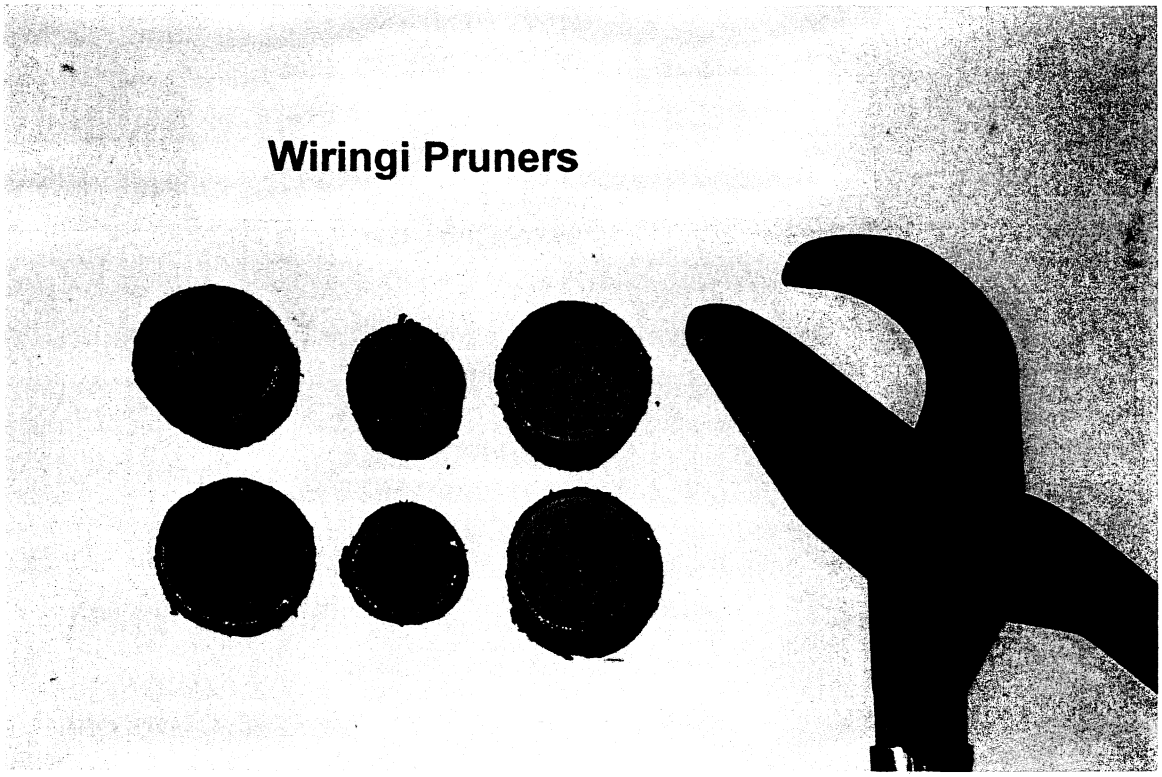
Weight : 1.85 kg
Total length : 615 mm
Maximum Branch Diameter : 55 mm

Haumi Big



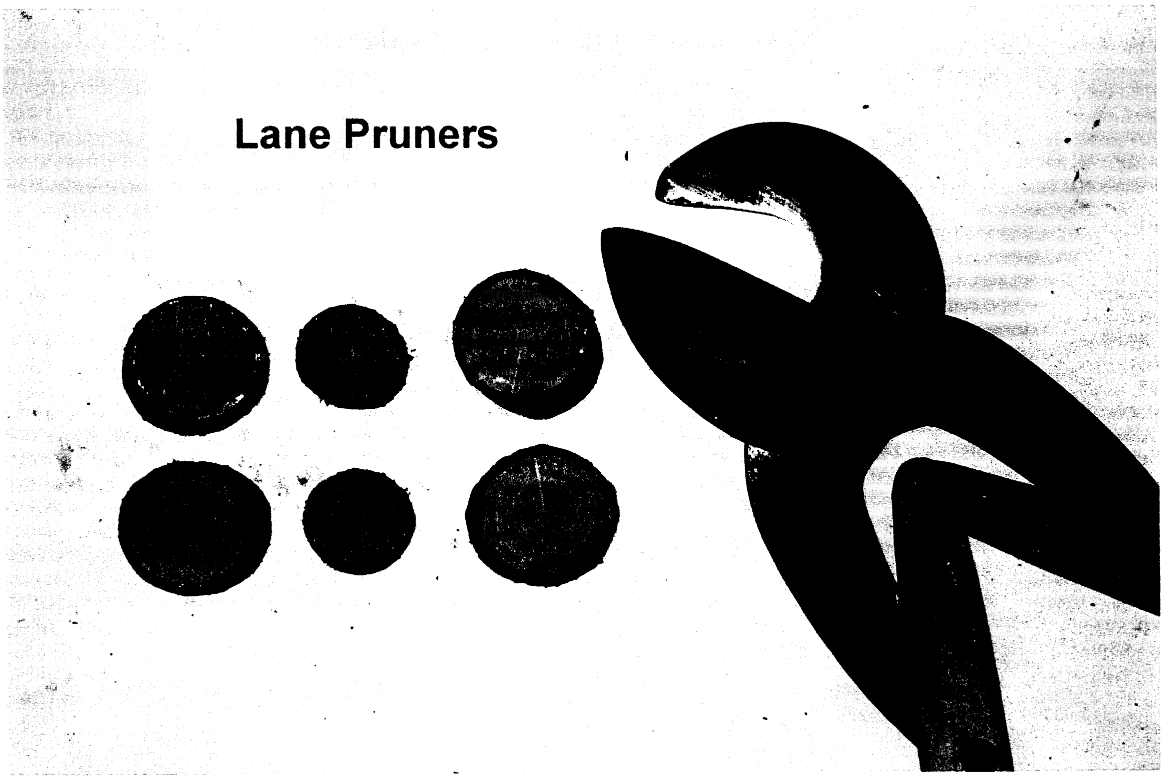
Weight : 2.14 kg
Total length : 688 mm
Maximum Branch Diameter : 66 mm

Wiringi Pruners



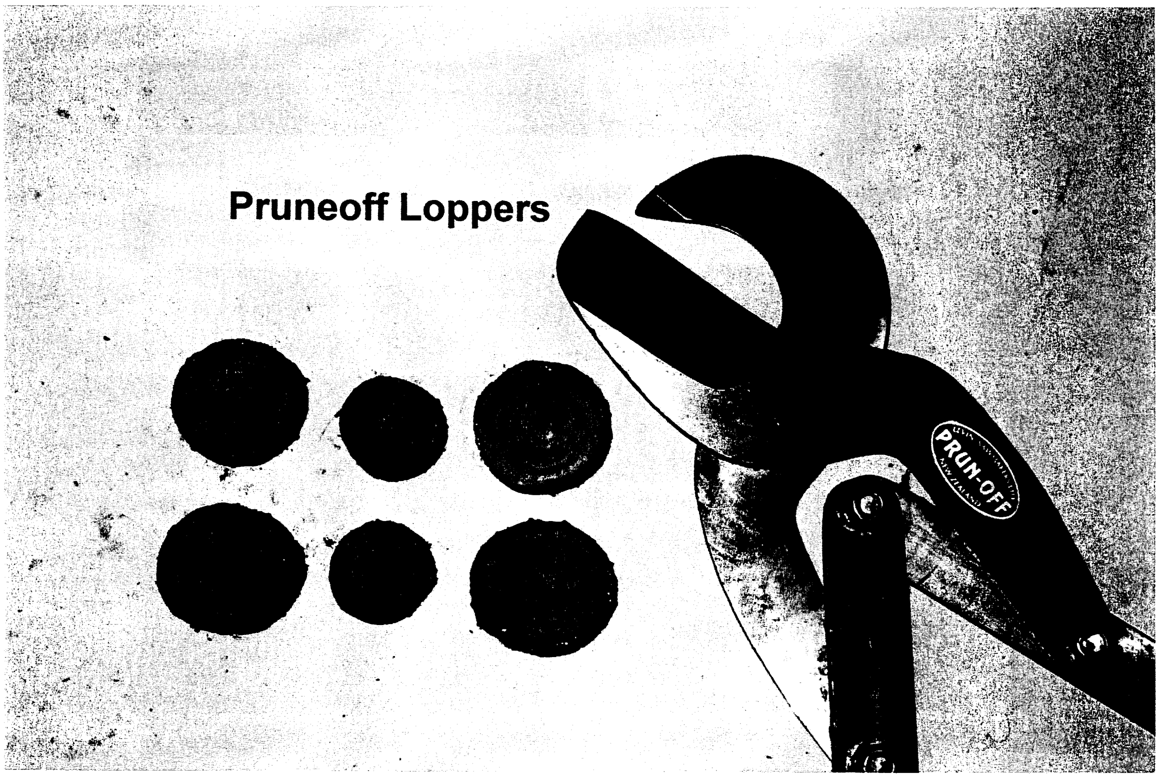
Weight : 1.58 kg
Total length : 700 mm
Maximum Branch Diameter : 60 mm

Lane Pruners



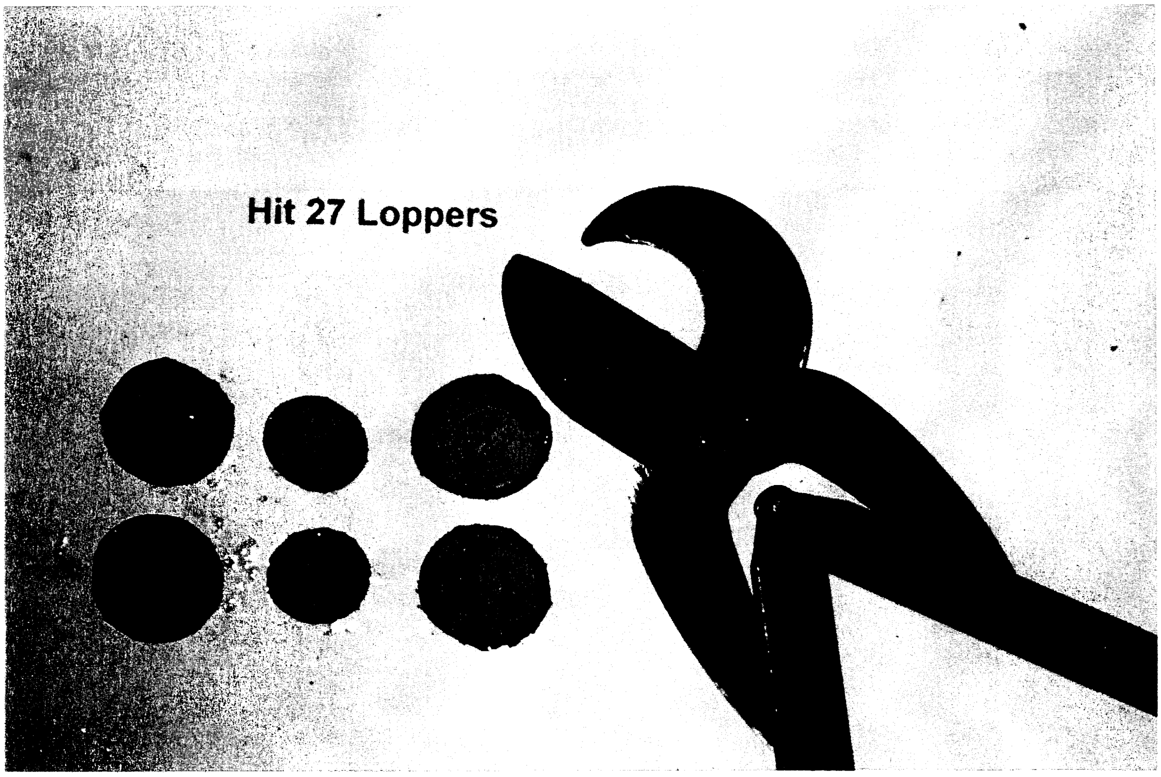
Weight : 1.84 kg
Total length : 568 mm
Maximum Branch Diameter : 55 mm

Pruneoff Loppers



Weight : 2.25 kg
Total length : 671 mm
Maximum Branch Diameter : 58 mm

Hit 27 Loppers



Weight : 2.28 kg
Total length : 702 mm
Maximum Branch Diameter : 63 mm

Appendix 3 - Summary of Raw Data

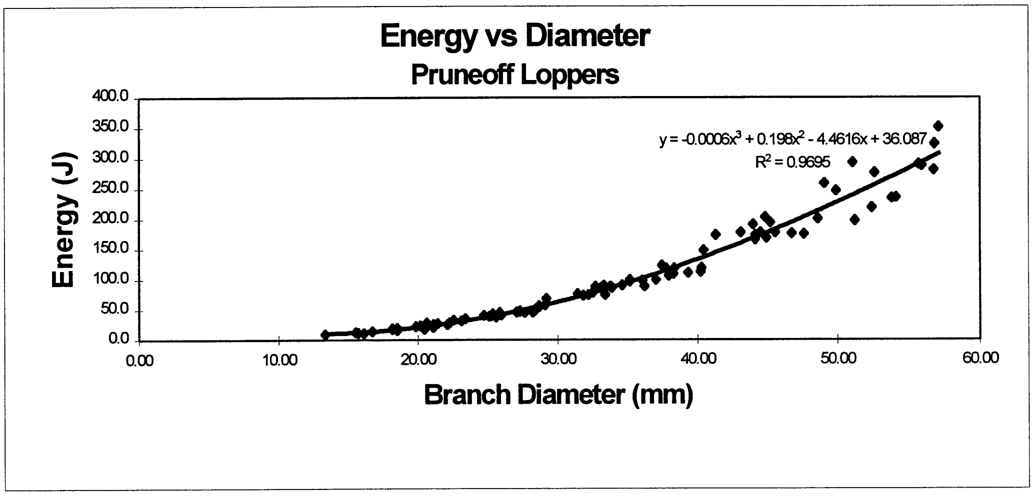
This appendix gives the raw data from each set of loppers tested.

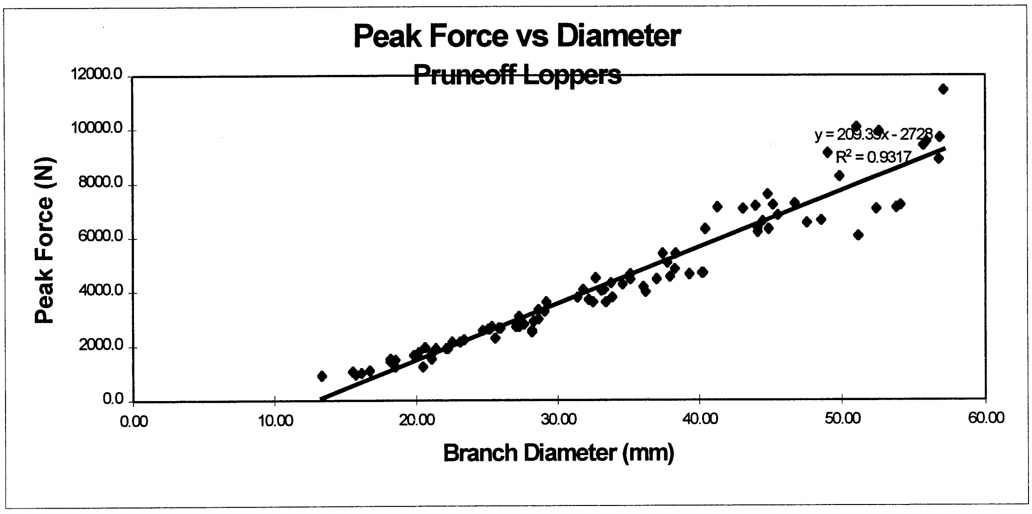
Pruneoff loppers (new, standard)

Weight: 2.25 kg
Overall Length: 671mm

sample	Planimeter area (cm^2)			Energy (Joules)	Force (N)	Peak Force (N)	Test Works File #	Branch diameter (mm)
	Run 1	Run 2	Average					
1	25.5	25.7	25.60	350.8	5221	11446.0	Pruneoff 1	57.09
2	25.4	25.3	25.35	323.6	4420	9690.0	Pruneoff 2	56.81
3	20.6	20.4	20.50	292.6	4593	10069.3	Pruneoff 3	51.09
4	18.9	18.9	18.90	258.8	4160	9120.0	Pruneoff 4	49.06
5	1.9	1.9	1.90	12.2	477	1045.7	Pruneoff 5	15.55
6	2.0	1.9	1.95	11.4	433	949.3	Pruneoff 6	15.76
7	3.2	3.0	3.10	22.4	758	1661.8	Pruneoff 7	19.87
8	2.7	2.7	2.70	19.3	672	1473.2	Pruneoff 8	18.54
9	3.8	3.9	3.85	25.1	867	1900.7	Pruneoff 9	22.14
10	2.7	2.5	2.60	17.5	650	1425.0	Pruneoff 10	18.19
11	4.2	4.4	4.30	35.2	1018	2231.8	Pruneoff 11	23.40
12	4.1	3.9	4.00	32.6	975	2137.5	Pruneoff 12	22.57
13	3.8	4.0	3.90	29.0	867	1900.7	Pruneoff 13	22.28
14	2.6	2.6	2.60	18.4	693	1519.3	Pruneoff 14	18.19
15	3.6	3.6	3.60	27.2	867	1900.7	Pruneoff 15	21.41
16	3.6	3.4	3.50	25.8	780	1710.0	Pruneoff 16	21.11
17	3.4	3.3	3.35	27.7	888	1946.8	Pruneoff 17	20.65
18	3.2	3.2	3.20	23.4	802	1758.2	Pruneoff 18	20.19
19	15.2	15.2	15.20	190.7	3272	7173.2	Pruneoff 19	43.99
20	13.3	13.5	13.40	173.2	3250	7125.0	Pruneoff 20	41.31
21	16.1	16.0	16.05	194.2	3293	7219.3	Pruneoff 21	45.21
22	15.6	15.5	15.55	177.5	3012	6603.2	Pruneoff 22	44.50
23	15.9	15.7	15.80	203.1	3466	7598.5	Pruneoff 23	44.85
24	15.2	15.4	15.30	173.0	2903	6364.3	Pruneoff 24	44.14
25	14.7	14.5	14.60	177.4	3228	7076.8	Pruneoff 25	43.12
26	15.3	15.3	15.30	166.5	2838	6221.8	Pruneoff 26	44.14
27	12.9	12.8	12.85	148.3	2882	6318.2	Pruneoff 27	40.45
28	11.5	11.6	11.55	118.8	2470	5415.0	Pruneoff 28	38.35
29	9.7	9.7	9.70	97.1	2037	4465.7	Pruneoff 29	35.14
30	8.6	8.6	8.60	86.3	1842	4038.2	Pruneoff 30	33.09
31	9.8	9.6	9.70	99.2	2123	4654.3	Pruneoff 31	35.14
32	8.6	8.8	8.70	89.7	1863	4084.3	Pruneoff 32	33.28
33	7.8	7.7	7.75	76.3	1733	3799.3	Pruneoff 33	31.41
34	6.7	6.7	6.70	68.0	1647	3610.7	Pruneoff 34	29.21
35	11.1	10.9	11.00	123.1	2470	5415.0	Pruneoff 35	37.42
36	11.1	11.3	11.20	118.2	2318	5081.8	Pruneoff 36	37.76
37	11.6	11.4	11.50	109.9	2210	4845.0	Pruneoff 37	38.27
38	9.0	9.0	9.00	86.6	1733	3799.3	Pruneoff 38	33.85
39	6.7	6.6	6.65	57.9	1495	3277.5	Pruneoff 39	29.10
40	6.3	6.3	6.30	47.7	1322	2898.2	Pruneoff 40	28.32
41	9.4	9.4	9.40	90.7	1950	4275.0	Pruneoff 41	34.60
42	10.3	10.3	10.30	88.8	1820	3990.0	Pruneoff 42	36.21
43	8.9	9.0	8.95	88.4	1972	4323.2	Pruneoff 43	33.76
44	8.2	8.1	8.15	74.7	1690	3705.0	Pruneoff 44	32.21
45	8.4	8.4	8.40	88.6	2058	4511.8	Pruneoff 45	32.70
46	7.9	8.0	7.95	73.9	1863	4084.3	Pruneoff 46	31.82
47	10.2	10.2	10.20	98.6	1907	4180.7	Pruneoff 47	36.04
48	8.8	8.7	8.75	75.0	1647	3610.7	Pruneoff 48	33.38
49	10.8	10.7	10.75	99.4	2037	4465.7	Pruneoff 49	37.00
50	8.3	8.3	8.30	79.1	1647	3610.7	Pruneoff 50	32.51
51	6.5	6.4	6.45	56.2	1517	3325.7	Pruneoff 51	28.66
52	5.9	5.8	5.85	47.7	1408	3086.8	Pruneoff 52	27.29
53	6.5	6.4	6.45	55.0	1365	2992.5	Pruneoff 53	28.66
54	5.7	5.8	5.75	46.0	1235	2707.5	Pruneoff 54	27.06
55	5.4	5.2	5.30	41.7	1213	2659.3	Pruneoff 55	25.98
56	5.0	4.9	4.95	38.7	1192	2613.2	Pruneoff 56	25.10
57	5.9	5.8	5.85	46.7	1235	2707.5	Pruneoff 57	27.29
58	5.1	5.2	5.15	37.3	1040	2280.0	Pruneoff 58	25.61
59	5.0	5.0	5.00	40.1	1192	2613.2	Pruneoff 59	25.23
60	4.9	4.7	4.80	40.8	1170	2565.0	Pruneoff 60	24.72
61	5.1	5.0	5.05	42.7	1235	2707.5	Pruneoff 61	25.36
62	4.2	4.2	4.20	32.0	975	2137.5	Pruneoff 62	23.12
63	5.2	5.3	5.25	45.4	1213	2659.3	Pruneoff 63	25.85
64	6.0	6.0	6.00	45.7	1278	2801.8	Pruneoff 64	27.64
65	2.0	2.1	2.05	10.6	455	997.5	Pruneoff 65	16.16
66	1.5	1.3	1.40	8.4	411	901.0	Pruneoff 66	13.35

67	2.7	2.7	2.70	16.0	563	1234.3	Pruneoff 67	18.54
68	3.3	3.3	3.30	17.3	563	1234.3	Pruneoff 68	20.50
69	3.4	3.6	3.50	20.5	693	1519.3	Pruneoff 69	21.11
70	2.2	2.2	2.20	13.9	498	1091.8	Pruneoff 70	16.74
71	6.4	6.1	6.25	46.7	1148	2516.8	Pruneoff 71	28.21
72	6.2	6.3	6.25	46.5	1169	2562.8	Pruneoff 72	28.21
73	12.7	12.7	12.70	112.9	2144	4700.3	Pruneoff 73	40.21
74	11.3	11.3	11.30	106.9	2079	4557.8	Pruneoff 74	37.93
75	15.8	15.9	15.85	168.5	2880	6313.8	Pruneoff 75	44.92
76	16.2	16.4	16.30	177.2	3118	6835.6	Pruneoff 76	45.56
77	12.8	12.7	12.75	118.9	2144	4700.3	Pruneoff 77	40.29
78	12.2	12.1	12.15	111.5	2122	4652.1	Pruneoff 78	39.33
79	19.5	19.6	19.55	246.6	3767	8258.4	Pruneoff 79	49.89
80	21.9	21.6	21.75	276.0	4525	9920.2	Pruneoff 80	52.62
81	24.6	24.5	24.55	287.6	4352	9540.9	Pruneoff 81	55.91
82	24.2	24.5	24.35	290.5	4287	9398.4	Pruneoff 82	55.68
83	21.6	21.6	21.60	218.7	3226	7072.4	Pruneoff 83	52.44
84	20.5	20.7	20.60	197.3	2771	6074.9	Pruneoff 84	51.21
85	18.4	18.7	18.55	200.7	3031	6644.9	Pruneoff 85	48.60
86	17.9	17.7	17.80	175.2	2988	6550.6	Pruneoff 86	47.61
87	17.1	17.2	17.15	175.8	3312	7260.9	Pruneoff 87	46.73
88	22.9	23.1	23.00	235.5	3291	7214.9	Pruneoff 88	54.12
89	22.7	22.8	22.75	234.9	3247	7118.4	Pruneoff 89	53.82
90	25.3	25.3	25.30	280.8	4052	8883.2	Pruneoff 91	56.76

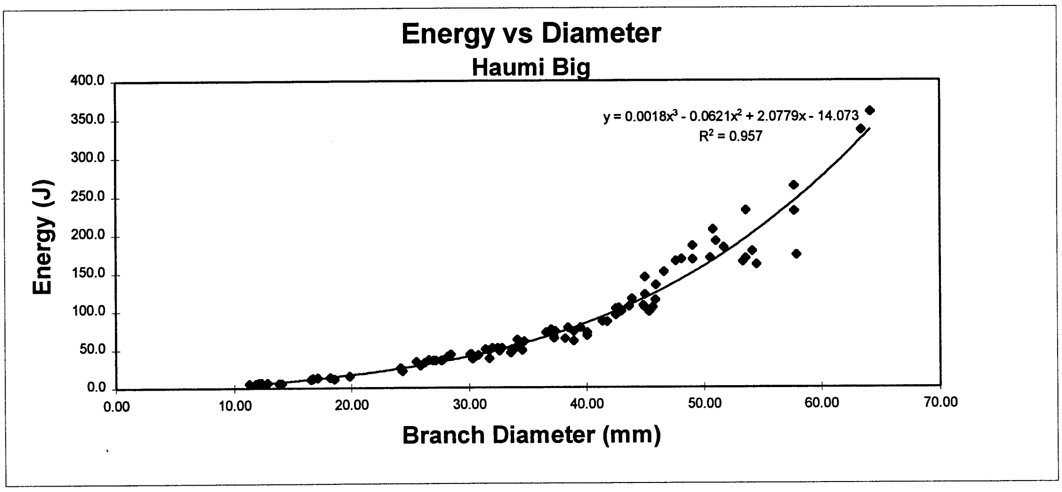


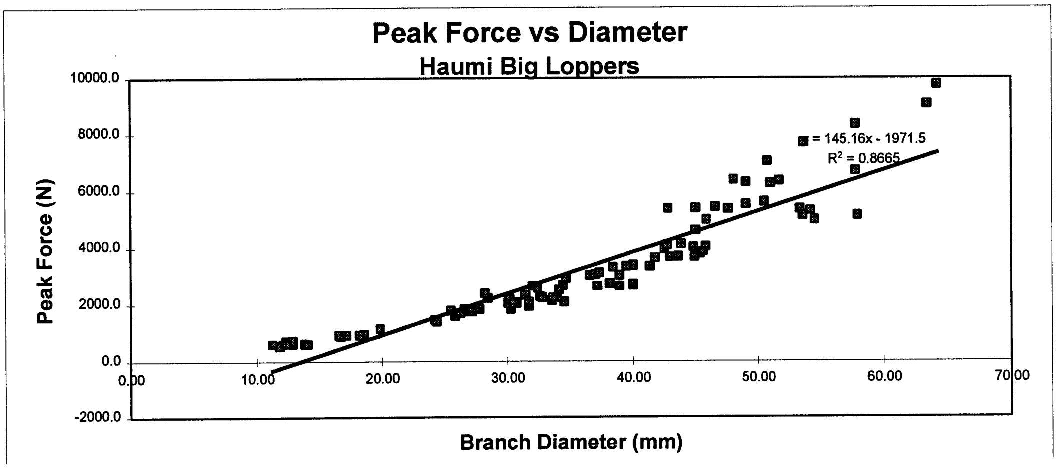


Haumi Lopper (new, standard)
Weight: 2.14 kg
Overall Length: 688mm

sample	Planimeter area (cm^2)			Energy	Force	Peak Force	Test Works	Branch
	Run 1	Run 2	Average	(Joules)	(N)	(N)	File #	diameter (mm)
1	23.1	23.0	23.05	177.7	3619	5315.4	Haumi big 1	54.17
2	22.5	22.2	22.35	164.4	3662	5378.6	Haumi big 2	53.35
3	16.6	16.4	16.50	114.3	2752	4042.0	Haumi big 3	45.83
4	15.8	15.8	15.80	106.9	2730	4009.7	Haumi big 4	44.85
5	23.3	23.4	23.35	160.7	3402	4996.7	Haumi big 5	54.53
6	13.5	13.4	13.45	86.5	2275	3341.4	Haumi big 6	41.38
7	14.5	14.5	14.50	99.3	2492	3660.1	Haumi big 7	42.97
8	14.3	14.1	14.20	102.5	2687	3946.5	Haumi big 8	42.52
9	15.0	14.9	14.95	105.9	2513	3691.0	Haumi big 9	43.63
10	14.4	14.4	14.40	98.8	3665	5383.0	Haumi big 10	42.82
11	12.0	11.8	11.90	72.8	2058	3022.7	Haumi big 11	38.92
12	7.8	7.7	7.75	49.7	1582	2323.6	Haumi big 12	31.41
13	10.6	10.4	10.50	71.9	2058	3022.7	Haumi big 13	36.56
14	10.8	10.7	10.75	75.5	2080	3055.0	Haumi big 14	37.00
15	10.9	10.9	10.90	64.5	1798	2640.8	Haumi big 15	37.25
16	9.4	9.2	9.30	58.2	1820	2673.1	Haumi big 16	34.41
17	9.4	9.3	9.35	48.9	1430	2100.3	Haumi big 17	34.50
18	9.1	9.0	9.05	51.5	1538	2258.9	Haumi big 18	33.95
19	12.7	12.5	12.60	72.0	2296	3372.3	Haumi big 19	40.05
20	12.3	12.2	12.25	77.6	2275	3341.4	Haumi big 20	39.49
21	6.3	6.4	6.35	43.4	1517	2228.1	Haumi big 21	28.43
22	6.4	6.1	6.25	40.4	1625	2386.7	Haumi big 22	28.21
23	8.0	7.8	7.90	37.6	1322	1941.7	Haumi big 23	31.72
24	7.5	7.4	7.45	41.9	1408	2068.0	Haumi big 24	30.80
25	8.9	8.8	8.85	45.5	1452	2132.6	Haumi big 25	33.57
26	8.3	8.4	8.35	47.8	1560	2291.3	Haumi big 26	32.61
27	8.0	7.8	7.90	48.4	1430	2100.3	Haumi big 27	31.72
28	8.4	8.5	8.45	51.5	1538	2258.9	Haumi big 28	32.80
29	7.3	7.1	7.20	37.1	1257	1846.2	Haumi big 29	30.28
30	7.2	7.0	7.10	43.0	1408	2068.0	Haumi big 30	30.07
31	5.6	5.5	5.55	36.1	1257	1846.2	Haumi big 31	26.58
32	5.6	5.8	5.70	35.4	1192	1750.8	Haumi big 32	26.94
33	8.0	8.1	8.05	51.5	1798	2640.8	Haumi big 33	32.01
34	8.3	8.2	8.25	51.3	1755	2577.7	Haumi big 34	32.41
35	6.1	6.0	6.05	35.9	1257	1846.2	Haumi big 35	27.75
36	6.1	5.9	6.00	35.0	1257	1846.2	Haumi big 36	27.64
37	5.2	5.3	5.25	28.5	1083	1590.7	Haumi big 37	25.85
38	5.2	5.0	5.10	33.4	1213	1781.6	Haumi big 38	25.48
39	7.1	7.2	7.15	43.9	1517	2228.1	Haumi big 39	30.17
40	9.0	8.8	8.90	49.6	1517	2228.1	Haumi big 40	33.66
41	4.6	4.6	4.60	25.4	997	1464.3	Haumi big 41	24.20
42	4.6	4.7	4.65	21.7	953	1399.7	Haumi big 42	24.33
43	7.3	7.3	7.30	39.2	1408	2068.0	Haumi big 43	30.49
44	9.4	9.5	9.45	60.2	1993	2927.2	Haumi big 44	34.69
45	5.9	5.7	5.80	35.0	1192	1750.8	Haumi big 45	27.17
46	5.4	5.4	5.40	32.6	1148	1686.1	Haumi big 46	26.22
47	1.1	1.2	1.15	6.3	412	605.1	Haumi big 47	12.10
48	1.2	1.0	1.10	5.6	368	540.5	Haumi big 48	11.83
49	2.8	2.6	2.70	11.5	650	954.7	Haumi big 49	18.54
50	2.5	2.7	2.60	13.3	628	922.4	Haumi big 50	18.19
51	2.4	2.2	2.30	12.9	628	922.4	Haumi big 51	17.11
52	2.3	2.1	2.20	11.9	607	891.5	Haumi big 52	16.74
53	1.6	1.4	1.50	5.2	412	605.1	Haumi big 53	13.82
54	1.3	1.3	1.30	6.7	412	605.1	Haumi big 54	12.87
55	3.2	3.0	3.10	15.2	780	1145.6	Haumi big 55	19.87
56	2.1	2.2	2.15	10.8	628	922.4	Haumi big 56	16.55
57	1.5	1.5	1.50	6.0	433	636.0	Haumi big 57	13.82
58	1.6	1.5	1.55	6.1	412	605.1	Haumi big 58	14.05
59	1.2	1.2	1.20	5.5	477	700.6	Haumi big 59	12.36
60	1.3	1.3	1.30	6.5	498	731.4	Haumi big 60	12.87
61	1.3	1.1	1.20	6.4	433	636.0	Haumi big 61	12.36
62	1.0	1.0	1.00	5.3	412	605.1	Haumi big 62	11.28
63	22.5	22.6	22.55	168.5	3510	5155.3	Haumi big 63	53.58
64	26.3	26.4	26.35	173.0	3510	5155.3	Haumi big 64	57.92
65	12.6	12.6	12.60	67.5	1842	2705.4	Haumi big 65	40.05
66	11.9	11.9	11.90	60.4	1798	2640.8	Haumi big 66	38.92

67	14.2	14.2	14.20	94.5	2708	3977.4	Haumi big 67	42.52
68	13.7	13.7	13.70	86.0	2470	3627.8	Haumi big 68	41.77
69	16.2	16.1	16.15	98.8	2578	3786.4	Haumi big 69	45.35
70	11.4	11.5	11.45	63.6	1863	2736.3	Haumi big 70	38.18
71	10.9	10.8	10.85	68.8	1798	2640.8	Haumi big 71	37.17
72	9.2	9.1	9.15	61.9	1712	2514.5	Haumi big 72	34.13
73	11.6	11.6	11.60	78.0	2253	3309.1	Haumi big 73	38.43
74	11.0	10.9	10.95	73.6	2123	3118.2	Haumi big 74	37.34
75	16.4	16.3	16.35	104.4	2621	3849.6	Haumi big 75	45.63
76	16.0	15.7	15.85	104.6	2491	3658.7	Haumi big 76	44.92
77	26.1	26.3	26.20	262.9	5693	8361.6	Haumi big 79	57.76
78	20.1	20.0	20.05	169.3	3832	5628.3	Haumi big 80	50.53
79	18.9	18.9	18.90	167.1	3767	5532.8	Haumi big 81	49.06
80	22.7	22.5	22.60	231	5244	7702.1	Haumi big 82	53.64
81	20.3	20.2	20.25	205.9	4811	7066.2	Haumi big 83	50.78
82	20.4	20.5	20.45	191.3	4269	6270.1	Haumi big 84	51.03
83	18.9	18.9	18.90	184.9	4291	6302.4	Haumi big 85	49.06
84	17.8	17.8	17.80	164.9	3662	5378.6	Haumi big 86	47.61
85	17.0	17.1	17.05	150.6	3706	5443.2	Haumi big 87	46.59
86	15.2	15.0	15.10	115.7	2817	4137.5	Haumi big 88	43.85
87	14.4	14.3	14.35	103.7	2795	4105.2	Haumi big 89	42.74
88	15.8	16.0	15.90	121.1	3142	4614.8	Haumi big 90	44.99
89	15.9	15.9	15.90	143.6	3684	5410.9	Haumi big 91	44.99
90	18.2	18.1	18.15	167.7	4356	6397.9	Haumi big 92	48.07
91	21.1	20.9	21.00	182.7	4334	6365.6	Haumi big 93	51.71
92	16.7	16.4	16.55	133.5	3402	4996.7	Haumi big 94	45.90
93	26.2	26.2	26.20	230.5	4572	6715.1	Haumi big 97	57.76
94	32.4	32.3	32.35	359.6	6652	9770.1	Haumi big 95	64.18
95	31.5	31.6	31.55	335.9	6175	9069.5	Haumi big 96	63.38



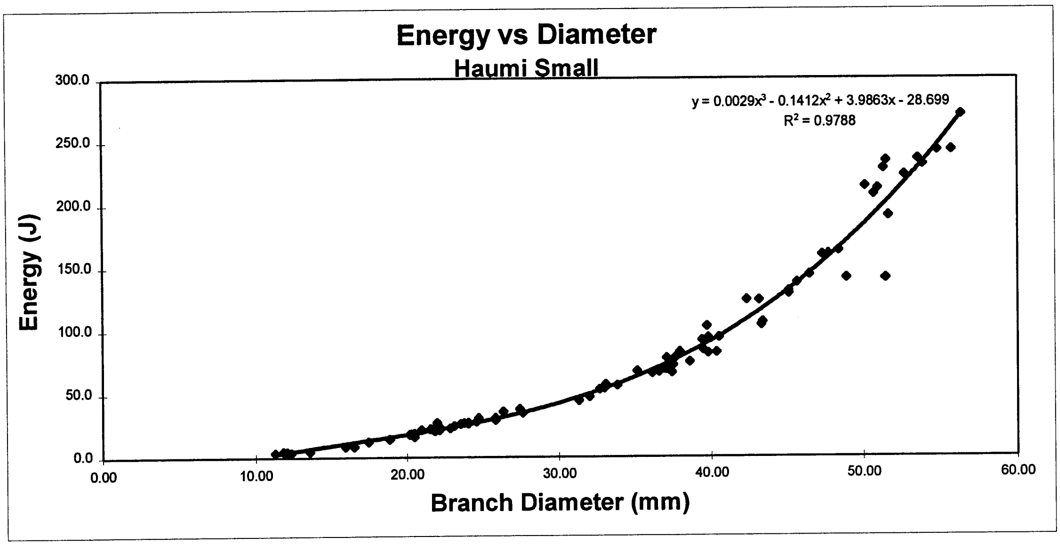


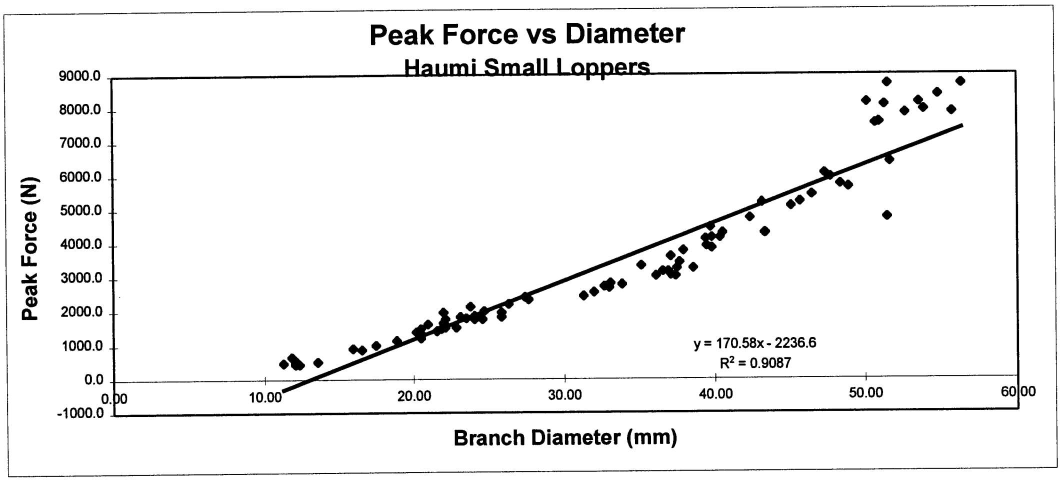
Haumi Pruner (new, standard)

Weight: 1.85 kg
Overall Length: 615mm

sample	Planimeter area (cm^2)			Energy	Force	Peak Force	Test Works	Branch
	Run 1	Run 2	Average	(Joules)	(N)	(Newtons)	File #	diameter (mm)
1	25	24.9	24.95	270.7	5477	8698.8	Haumi small 1	56.36
2	23.7	23.5	23.60	242.5	5282	8389.1	Haumi small 2	54.82
3	1.2	1.1	1.15	4.4	346	549.5	Haumi small 3	12.10
4	1.1	0.9	1.00	3.8	303	481.2	Haumi small 4	11.28
5	1.2	1.1	1.15	4.4	325	516.2	Haumi small 5	12.10
6	1.2	1.1	1.15	3.8	325	516.2	Haumi small 6	12.10
7	1.1	1.1	1.10	4.8	411	652.8	Haumi small 7	11.83
8	1.5	1.4	1.45	4.6	325	516.2	Haumi small 8	13.59
9	1.2	1.2	1.20	3.7	281	446.3	Haumi small 9	12.36
10	1.1	1.2	1.15	3.2	281	446.3	Haumi small 10	12.10
11	18.3	18.5	18.40	163.1	3615	5741.5	Haumi small 11	48.40
12	17.9	17.9	17.90	160.4	3745	5947.9	Haumi small 12	47.74
13	17.1	16.9	17.00	144.0	3420	5431.8	Haumi small 13	46.52
14	16	16	16.00	130.9	3204	5088.7	Haumi small 14	45.14
15	14.6	14.7	14.65	124.2	3269	5191.9	Haumi small 15	43.19
16	14	14.2	14.10	124.4	2987	4744.1	Haumi small 16	42.37
17	12.3	12.1	12.20	92.3	2598	4126.2	Haumi small 17	39.41
18	11.2	11.4	11.30	83.3	2381	3781.6	Haumi small 18	37.93
19	13	12.8	12.90	94.9	2706	4297.8	Haumi small 19	40.53
20	12.3	12.2	12.25	84.7	2468	3919.8	Haumi small 20	39.49
21	10.9	10.7	10.80	78.2	2273	3610.1	Haumi small 21	37.08
22	11.1	11.2	11.15	78.7	2165	3438.5	Haumi small 22	37.68
23	9.7	9.7	9.70	67.9	2100	3335.3	Haumi small 23	35.14
24	10.4	10.6	10.50	67.1	1991	3162.2	Haumi small 24	36.56
25	12.7	12.9	12.80	82.9	2619	4159.6	Haumi small 25	40.37
26	12.5	12.4	12.45	82.3	2424	3849.9	Haumi small 26	39.81
27	10.8	10.6	10.70	69.4	1991	3162.2	Haumi small 27	36.91
28	10.2	10.3	10.25	66.1	1905	3025.6	Haumi small 28	36.13
29	11	11	11.00	66.9	1905	3025.6	Haumi small 29	37.42
30	10.8	10.8	10.80	69.3	1927	3060.5	Haumi small 30	37.08
31	14.8	14.8	14.80	106.6	2706	4297.8	Haumi small 31	43.41
32	14.7	14.8	14.75	104.4	2706	4297.8	Haumi small 32	43.34
33	8.5	8.7	8.60	57.2	1775	2819.1	Haumi small 33	33.09
34	8.5	8.6	8.55	54.3	1688	2680.9	Haumi small 34	32.99
35	9	9	9.00	56.7	1753	2784.2	Haumi small 35	33.85
36	8.4	8.4	8.40	53.4	1710	2715.9	Haumi small 36	32.70
37	11.6	11.8	11.70	75.3	2056	3265.4	Haumi small 37	38.60
38	11	11.1	11.05	72.6	2056	3265.4	Haumi small 38	37.51
39	5.8	6	5.90	37.8	1515	2406.2	Haumi small 39	27.41
40	6	6	6.00	34.9	1472	2337.9	Haumi small 40	27.64
41	5.4	5.5	5.45	36.0	1385	2199.7	Haumi small 41	26.34
42	4.7	4.8	4.75	27.8	1104	1753.4	Haumi small 42	24.59
43	3.9	3.8	3.85	23.9	952	1512.0	Haumi small 43	22.14
44	3.6	3.7	3.65	22.2	888	1410.4	Haumi small 44	21.56
45	8.1	8	8.05	47.5	1602	2544.4	Haumi small 45	32.01
46	7.8	7.6	7.70	44.7	1537	2441.1	Haumi small 46	31.31
47	4.8	4.8	4.80	30.9	1255	1993.2	Haumi small 47	24.72
48	4.5	4.6	4.55	27.4	1104	1753.4	Haumi small 48	24.07
49	3.8	3.8	3.80	27.3	1234	1959.9	Haumi small 49	22.00
50	3.7	3.9	3.80	24.6	1039	1650.2	Haumi small 50	22.00
51	4.2	4	4.10	23.0	952	1512.0	Haumi small 51	22.85
52	3.8	3.7	3.75	20.7	931	1478.6	Haumi small 52	21.85
53	5.2	5.3	5.25	30.9	1234	1959.9	Haumi small 53	25.85
54	5.3	5.2	5.25	29.3	1147	1821.7	Haumi small 54	25.85
55	3.9	3.8	3.85	23.4	1104	1753.4	Haumi small 55	22.14
56	3.9	3.8	3.85	21.2	996	1581.9	Haumi small 56	22.14
57	4.6	4.5	4.55	26.6	1169	1856.6	Haumi small 57	24.07
58	4.5	4.4	4.45	26.8	1342	2131.4	Haumi small 58	23.80
59	4.3	4.4	4.35	26.2	1126	1788.4	Haumi small 59	23.53
60	4.1	4.3	4.20	24.5	1147	1821.7	Haumi small 60	23.12
61	3.4	3.2	3.30	19.1	931	1478.6	Haumi small 61	20.50
62	3.3	3.3	3.30	17.4	844	1340.5	Haumi small 62	20.50
63	3.2	3.2	3.20	18.1	866	1375.4	Haumi small 63	20.19
64	3.3	3.3	3.30	16.1	758	1203.9	Haumi small 64	20.50
65	2.2	2.1	2.15	8.4	541	859.2	Haumi small 65	16.55
66	2	2	2.00	8.4	563	894.2	Haumi small 66	15.96
67	2.8	2.8	2.80	14.4	714	1134.0	Haumi small 67	18.88

68	2.5	2.3	2.40	12.4	628	997.4	Haumi small 68	17.48
69	3.4	3.5	3.45	21.5	1017	1615.2	Haumi small 69	20.96
70	3.2	3.3	3.25	18.4	866	1375.4	Haumi small 70	20.34
71	22.9	22.7	22.80	231.1	5000	7941.2	Haumi small 71	53.88
72	24.5	24.3	24.40	242.9	4957	7872.9	Haumi small 72	55.74
73	16.4	16.4	16.40	137.6	3290	5225.3	Haumi small 73	45.70
74	16.1	15.9	16.00	129.0	3204	5088.7	Haumi small 74	45.14
75	12.5	12.3	12.40	103.5	2814	4469.3	Haumi small 75	39.73
76	12.4	12.5	12.45	94.3	2619	4159.6	Haumi small 76	39.81
77	18.9	18.7	18.80	141.5	3554	5644.6	Haumi small 77	48.93
78	20.9	20.7	20.80	140.9	2990	4748.8	Haumi small 78	51.46
79	22.5	22.6	22.55	235.5	5136	8157.2	Haumi small 79	53.58
80	20.7	20.7	20.70	227.7	5092	8087.3	Haumi small 80	51.34
81	20.1	20.3	20.20	207.5	4746	7537.8	Haumi small 81	50.71
82	21.9	21.7	21.80	222.7	4941	7847.5	Haumi small 82	52.68
83	21.1	20.8	20.95	190.6	4030	6400.6	Haumi small 83	51.65
84	17.6	17.6	17.60	159.6	3814	6057.5	Haumi small 84	47.34
85	20.5	20.3	20.40	212.2	4769	7574.3	Haumi small 85	50.96
86	19.8	19.7	19.75	214.0	5136	8157.2	Haumi small 86	50.15
87	20.9	20.8	20.85	234.0	5482	8706.7	Haumi small 87	51.52



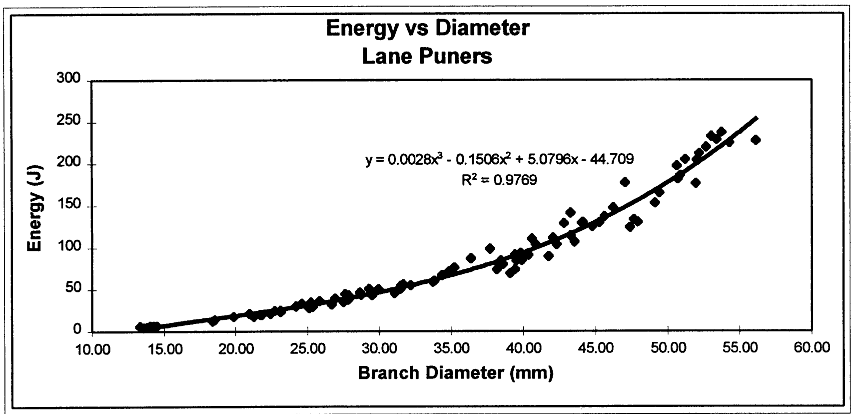


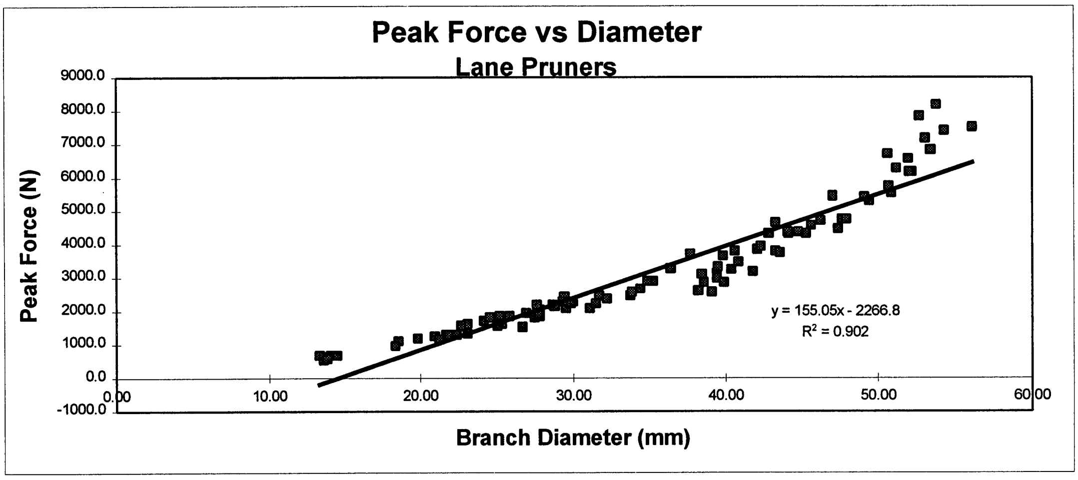
Lane Pruners (used)

Weight: 1.84 kg
Overall length: 568mm

sample	Planimeter area (cm^2)			Energy	Force	Peak Force	Test Works	Branch
	Run 1	Run 2	Average	(Joules)	(N)	(N)	File	diameter (mm)
1	6.8	6.9	6.85	42.7	953	2089.3	lane2	29.53
2	6.9	6.7	6.80	48.7	1105	2422.5	lane3	29.42
3	6.7	6.8	6.75	50.6	1040	2280.0	lane4	29.32
4	6.1	6.1	6.10	43.1	931	2041.0	lane5	27.87
5	4.7	4.5	4.60	29.6	780	1710.0	lane6	24.20
6	3.4	3.5	3.45	20.8	563	1234.3	lane7	20.96
7	3.7	3.7	3.70	19.9	585	1282.5	lane8	21.70
8	4	3.9	3.95	20.8	585	1282.5	lane9	22.43
9	2.7	2.7	2.70	13.7	498	1091.8	lane10	18.54
10	4.2	4.2	4.20	22.8	606	1328.5	lane11	23.12
11	5	5	5.00	34.5	845	1852.5	lane12	25.23
12	6	6	6.00	37.8	866	1898.5	lane13	27.64
13	5.1	5	5.05	29.2	736	1613.5	lane14	25.36
14	6.5	6.4	6.45	46.3	996	2183.5	lane15	28.66
15	7.9	7.9	7.90	56.1	1126	2468.5	lane16	31.72
16	7.8	7.8	7.80	54.6	1018	2231.8	lane17	31.51
17	5.6	5.6	5.60	31.8	693	1519.3	lane18	26.70
18	11.2	11.1	11.15	98.1	1689	3702.8	lane19	37.68
19	9.7	9.8	9.75	75.7	1321	2896.0	lane20	35.23
20	12.5	12.4	12.45	93.5	1668	3656.8	lane21	39.81
21	12.2	12.2	12.20	91.3	1430	3135.0	lane22	39.41
22	11.6	11.6	11.60	84.2	1408	3086.8	lane23	38.43
23	15.2	15.4	15.30	129.9	1971	4321.0	lane24	44.14
24	20.2	20.1	20.15	196.9	3054	6695.3	lane25	50.65
25	20.3	20.4	20.35	186	2534	5555.3	lane26	50.90
26	13.9	13.9	13.90	111.2	1754	3845.3	lane27	42.07
27	7.1	7	7.05	50.3	1040	2280.0	lane28	29.96
28	7	7	7.00	48.8	1018	2231.8	lane29	29.85
29	5.9	6.1	6.00	44.2	996	2183.5	lane30	27.64
30	5.8	5.6	5.70	39.2	888	1946.8	lane31	26.94
31	6.2	6	6.10	38	845	1852.5	lane32	27.87
32	5.3	5.2	5.25	36.3	845	1852.5	lane33	25.85
33	4.8	4.7	4.75	33.1	823	1804.3	lane34	24.59
34	11.6	11.8	11.70	80	1300	2850.0	lane35	38.60
35	12.2	12.3	12.25	84.2	1516	3323.5	lane36	39.49
36	10.5	10.3	10.40	86.9	1495	3277.5	lane37	36.39
37	13.2	13	13.10	104.1	1581	3466.0	lane38	40.84
38	16.1	16.1	16.10	129.5	1971	4321.0	lane39	45.28
39	20.3	20.1	20.20	181.2	2621	5746.0	lane40	50.71
40	14.8	14.6	14.70	113.8	1733	3799.3	lane41	43.26
41	9.3	9.3	9.30	66.7	1213	2659.3	lane42	34.41
42	8.2	8.1	8.15	54.7	1083	2374.3	lane43	32.21
43	6	6.1	6.05	37.7	866	1898.5	lane44	27.75
44	7.7	7.5	7.60	45.4	953	2089.3	lane45	31.11
45	5.9	6	5.95	35.2	823	1804.3	lane46	27.52
46	3.1	3.1	3.10	17.1	541	1186.0	lane47	19.87
47	1.6	1.5	1.55	6.4	303	664.3	lane48	14.05
48	1.6	1.6	1.60	6.4	303	664.3	lane49	14.27
49	1.7	1.6	1.65	6.1	303	664.3	lane50	14.49
50	1.5	1.4	1.45	4.1	238	521.8	lane51	13.59
51	1.4	1.4	1.40	5.5	303	664.3	lane52	13.35
52	1.6	1.4	1.50	4.7	260	570.0	lane53	13.82
53	12.2	12.2	12.20	73.7	1365	2992.5	lane54	39.41
54	12.8	12.8	12.80	90.9	1473	3229.3	lane55	40.37
55	11.4	11.5	11.45	73.6	1191	2611.0	lane56	38.18
56	15.8	15.7	15.75	124.7	1993	4369.3	lane57	44.78
57	14	14.1	14.05	103.7	1798	3941.8	lane58	42.30
58	19.2	19.2	19.20	165.3	2426	5318.5	lane59	49.44
59	9.6	9.5	9.55	71.2	1321	2896.0	lane60	34.87
60	8.9	9	8.95	58.9	1126	2468.5	lane61	33.76
61	7.9	7.7	7.80	50.9	1018	2231.8	lane62	31.51
62	9.1	8.9	9.00	60	1170	2565.0	lane63	33.85
63	6.5	6.5	6.50	43.5	975	2137.5	lane64	28.77
64	4.9	5	4.95	27.8	715	1567.5	lane65	25.10
65	6	6.1	6.05	39.1	866	1898.5	lane66	27.75
66	14.9	14.9	14.90	106.4	1711	3751.0	lane67	43.56
67	13.8	13.6	13.70	89.6	1451	3181.0	lane68	41.77

68	19	18.9	18.95	153	2469	5412.8	lane69	49.12
69	12.6	12.4	12.50	84.9	1300	2850.0	lane70	39.89
70	12	12	12.00	68.8	1170	2565.0	lane71	39.09
71	3.6	3.5	3.55	17.3	520	1140.0	lane72	21.26
72	2.7	2.6	2.65	12.2	433	949.3	lane73	18.37
73	3.8	3.7	3.75	19.7	585	1282.5	lane74	21.85
74	4.2	4.2	4.20	24.9	736	1613.5	lane75	23.12
75	4	4.1	4.05	24.5	715	1567.5	lane76	22.71
76	17.9	17.8	17.85	133.3	2166	4748.5	lane77	47.67
77	18.1	18	18.05	130.3	2166	4748.5	lane78	47.94
78	17.7	17.6	17.65	123.8	2036	4463.5	lane79	47.41
79	17.5	17.3	17.40	177	2491	5461.0	lane80	47.07
80	16.8	16.8	16.80	147.2	2144	4700.3	lane81	46.25
81	13	12.9	12.95	110.5	1733	3799.3	lane82	40.61
82	14.7	14.7	14.70	141.3	2122	4652.1	lane83	43.26
83	14.3	14.5	14.40	128.6	1971	4321.0	lane84	42.82
84	22.6	22.8	22.70	237.4	3723	8162.0	lane86	53.76
85	22.2	22	22.10	232.6	3269	7166.7	lane87	53.05
86	22.5	22.3	22.40	228.2	3117	6833.4	lane88	53.40
87	20.6	20.6	20.60	204.8	2857	6263.4	lane89	51.21
88	16.3	16.4	16.35	137.1	2078	4555.6	lane90	45.63
89	15.3	15.2	15.25	129.1	1992	4367.1	lane91	44.06
90	21.9	21.7	21.80	219.4	3575	7837.5	lane92	52.68
91	21.1	21.3	21.20	176.0	2990	6555.0	lane93	51.95
92	21.5	21.3	21.40	212.1	2817	6175.7	lane94	52.20
93	21.3	21.2	21.25	204.1	2817	6175.7	lane95	52.02
94	24.7	24.8	24.75	227.3	3423	7504.3	lane96	56.14
95	23.1	23.2	23.15	224.5	3380	7410.0	lane97	54.29

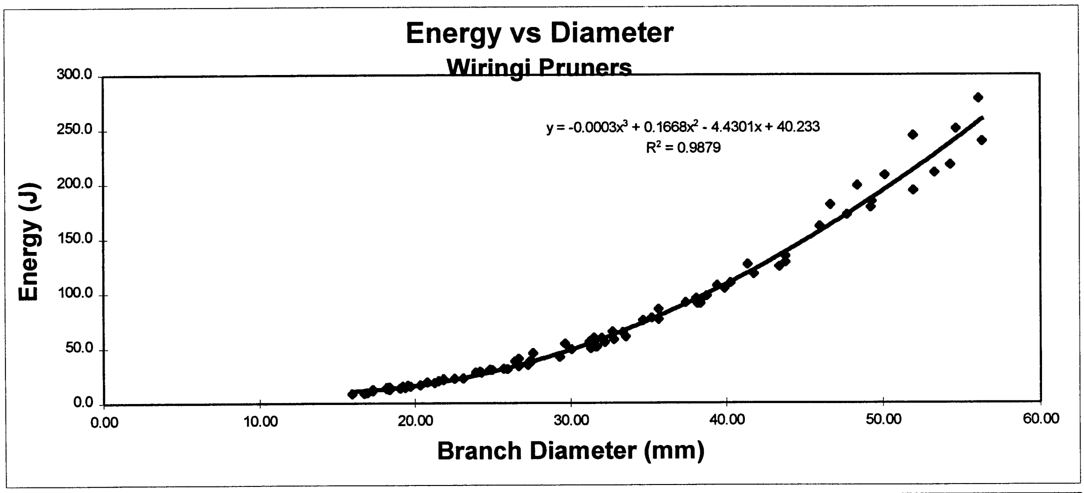


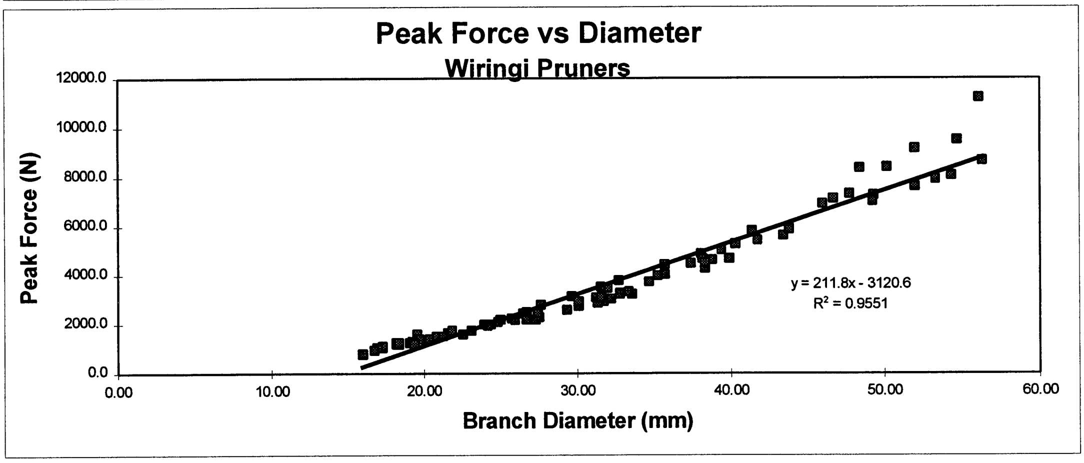


Wiringi Pruners (new, standard)
Weight: 1.58 kg
Overall Length: 700mm

Sample	Planimeter area (cm^2) Run 1	Run 2	Average	Energy (Joules)	Force (N)	Peak Force (N)	Test Works File #	Branch diameter (mm)
1	1.9	2.1	2.00	8.3	325	748.1	Wiringi 1	15.96
2	2.0	2.0	2.00	8.2	347	798.8	Wiringi 2	15.96
3	2.8	2.5	2.65	12.1	498	1146.3	Wiringi 3	18.37
4	2.4	2.3	2.35	10.9	455	1047.4	Wiringi 4	17.30
5	2.6	2.6	2.60	13.6	520	1197.0	Wiringi 5	18.19
6	2.3	2.4	2.35	12.1	477	1098.0	Wiringi 6	17.30
7	4.2	4.2	4.20	22.5	758	1744.8	Wiringi 7	23.12
8	4.0	4.0	4.00	21.9	693	1595.2	Wiringi 8	22.57
9	2.9	2.8	2.85	13.4	542	1247.6	Wiringi 9	19.05
10	2.7	2.5	2.60	13.0	542	1247.6	Wiringi 10	18.19
11	3.8	3.7	3.75	21.6	737	1696.5	Wiringi 11	21.85
12	3.7	3.6	3.65	20.0	715	1645.8	Wiringi 12	21.56
13	3.0	3.0	3.00	15.7	693	1595.2	Wiringi 13	19.54
14	2.6	2.7	2.65	14.0	542	1247.6	Wiringi 14	18.37
15	3.2	3.3	3.25	16.0	607	1397.2	Wiringi 15	20.34
16	3.0	3.1	3.05	15.1	607	1397.2	Wiringi 16	19.71
17	18.5	18.3	18.40	198.4	3639	8376.6	Wiringi 17	48.40
18	17.2	17.0	17.10	180.7	3098	7131.2	Wiringi 18	46.66
19	24.9	24.9	24.90	238.9	3769	8675.8	Wiringi 19	56.31
20	23.1	23.2	23.15	217.5	3509	8077.3	Wiringi 20	54.29
21	15.1	15.0	15.05	133.9	2578	5934.3	Wiringi 21	43.77
22	14.7	14.9	14.80	124.3	2448	5635.0	Wiringi 22	43.41
23	12.9	12.6	12.75	109.3	2296	5285.1	Wiringi 23	40.29
24	11.8	11.8	11.80	97.6	2015	4638.3	Wiringi 24	38.76
25	11.5	11.3	11.40	95.4	2123	4886.9	Wiringi 25	38.10
26	11.1	10.9	11.00	91.4	1950	4488.7	Wiringi 26	37.42
27	13.3	13.6	13.45	126.2	2534	5833.0	Wiringi 27	41.38
28	12.3	12.1	12.20	106.9	2188	5036.5	Wiringi 28	39.41
29	12.5	12.5	12.50	104.4	2036	4686.6	Wiringi 29	39.89
30	11.6	11.5	11.55	93.8	1863	4288.4	Wiringi 30	38.35
31	8.7	9.0	8.85	60.3	1408	3241.1	Wiringi 31	33.57
32	7.8	7.9	7.85	51.1	1386	3190.4	Wiringi 32	31.61
33	8.5	8.3	8.40	65.1	1646	3788.9	Wiringi 33	32.70
34	8.0	8.1	8.05	58.9	1516	3489.7	Wiringi 34	32.01
35	8.4	8.5	8.45	57.7	1430	3291.7	Wiringi 35	32.80
36	8.0	7.8	7.90	51.2	1278	2941.8	Wiringi 36	31.72
37	7.8	7.8	7.80	59.4	1538	3540.3	Wiringi 37	31.51
38	7.7	7.6	7.65	55.5	1343	3091.4	Wiringi 38	31.21
39	8.1	8.2	8.15	55.1	1321	3040.8	Wiringi 39	32.21
40	7.6	7.8	7.70	49.6	1235	2842.8	Wiringi 40	31.31
41	10.1	9.9	10.00	76.0	1755	4039.8	Wiringi 41	35.68
42	9.8	9.7	9.75	77.7	1733	3989.2	Wiringi 42	35.23
43	10.1	9.9	10.00	85.4	1928	4438.0	Wiringi 43	35.68
44	9.5	9.4	9.45	75.3	1625	3740.6	Wiringi 44	34.69
45	8.8	8.7	8.75	64.1	1451	3340.0	Wiringi 45	33.38
46	8.4	8.5	8.45	57.7	1408	3241.1	Wiringi 46	32.80
47	7.8	7.8	7.80	54.6	1343	3091.4	Wiringi 47	31.51
48	7.2	7.0	7.10	48.9	1191	2741.5	Wiringi 48	30.07
49	6.9	6.9	6.90	53.9	1365	3142.1	Wiringi 49	29.64
50	6.0	6.0	6.00	45.2	1213	2792.2	Wiringi 50	27.64
51	6.0	5.9	5.95	37.8	996	2292.7	Wiringi 51	27.52
52	5.9	5.8	5.85	34.5	953	2193.7	Wiringi 52	27.29
53	5.2	5.2	5.20	31.1	975	2244.3	Wiringi 53	25.73
54	6.0	5.8	5.90	37.6	1061	2442.3	Wiringi 54	27.41
55	5.5	5.7	5.60	40.3	1083	2492.9	Wiringi 55	26.70
56	5.6	5.4	5.50	37.7	1061	2442.3	Wiringi 56	26.46
57	4.6	4.4	4.50	27.4	866	1993.4	Wiringi 57	23.94
58	3.8	3.7	3.75	20.8	758	1744.8	Wiringi 58	21.85
59	5.7	5.5	5.60	33.5	953	2193.7	Wiringi 59	26.70
60	5.4	5.2	5.30	30.6	931	2143.1	Wiringi 60	25.98
61	5.0	4.8	4.90	29.9	953	2193.7	Wiringi 61	24.98
62	4.7	4.6	4.65	27.4	866	1993.4	Wiringi 62	24.33
63	4.9	4.8	4.85	30.5	910	2094.7	Wiringi 63	24.85
64	4.7	4.5	4.60	28.3	845	1945.1	Wiringi 64	24.20
65	3.0	2.8	2.90	14.8	563	1296.0	Wiringi 65	19.22
66	3.0	2.9	2.95	13.7	520	1197.0	Wiringi 66	19.38
67	3.4	3.4	3.40	18.8	650	1496.2	Wiringi 67	20.81

68	3.6	3.5	3.55	18.3	650	1496.2	Wiringi 68	21.26
69	2.2	2.3	2.25	9.2	455	1047.4	Wiringi 69	16.93
70	2.2	2.2	2.20	8.7	412	948.4	Wiringi 70	16.74
71	7.0	7.2	7.10	48.7	1278	2941.8	Wiringi 71	30.07
72	6.7	6.8	6.75	41.8	1126	2591.9	Wiringi 72	29.32
73	11.5	11.4	11.45	90.4	2036	4686.6	Wiringi 73	38.18
74	11.6	11.5	11.55	90.6	1971	4537.0	Wiringi 74	38.35
75	18.0	17.8	17.90	171.8	3184	7329.2	Wiringi 75	47.74
76	16.7	16.5	16.60	160.9	3011	6931.0	Wiringi 76	45.97
77	15.0	15.1	15.05	128.3	2556	5883.6	Wiringi 77	43.77
78	13.8	13.6	13.70	117.9	2361	5434.8	Wiringi 78	41.77
79	19.1	19.1	19.10	184.0	3160	7274.0	Wiringi 79	49.31
80	19.1	19.0	19.05	178.4	3052	7025.4	Wiringi 80	49.25
81	22.2	22.4	22.30	210.4	3441	7920.8	Wiringi 81	53.29
82	21.1	21.3	21.20	193.7	3312	7623.8	Wiringi 82	51.95
83	24.8	24.6	24.70	277.9	4870	11210.2	Wiringi 83	56.08
84	23.3	23.6	23.45	250.4	4134	9516.0	Wiringi 84	54.64
85	21.3	21.1	21.20	243.9	3982	9166.1	Wiringi 85	51.95
86	19.7	19.8	19.75	207.9	3658	8420.3	Wiringi 86	50.15





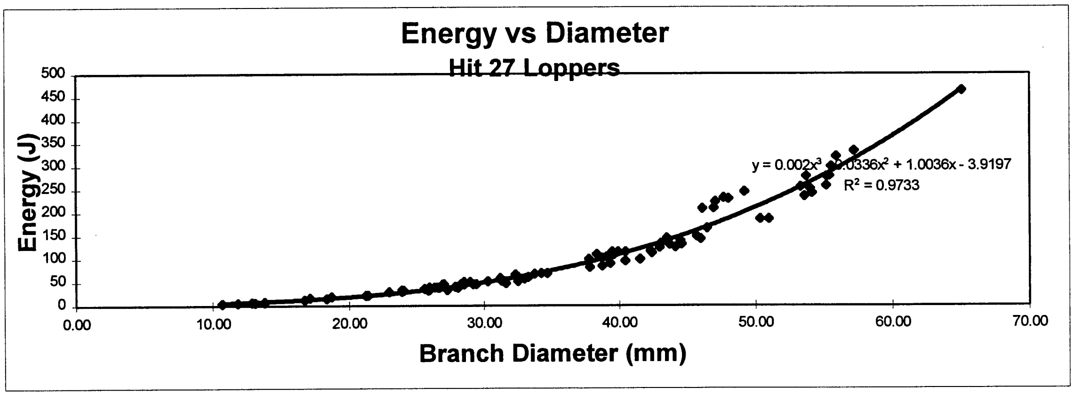
Hit 27 (new, standard)

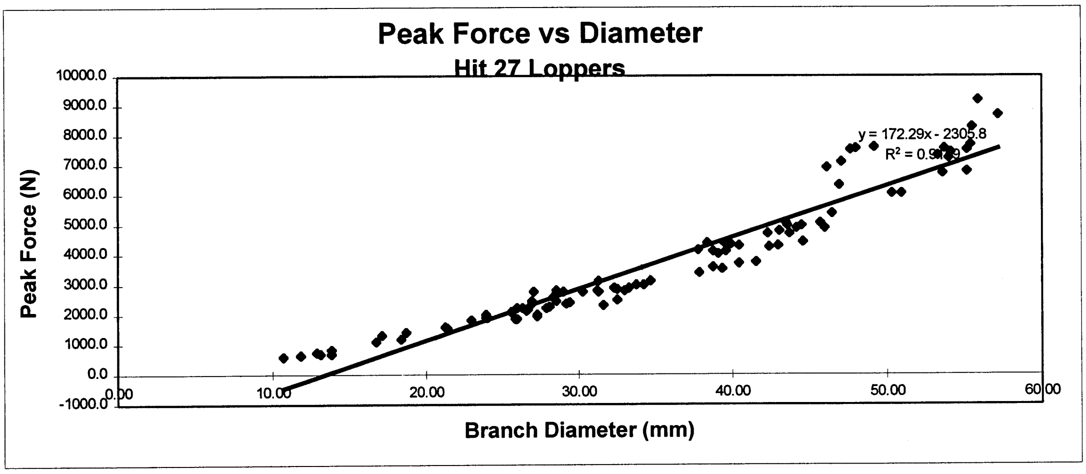
Weight: 2.28 kg

Overall Length: 702mm

sample	Planimeter area (cm^2)			Energy	Force	Peak Force	Test Works	Branch
	Run 1	Run 2	Average	(Joules)	(N)	(N)	File #	diameter (mm)
1	24.1	24.1	24.10	279	3682	7698.7	Hit 27 1	55.39
2	23.9	23.9	23.90	257.3	3249	6793.4	Hit 27 2	55.16
3	25.7	25.7	25.70	332.4	4158	8694.0	Hit 27 3	57.20
4	23.8	24	23.90	277.6	3595	7516.8	Hit 27 4	55.16
5	16.6	16.6	16.60	142.8	2339	4890.6	Hit 27 5	45.97
6	15.2	15.4	15.30	125.9	2339	4890.6	Hit 27 6	44.14
7	16.9	17	16.95	165.9	2577	5388.3	Hit 27 7	46.46
8	16.4	16.4	16.40	148.8	2426	5072.5	Hit 27 8	45.70
9	12.1	12.2	12.15	90.6	1689	3531.5	Hit 27 9	39.33
10	9.5	9.4	9.45	69.1	1494	3123.8	Hit 27 10	34.69
11	14.9	14.8	14.85	145.1	2426	5072.5	Hit 27 11	43.48
12	14.5	14.6	14.55	134.2	2296	4800.7	Hit 27 12	43.04
13	12.3	12.2	12.25	114.8	2101	4393.0	Hit 27 13	39.49
14	11.2	11.2	11.20	99.9	1992	4165.1	Hit 27 14	37.76
15	14.6	14.4	14.50	124.3	2057	4301.0	Hit 27 15	42.97
16	14.1	14	14.05	117.4	2252	4708.7	Hit 27 16	42.30
17	13.5	13.6	13.55	99.1	1798	3759.5	Hit 27 17	41.54
18	12.9	12.8	12.85	95.5	1776	3713.5	Hit 27 18	40.45
19	11.7	11.9	11.80	84.3	1711	3577.5	Hit 27 19	38.76
20	11.2	11.3	11.25	81.6	1624	3395.6	Hit 27 20	37.85
21	11.5	11.6	11.55	109.8	2101	4393.0	Hit 27 21	38.35
22	11.9	11.7	11.80	102.6	1971	4121.2	Hit 27 22	38.76
23	7.1	7.3	7.20	52.4	1321	2762.1	Hit 27 23	30.28
24	6.8	6.8	6.80	45.3	1148	2400.4	Hit 27 24	29.42
25	8.7	8.7	8.70	60.8	1386	2898.0	Hit 27 25	33.28
26	8.7	8.4	8.55	57.8	1343	2808.1	Hit 27 26	32.99
27	6.4	6.4	6.40	49.9	1343	2808.1	Hit 27 27	28.55
28	6.4	6.2	6.30	46.1	1234	2580.2	Hit 27 28	28.32
29	8.3	8.3	8.30	52.3	1191	2490.3	Hit 27 29	32.51
30	7.9	7.8	7.85	47.6	1105	2310.5	Hit 27 30	31.61
31	6.7	6.5	6.60	50.2	1321	2762.1	Hit 27 31	28.99
32	6.3	6.3	6.30	45.5	1234	2580.2	Hit 27 32	28.32
33	7.7	7.7	7.70	55.8	1494	3123.8	Hit 27 33	31.31
34	7.6	7.8	7.70	52.9	1321	2762.1	Hit 27 34	31.31
35	9	8.9	8.95	67.8	1429	2987.9	Hit 27 35	33.76
36	8.5	8.1	8.30	61.8	1364	2852.0	Hit 27 36	32.51
37	6.6	6.8	6.70	45.6	1126	2354.4	Hit 27 37	29.21
38	6.2	6.2	6.20	38.4	1083	2264.5	Hit 27 38	28.10
39	5.7	5.8	5.75	46	1321	2762.1	Hit 27 39	27.06
40	5.7	5.7	5.70	41.1	1169	2444.3	Hit 27 40	26.94
41	5.9	5.8	5.85	35.5	953	1992.6	Hit 27 41	27.29
42	5.8	5.9	5.85	33.7	931	1946.6	Hit 27 42	27.29
43	5.6	5.6	5.60	37.9	1040	2174.5	Hit 27 43	26.70
44	5.1	5.4	5.25	32.4	888	1856.7	Hit 27 44	25.85
45	6.5	6.3	6.40	44.8	1169	2444.3	Hit 27 45	28.55
46	6.2	6	6.10	39.5	1061	2218.5	Hit 27 46	27.87
47	5.5	5.4	5.45	39.2	1061	2218.5	Hit 27 47	26.34
48	5.3	5.3	5.30	33.8	888	1856.7	Hit 27 48	25.98
49	5.4	5.2	5.30	39.3	1061	2218.5	Hit 27 49	25.98
50	5.2	5.1	5.15	36.1	996	2082.5	Hit 27 50	25.61
51	4.4	4.6	4.50	32.3	953	1992.6	Hit 27 51	23.94
52	4.6	4.4	4.50	30.1	910	1902.7	Hit 27 52	23.94
53	2.3	2.3	2.30	16.2	628	1313.1	Hit 27 53	17.11
54	2.2	2.2	2.20	11.7	520	1087.3	Hit 27 54	16.74
55	2.7	2.8	2.75	18.2	671	1403.0	Hit 27 55	18.71
56	2.6	2.7	2.65	14.9	563	1177.2	Hit 27 56	18.37
57	3.7	3.5	3.60	21.1	736	1538.9	Hit 27 57	21.41
58	3.6	3.5	3.55	21.1	758	1584.9	Hit 27 58	21.26
59	4.5	4.6	4.55	31.2	910	1902.7	Hit 27 59	24.07
60	4.1	4.2	4.15	28.5	866	1810.7	Hit 27 60	22.99
61	5.6	5.8	5.70	44.2	1126	2354.4	Hit 27 61	26.94
62	5.5	5.6	5.55	39.2	1018	2128.5	Hit 27 62	26.58
63	1.6	1.4	1.50	7.3	390	815.5	Hit 27 63	13.82
64	1.6	1.4	1.50	6.3	325	679.5	Hit 27 64	13.82
65	1.3	1.3	1.30	6.5	347	725.5	Hit 27 65	12.87
66	1.3	1.4	1.35	6	325	679.5	Hit 27 66	13.11
67	1.1	1.1	1.10	5	303	633.5	Hit 27 67	11.83

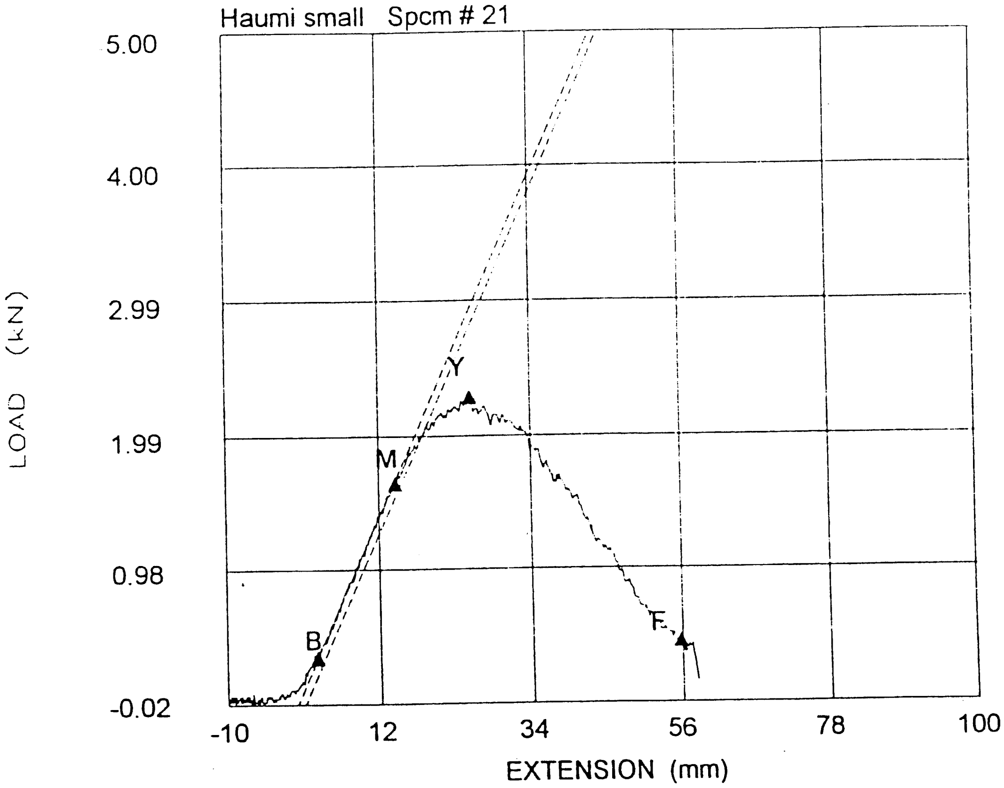
68	0.9	0.9	0.90	3.9	282	589.6	Hit 27 68	10.70
69	8.2	8.2	8.20	65.9	1386	2898.0	Hit 27 69	32.31
70	7.7	7.6	7.65	58.4	1343	2808.1	Hit 27 70	31.21
71	14.1	14.1	14.10	113.6	2036	4257.1	Hit 27 71	42.37
72	9.3	9.1	9.20	68.7	1430	2990.0	Hit 27 72	34.23
73	23.1	22.9	23.00	241.6	3552	7426.9	Hit 27 73	54.12
74	22.9	22.9	22.90	250.9	3466	7247.1	Hit 27 74	54.00
75	22.5	22.6	22.55	235.2	3227	6747.4	Hit 27 75	53.58
76	24.6	24.5	24.55	321	4397	9193.7	Hit 27 76	55.91
77	24.2	24.2	24.20	299	3964	8288.4	Hit 27 77	55.51
78	15.6	15.5	15.55	139.4	2381	4978.5	Hit 27 78	44.50
79	15	15	15.00	131	2251	4706.6	Hit 27 79	43.70
80	15.7	15.5	15.60	131.6	2121	4434.8	Hit 27 80	44.57
81	12.8	12.9	12.85	115.5	2057	4301.0	Hit 27 81	40.45
82	14.8	15	14.90	141.7	2381	4978.5	Hit 27 82	43.56
83	12.1	11.9	12.00	104.8	1927	4029.2	Hit 27 83	39.09
84	12.2	12.4	12.30	109.1	1970	4119.1	Hit 27 84	39.57
85	12.6	12.4	12.50	115.2	2078	4344.9	Hit 27 85	39.89
86	19.8	20	19.90	185.9	2902	6067.8	Hit 27 86	50.34
87	20.4	20.4	20.40	185.8	2902	6067.8	Hit 27 87	50.96
88	22.7	22.6	22.65	277.9	3617	7562.8	Hit 27 88	53.70
89	22.4	22.2	22.30	255.1	3509	7337.0	Hit 27 89	53.29
90	18.1	18.1	18.10	229.8	3617	7562.8	Hit 27 90	48.01
91	16.6	16.8	16.70	208.5	3314	6929.3	Hit 27 91	46.11
92	17.5	17.3	17.40	223.4	3401	7111.2	Hit 27 92	47.07
93	17.2	17.4	17.30	208.8	3032	6339.6	Hit 27 93	46.93
94	19.1	18.9	19.00	244.4	3639	7608.8	Hit 27 94	49.18
95	17.9	17.8	17.85	231.5	3595	7516.8	Hit 27 95	47.67
96	33.2	33.3	33.25	463.3	5872	12277.8	Hit 27 96	65.07



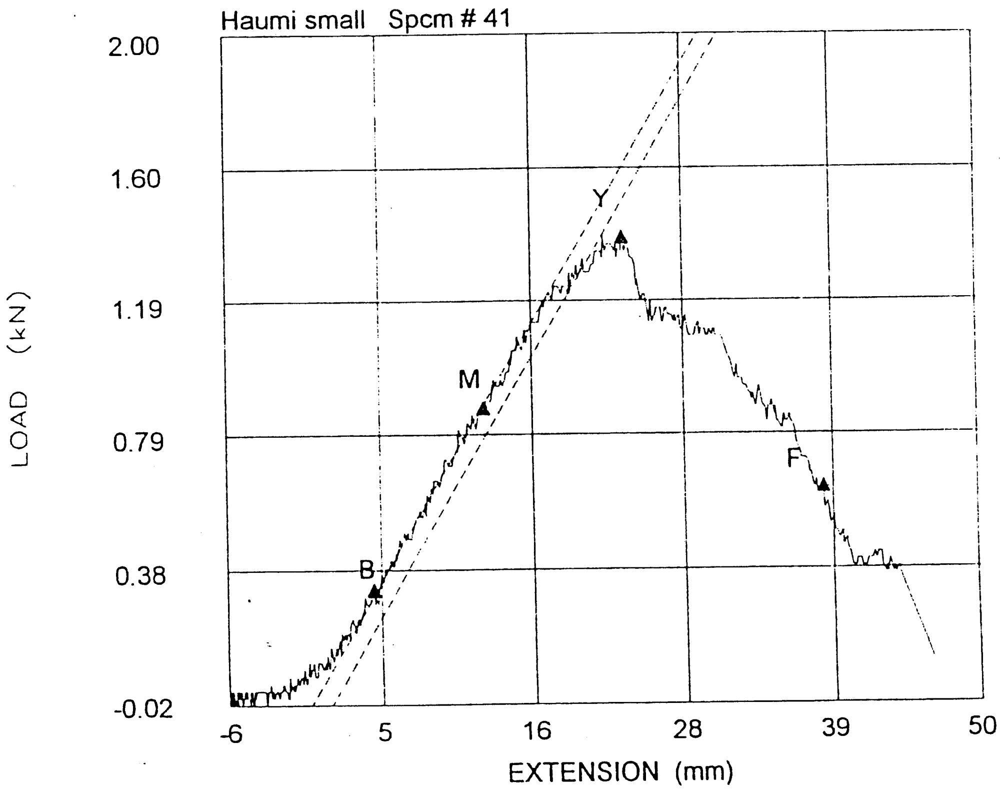


Appendix 4 - Force verse Displacement Graphs

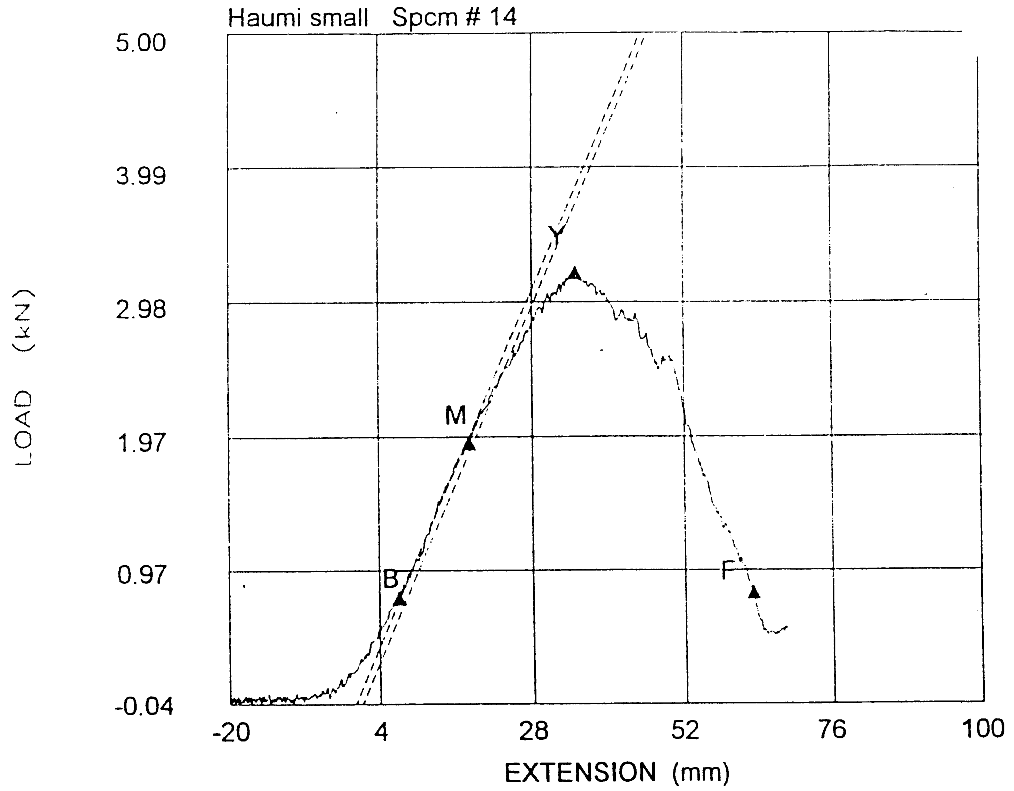
This appendix presents a sample of force verse displacement graphs for each of the loppers tested. These graphs were taken from 'Testworks,' the associated Test Rig program. The graphs were chosen as they represent cuts of approximately 25mm, 35mm, 45mm and 55mm in diameter. The particular graphs were chosen randomly provided they were in the above size range.



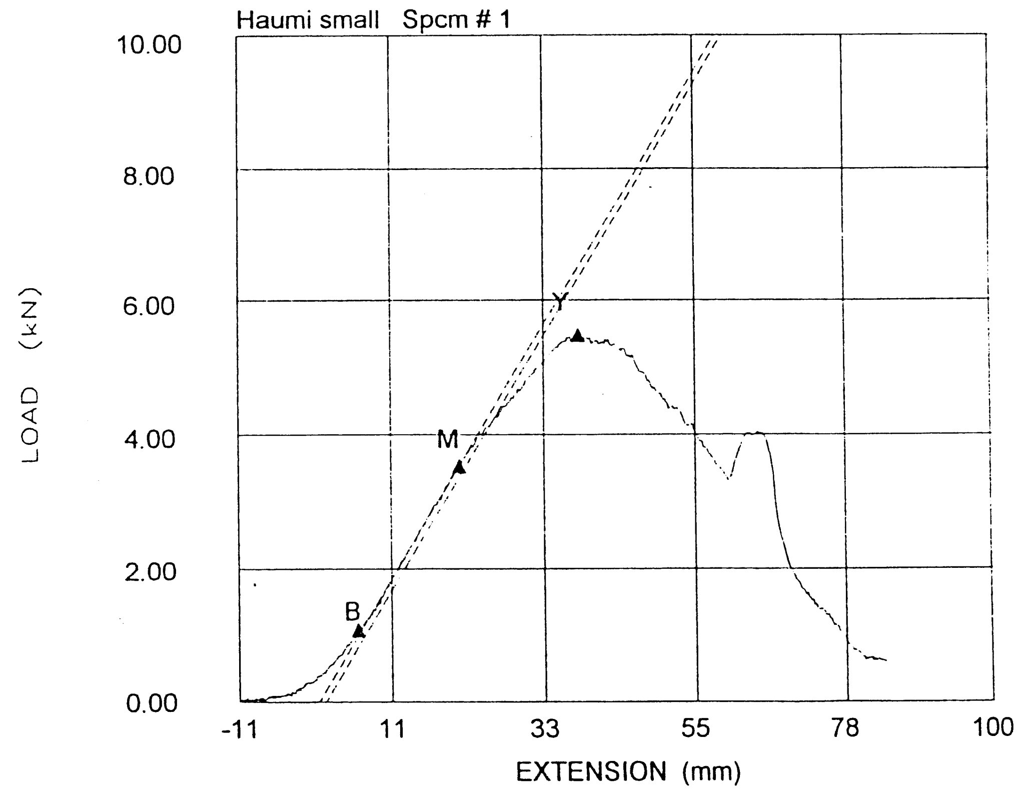
Branch diameter ~ 35 mm
Total Energy 782 J
Peak Force 3610.1 N



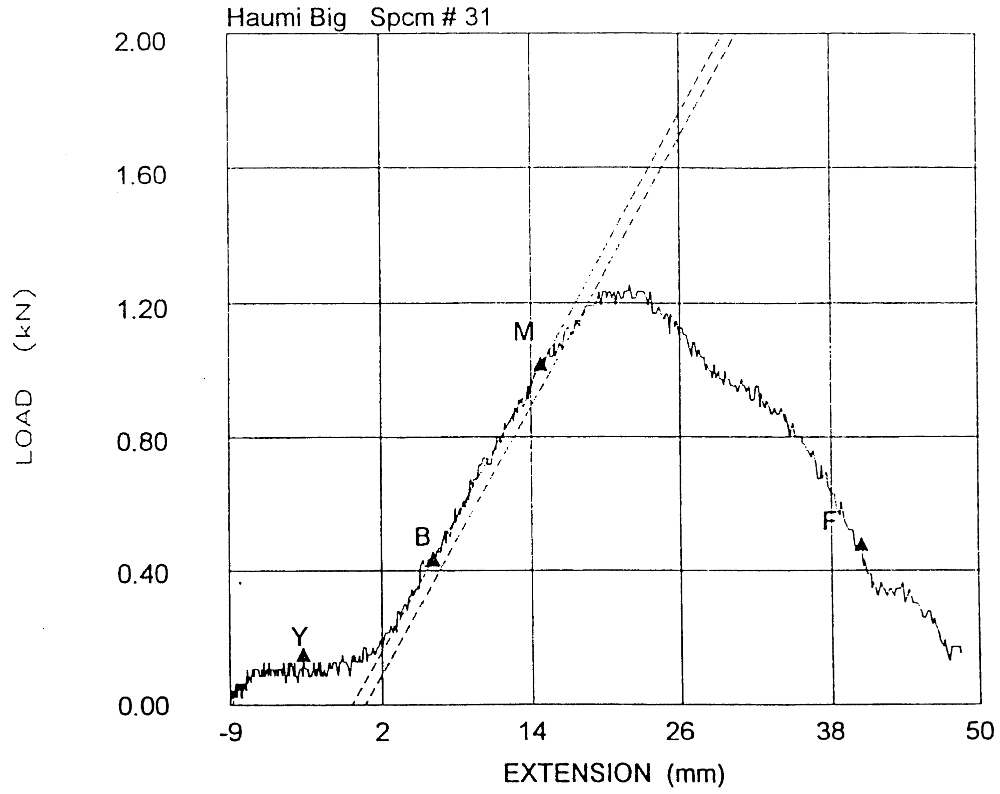
Branch diameter ~ 25 mm
Total Energy 36.0 J
Peak Force 2199.7 N



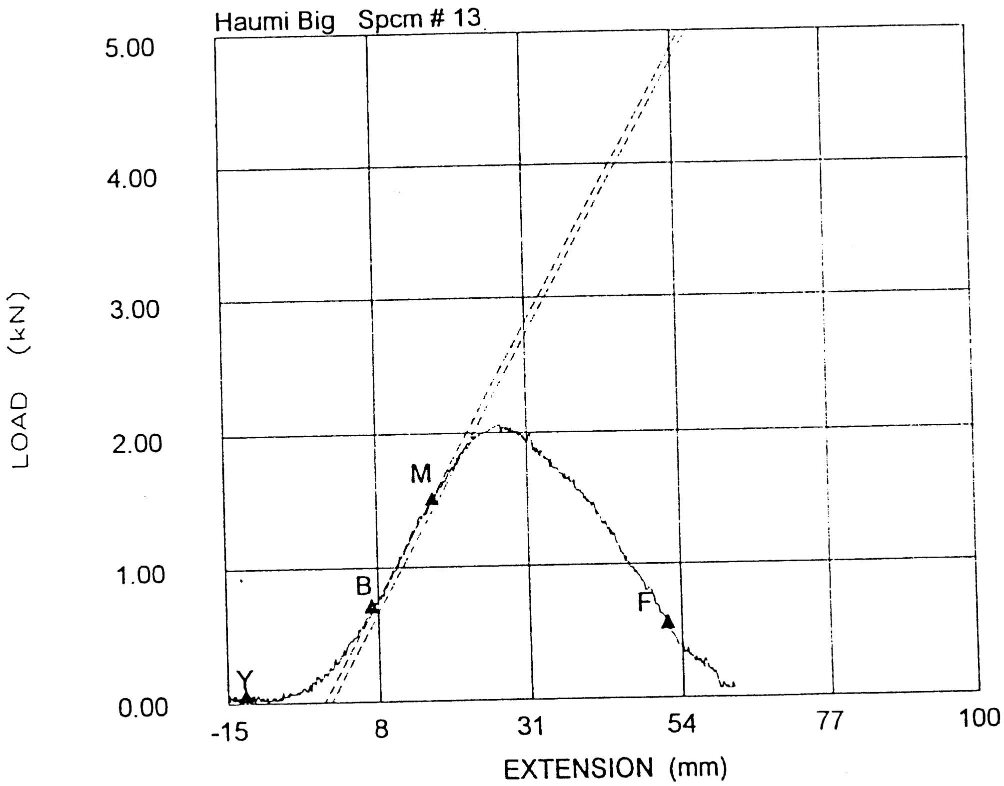
Branch diameter ~ 45 mm
Total Energy 130.9 J
Peak Force 5088.8 N



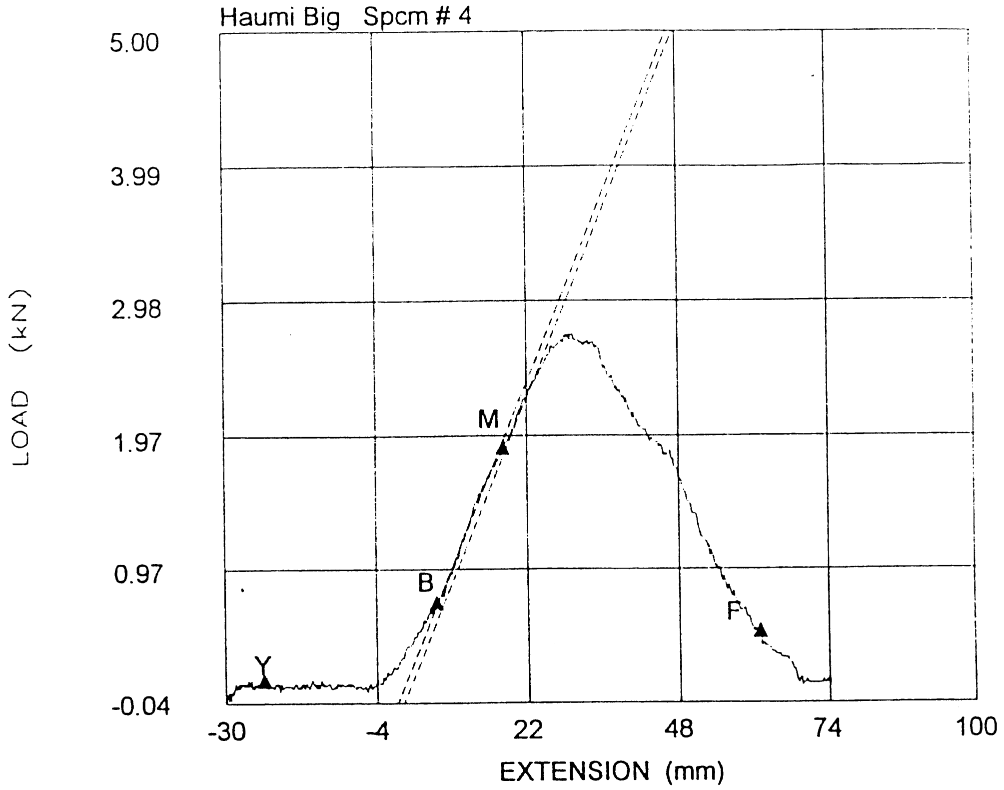
Branch diameter ~ 55 mm
Total Energy 270.7 J
Peak Force 8698.8 N



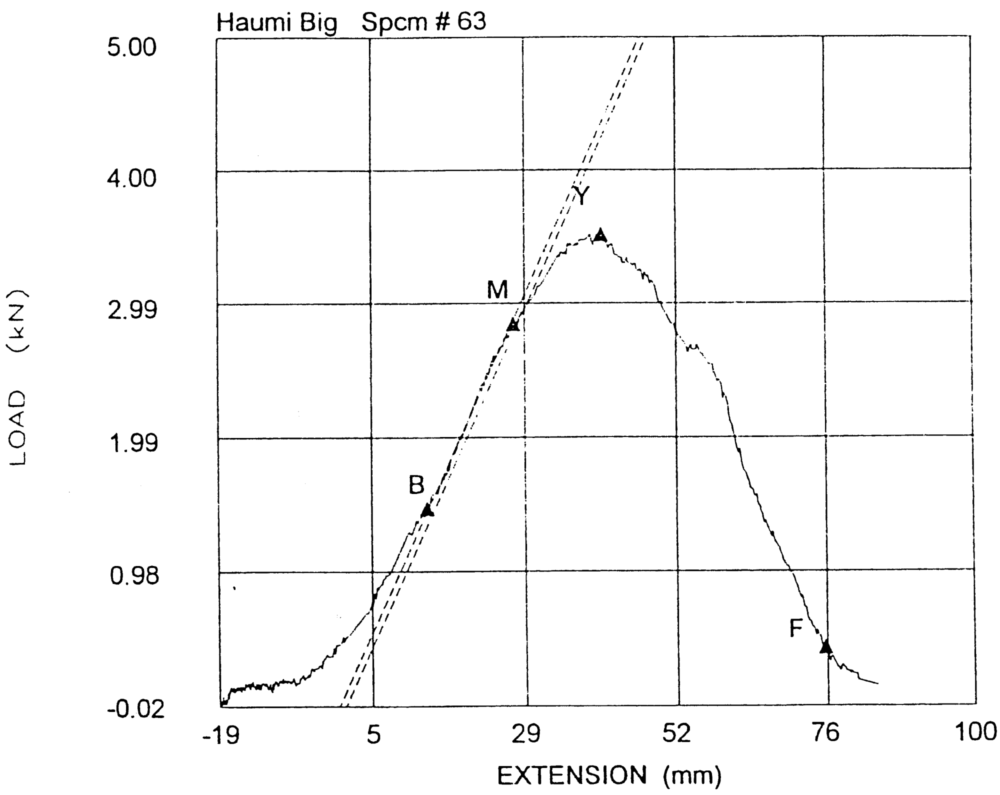
Branch diameter ~ 25 mm
Total Energy 36.1 J
Peak Force 1846.2 N



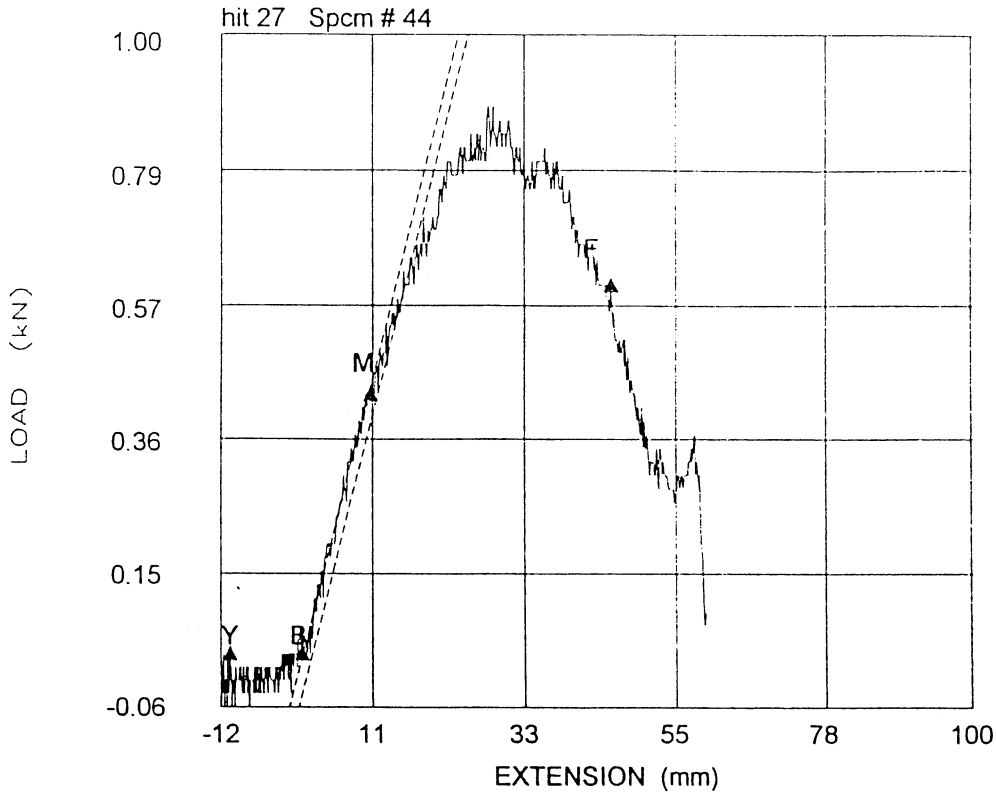
Branch diameter ~ 35 mm
Total Energy 71.9 J
Peak Force 3022.7 N



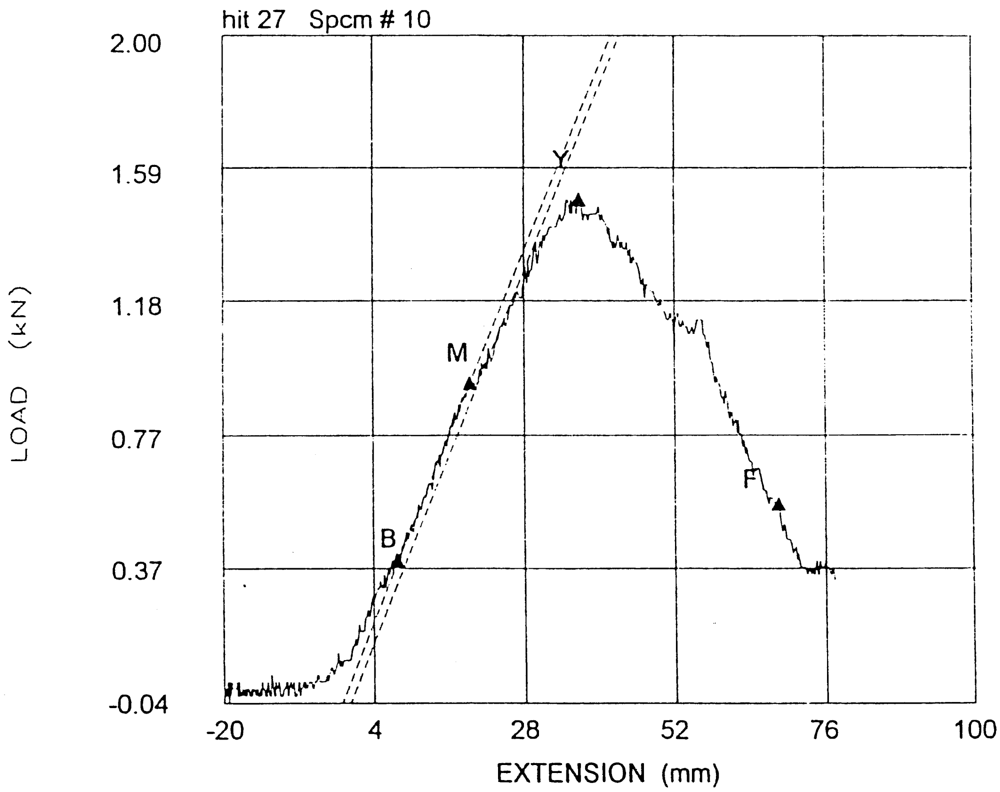
Branch diameter ~ 45 mm
Total Energy 106.9 J
Peak Force 4009.7 N



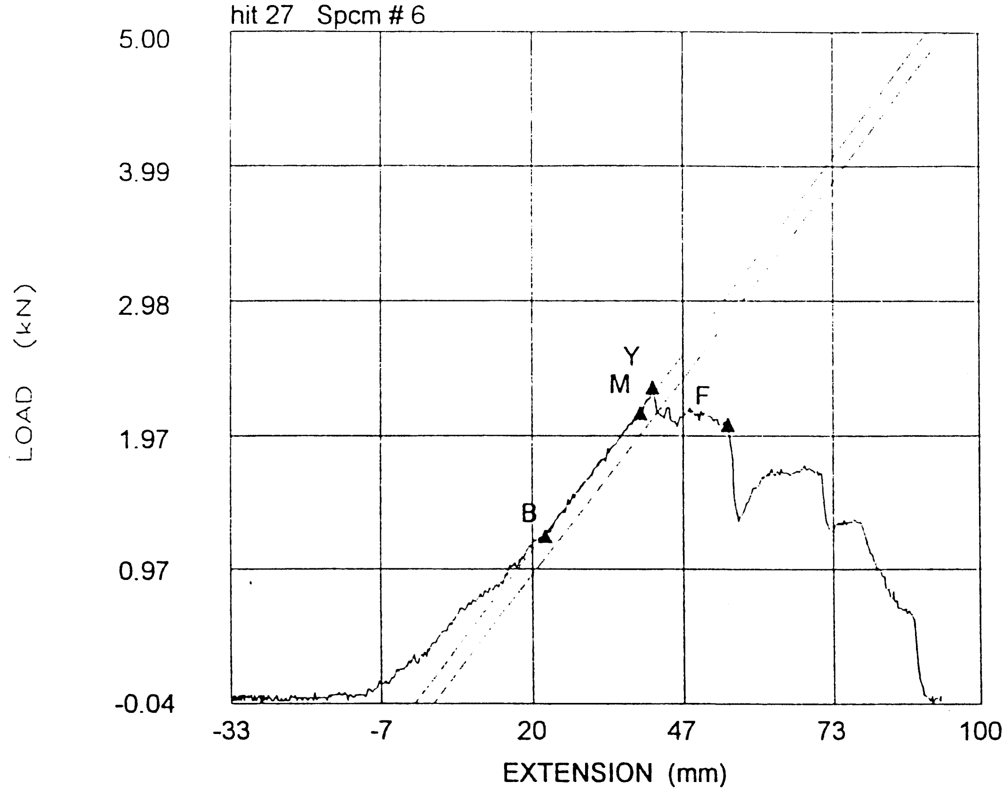
Branch diameter ~ 55 mm
Total Energy 168.5 J
Peak Force 5155.3 N



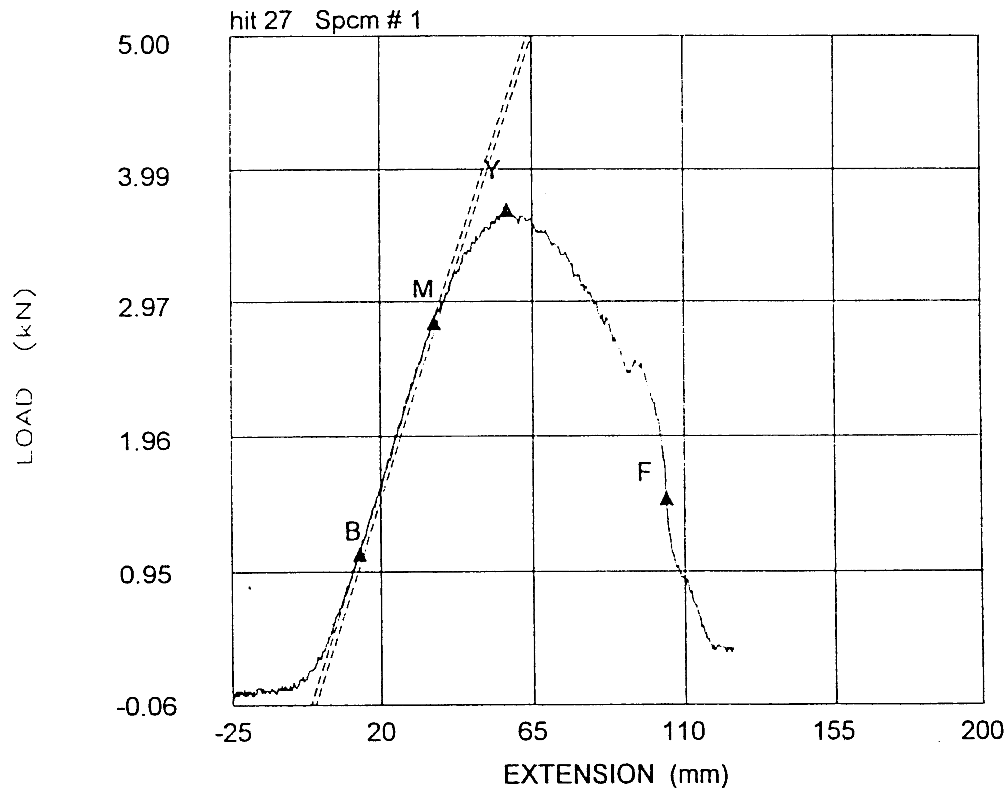
Branch diameter ~ 25 mm
Total Energy 32.8 J
Peak Force 1856.7 N



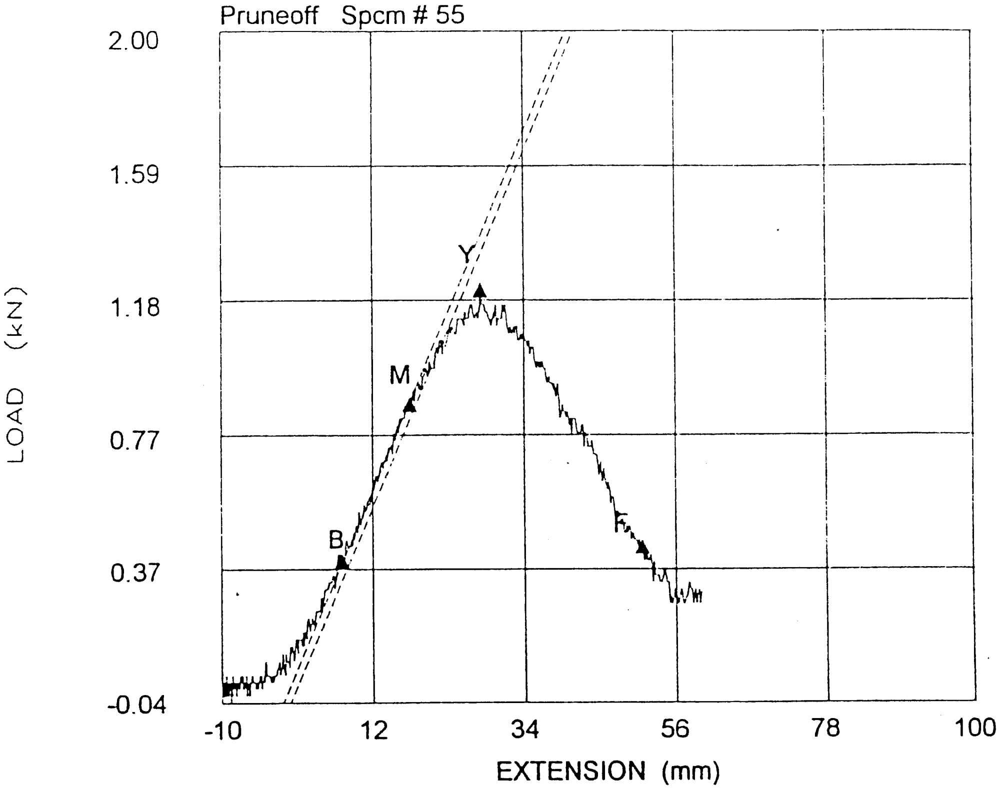
Branch diameter ~ 35 mm
Total Energy 69.1 J
Peak Force 3123.8 N



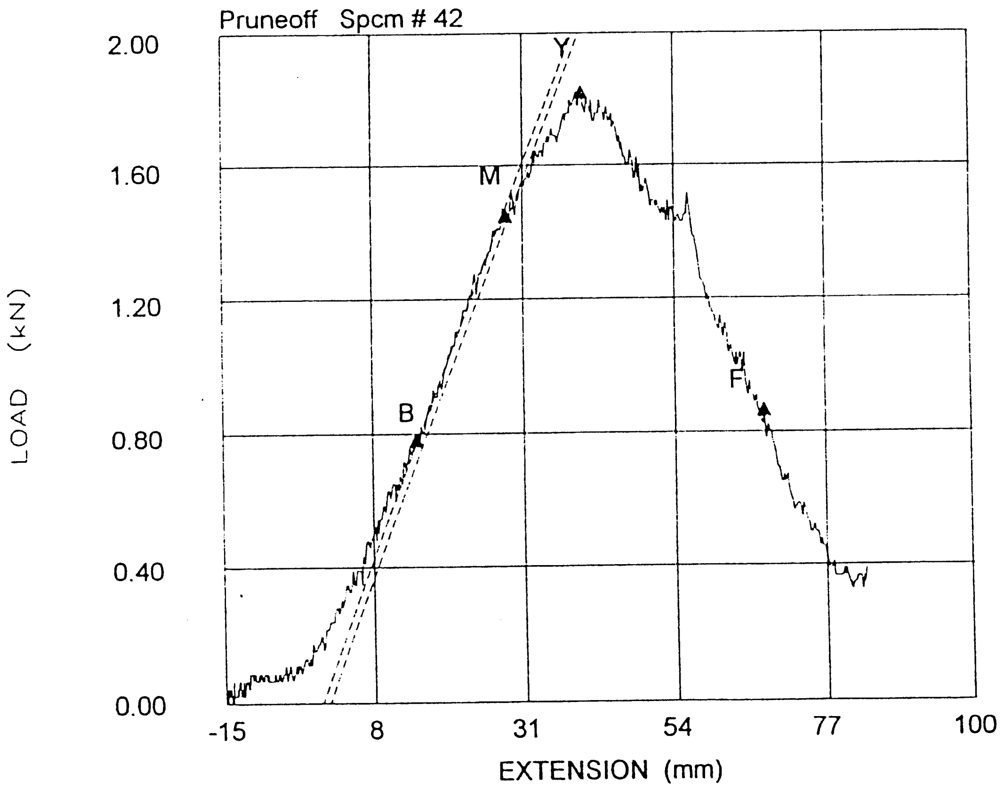
Branch diameter ~ 45 mm
Total Energy 125.9 J
Peak Force 4890.6 N



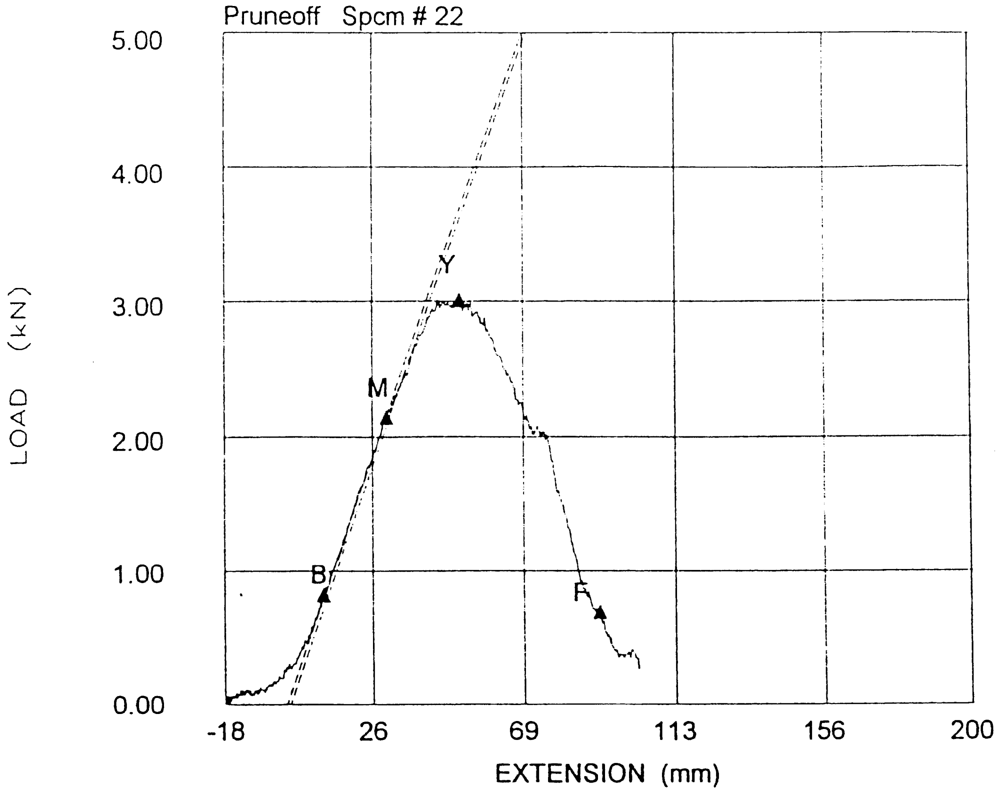
Branch diameter ~ 55 mm
Total Energy 279 J
Peak Force 7698.7 N



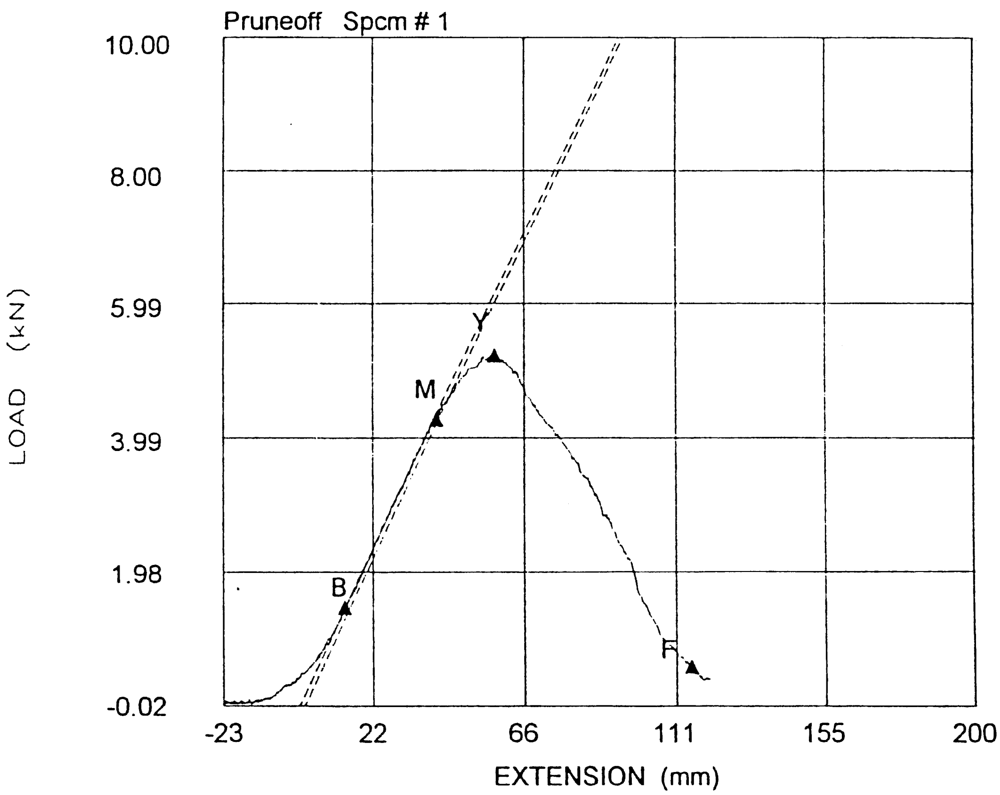
Branch diameter ~ 25 mm
Total Energy 41.7 J
Peak Force 2659.3 N



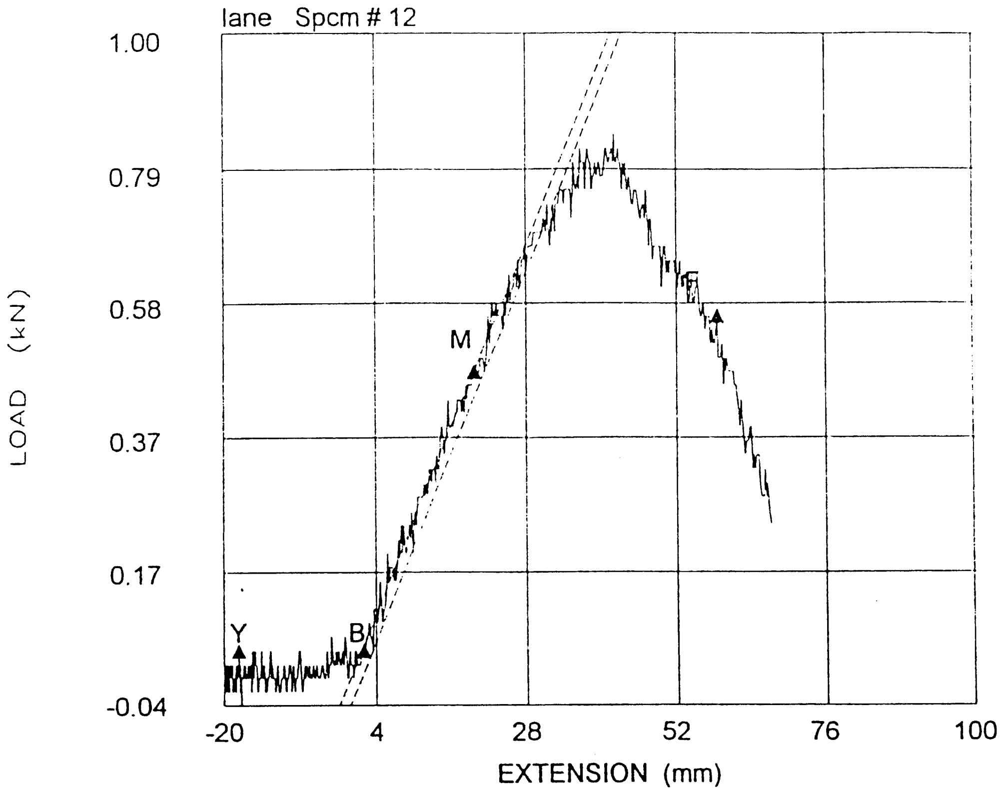
Branch diameter ~ 35 mm
Total Energy 88.8 J
Peak Force 3990 N



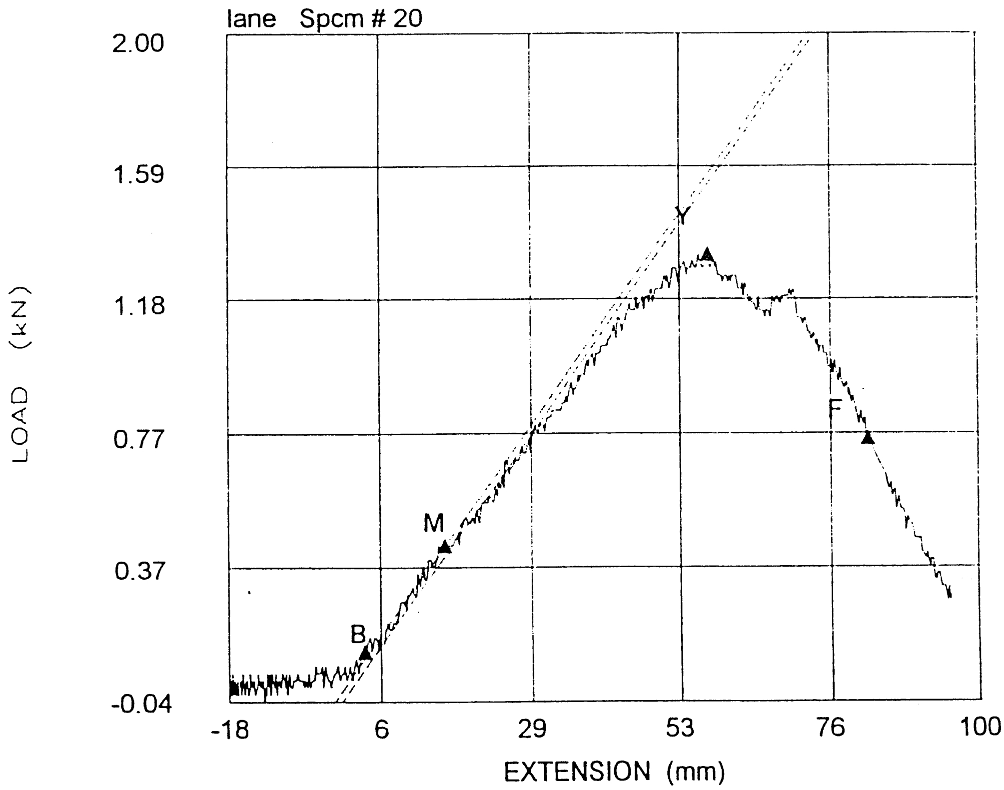
Branch diameter ~ 45 mm
Total Energy 177.5 J
Peak Force 6603.2 N



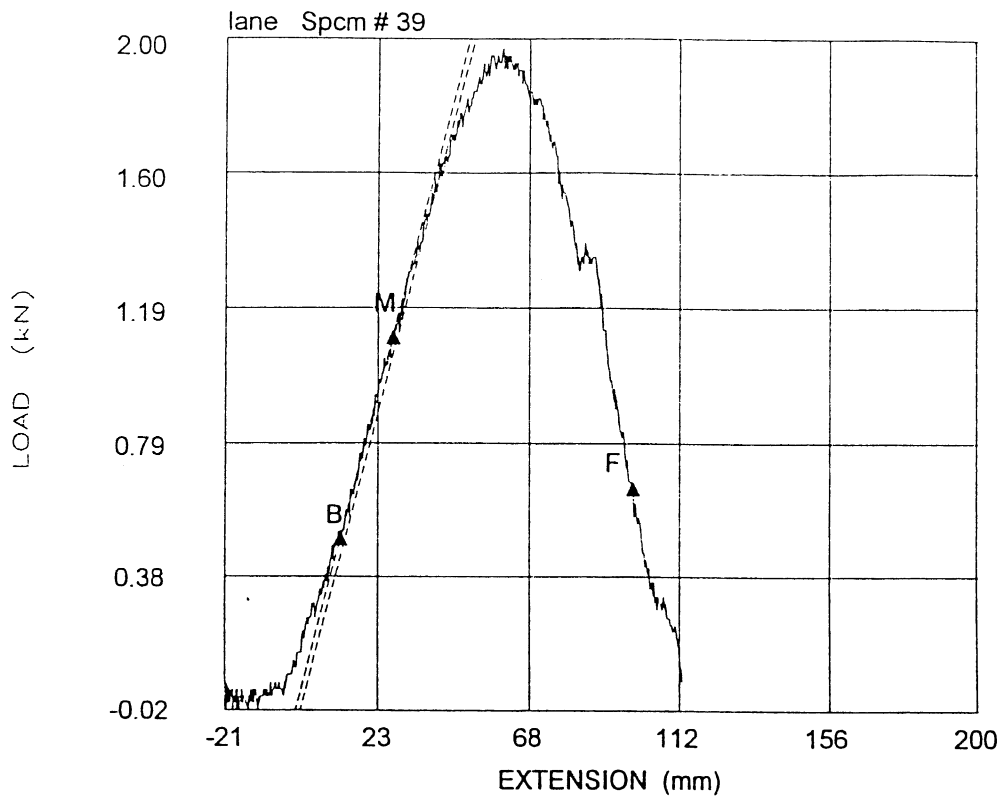
Branch diameter ~ 55 mm
Total Energy 350.8 J
Peak Force 11446 N



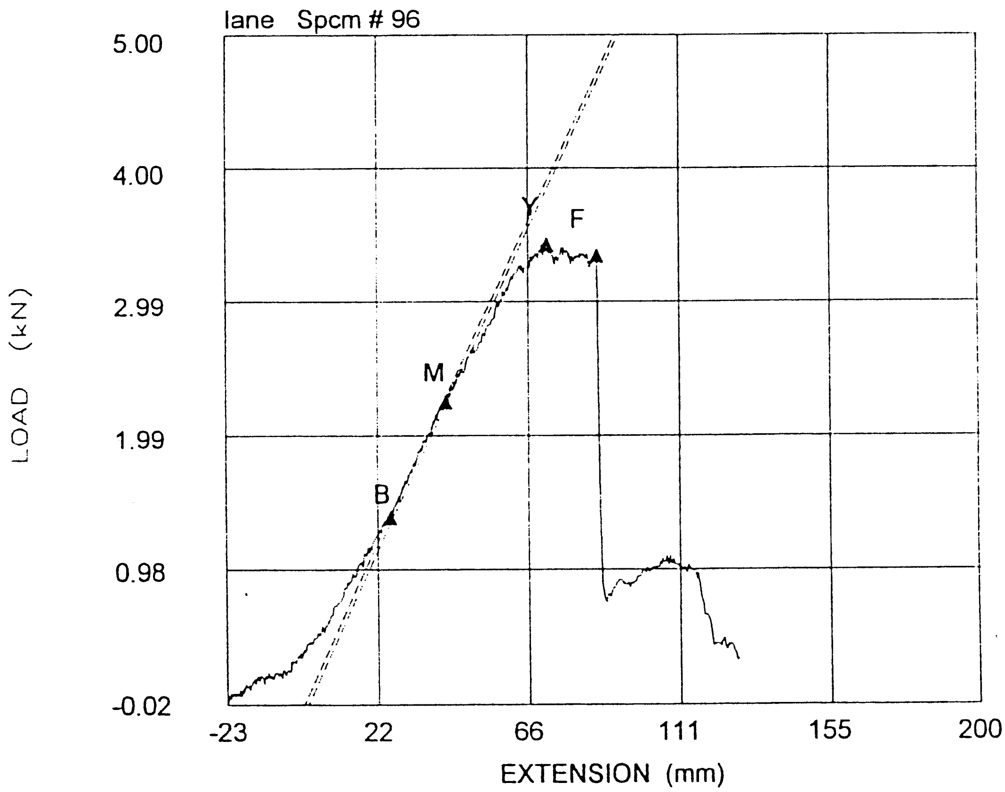
Branch diameter ~ 25 mm
Total Energy 34.5 J
Peak Force 1852.5 N



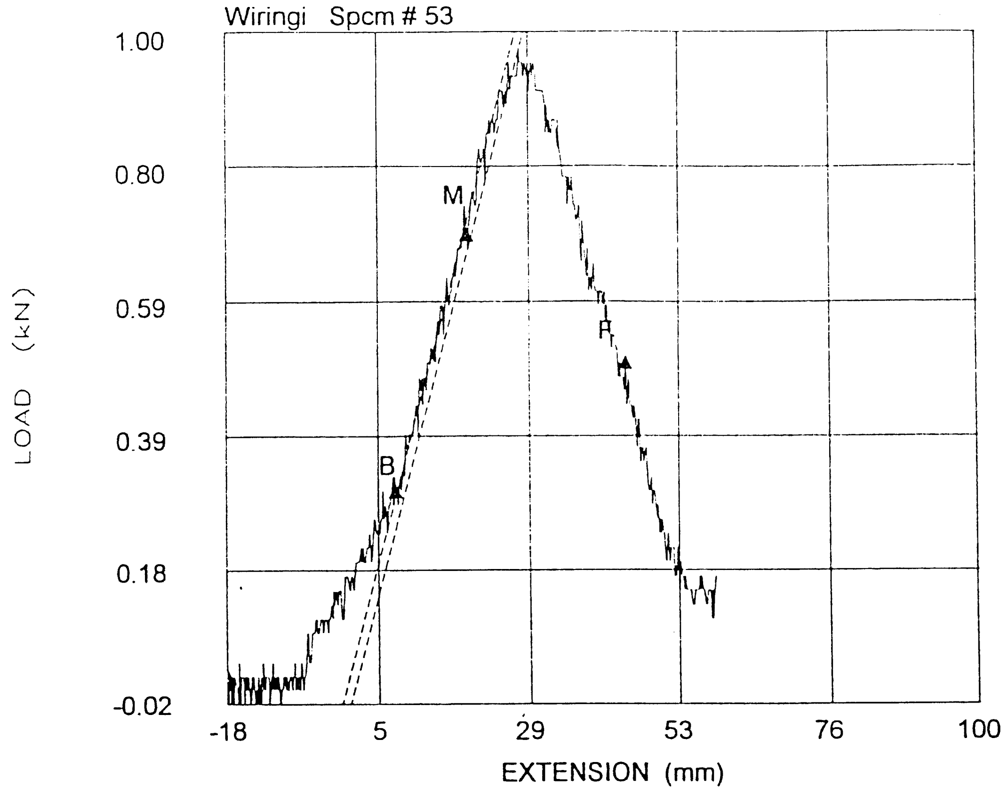
Branch diameter ~ 35 mm
Total Energy 75.7 J
Peak Force 2896 N



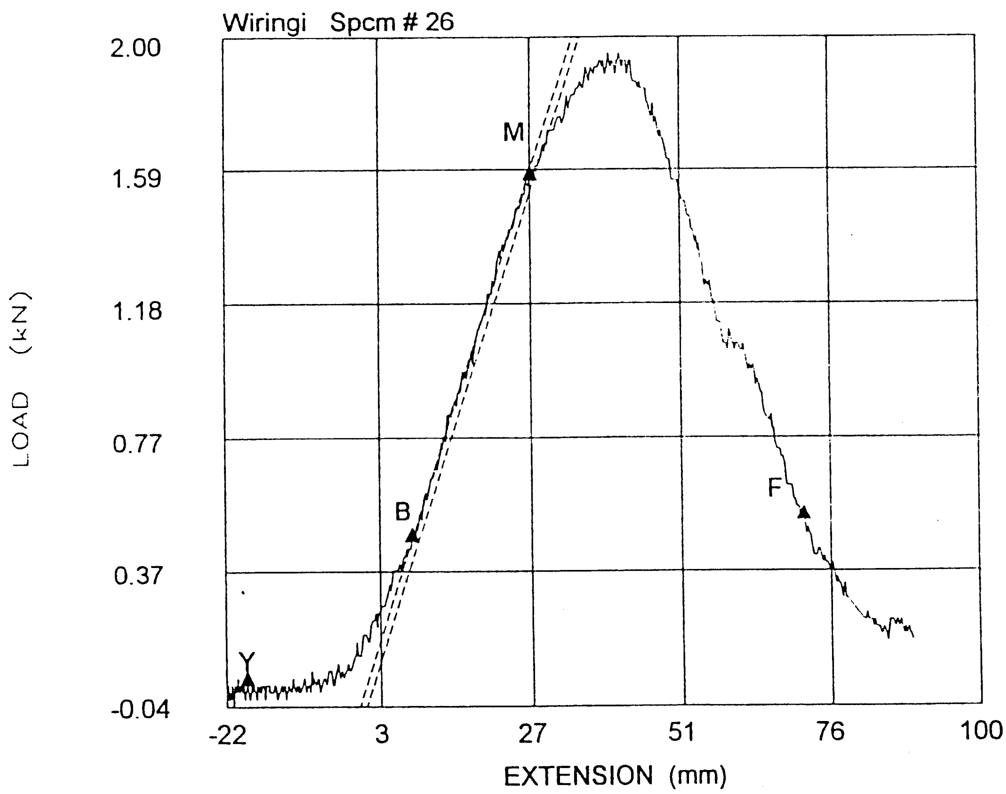
Branch diameter ~ 45 mm
Total Energy 129.5 J
Peak Force 4321 N



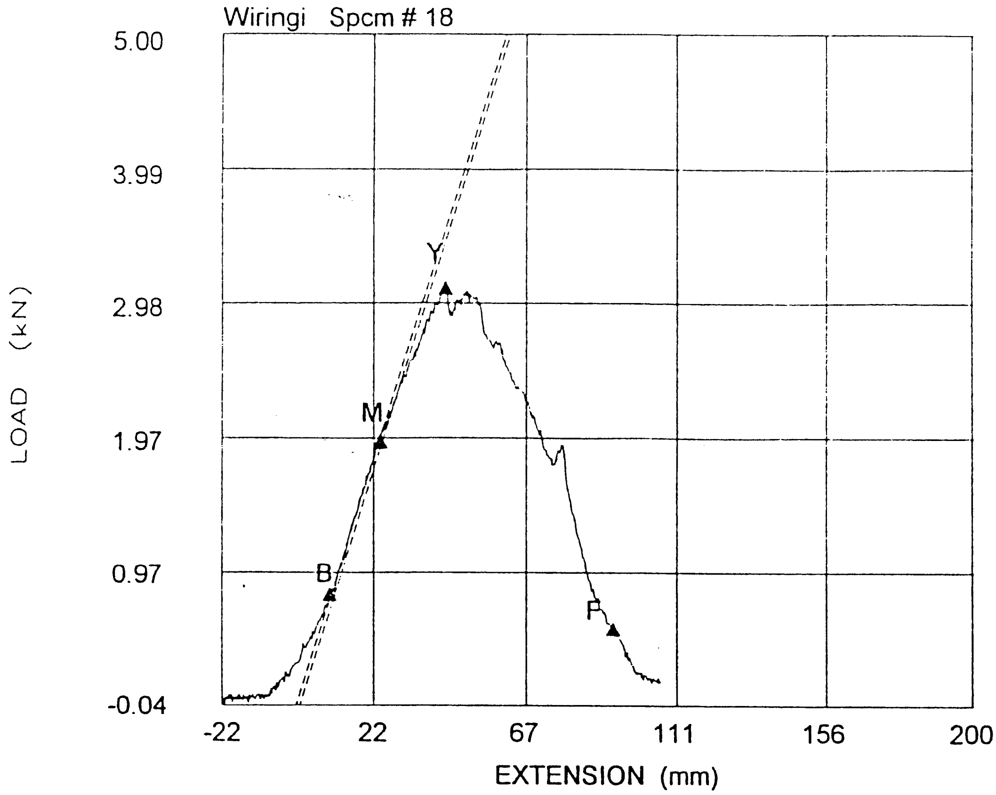
Branch diameter ~ 55 mm
Total Energy 227.3 J
Peak Force 7504.3 N



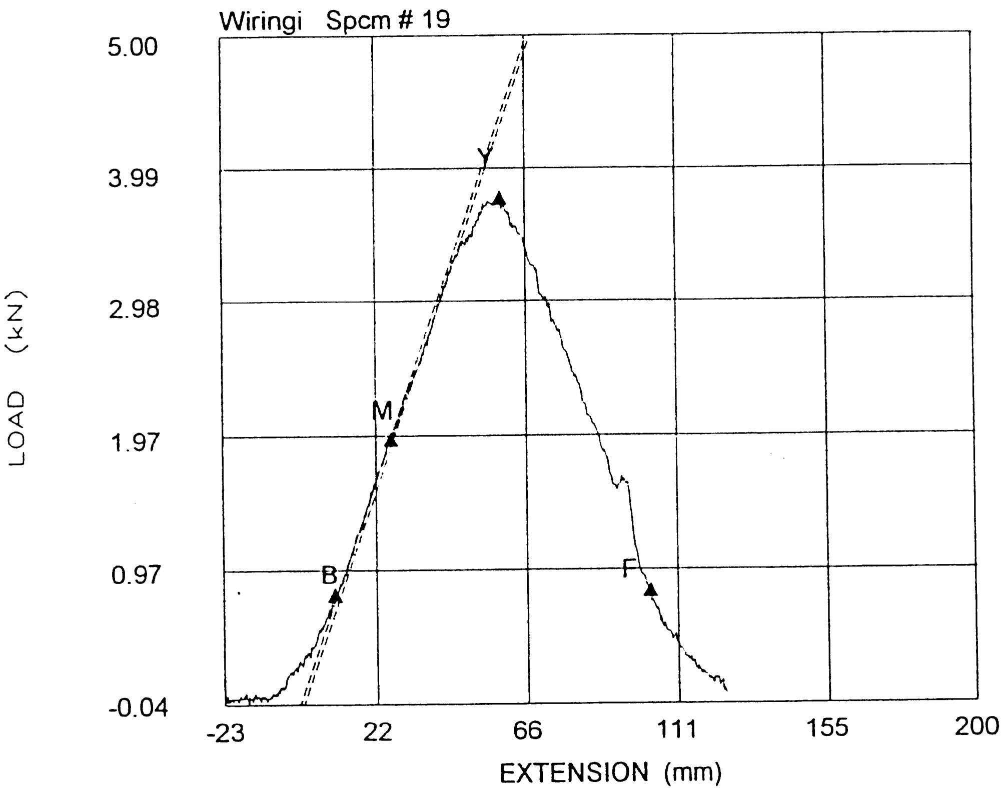
Branch diameter ~ 25 mm
Total Energy 31.1 J
Peak Force 2244.3 N



Branch diameter ~ 35 mm
Total Energy 91.4 J
Peak Force 4488.7 N



Branch diameter ~ 45 mm
Total Energy 180.7 J
Peak Force 7131.2 N

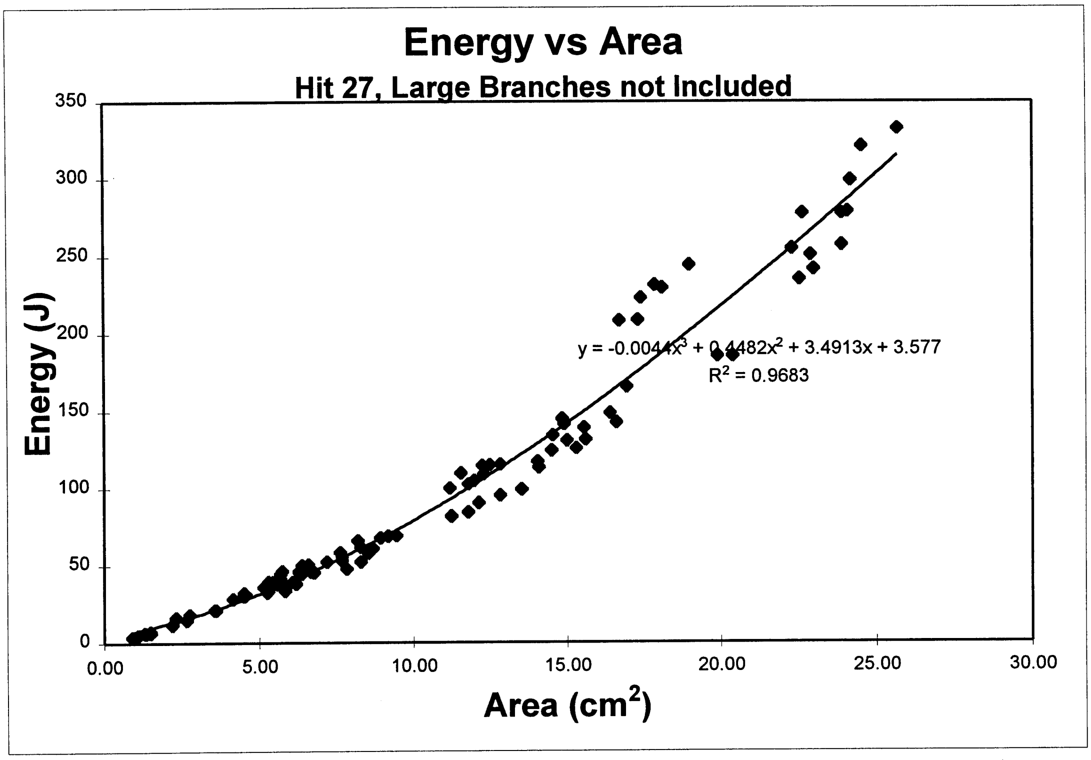


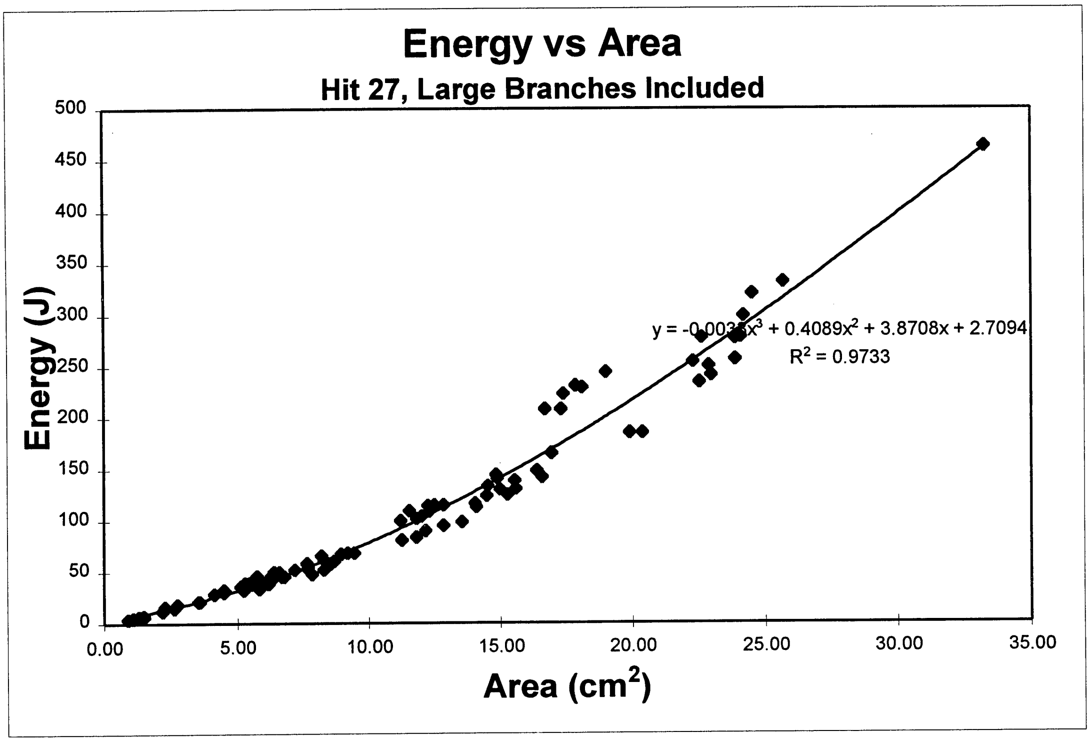
Branch diameter ~ 55 mm
Total Energy 238.9 J
Peak Force 8675.8 N

Appendix 5 - Large Branch Tests

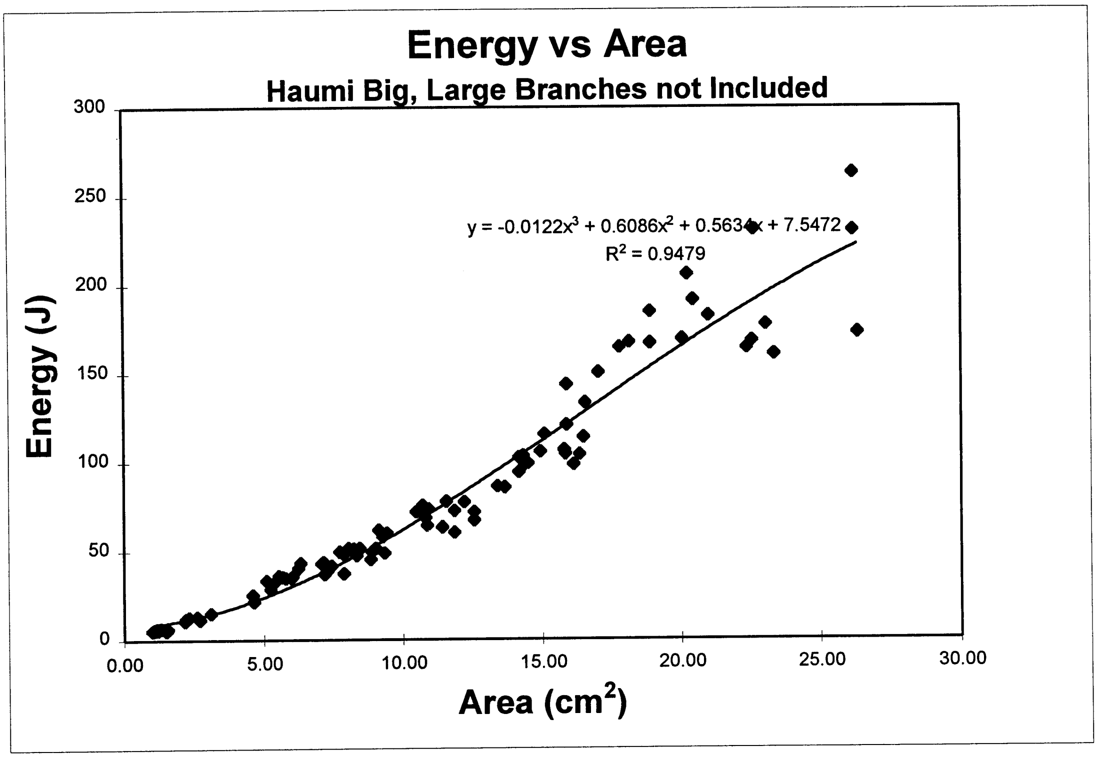
Some very large branches (~ 35 cm^2) were tested with the Haumi Big and Hit 27 loppers. These tests were done to see if they would represent a continuation of the trendline. It was found that the results from these large branches corresponded very closely with a continuation of the curve. This is shown in this appendix and can be seen by comparing the trendline equations for the curve excluding the big tests and the curve including the big tests.

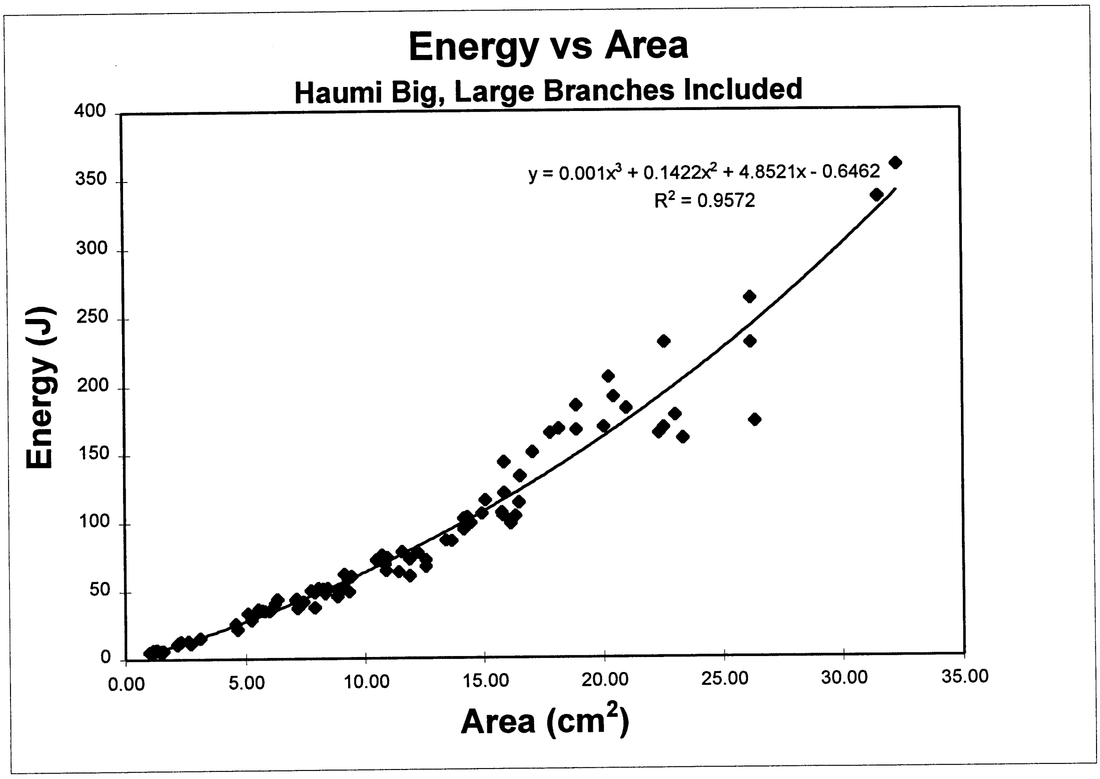
Large Branch Tests





Large Branch Tests





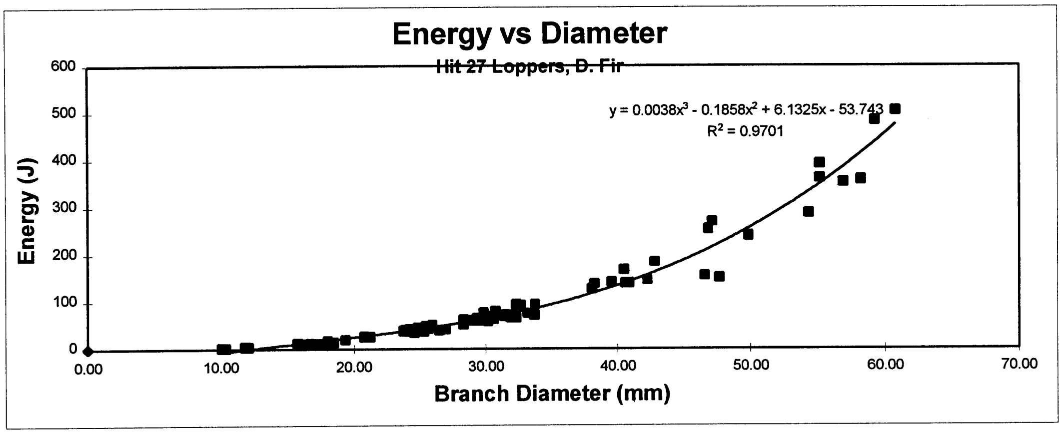
Appendix 6 - Douglas fir Results

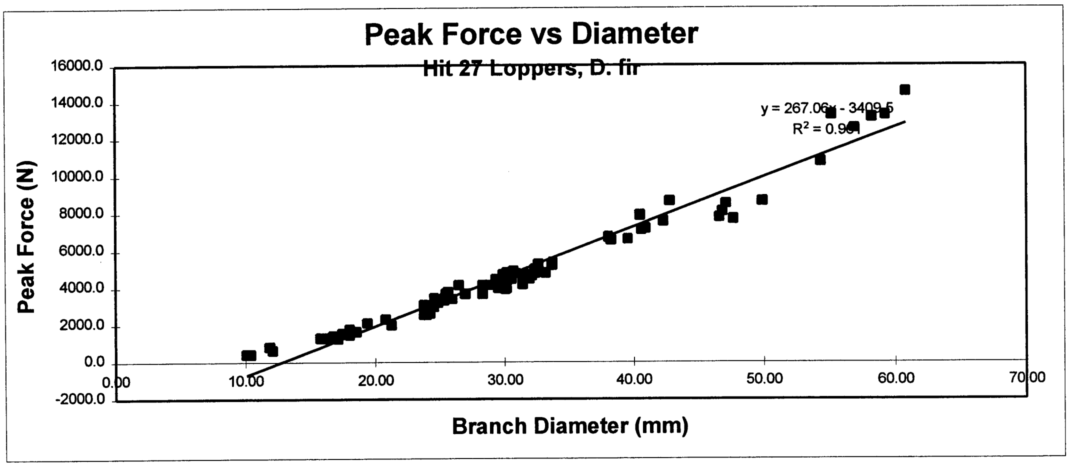
The Haumi Big loppers and the Hit 27 loppers were tested on Douglas fir branches to determine if they would confirm the trends found from the tests done on the Pine branches. The results of these tests are presented in this appendix.

Hit 27

sample	Planimeter area (cm^2)			Energy (Joules)	Force (N)	Peak Force (N)	Test Works File #	Branch diameter (mm)
	Run 1	Run 2	Average					
1	27.5	27.7	27.60	484.6	6363	13304.5	Hit 27 D. fir 1	59.28
2	26.7	26.6	26.65	358.9	6299	13170.6	Hit 27 D. fir 2	58.25
3	29.0	29.1	29.05	504.9	6970	14573.6	Hit 27 D. fir 3	60.82
4	25.4	25.5	25.45	352.9	6018	12583.1	Hit 27 D. fir 4	56.92
5	24.0	23.8	23.90	362.0	6386	13352.5	Hit 27 D. fir 5	55.16
6	23.9	23.9	23.90	392.2	6364	13306.5	Hit 27 D. fir 6	55.16
7	23.2	23.2	23.20	287.6	5152	10772.4	Hit 27 D. fir 7	54.35
8	19.6	19.5	19.55	240.1	4135	8645.9	Hit 27 D. fir 8	49.89
9	17.4	17.5	17.45	268.0	4070	8510.0	Hit 27 D. fir 9	47.14
10	17.1	17.4	17.25	253.7	3875	8102.3	Hit 27 D. fir 10	46.87
11	17.7	18.0	17.85	151.1	3680	7694.5	Hit 27 D. fir 11	47.67
12	17.0	17.1	17.05	154.9	3723	7784.5	Hit 27 D. fir 12	46.59
13	8.4	8.3	8.35	92.6	2511	5250.3	Hit 27 D. fir 13	32.61
14	8.2	8.2	8.20	94.2	2381	4978.5	Hit 27 D. fir 14	32.31
15	7.9	8.1	8.00	71.7	2143	4480.8	Hit 27 D. fir 15	31.92
16	7.8	7.7	7.75	68.4	2013	4209.0	Hit 27 D. fir 16	31.41
17	9.0	8.8	8.90	72.7	2489	5204.3	Hit 27 D. fir 17	33.66
18	8.7	8.6	8.65	75.3	2295	4798.6	Hit 27 D. fir 18	33.19
19	8.2	8.2	8.20	65.5	2273	4752.6	Hit 27 D. fir 19	32.31
20	8.0	8.2	8.10	70.4	2230	4662.7	Hit 27 D. fir 20	32.11
21	8.9	9.0	8.95	94.2	2554	5340.2	Hit 27 D. fir 21	33.76
22	7.9	8.1	8.00	65.5	2251	4706.6	Hit 27 D. fir 22	31.92
23	7.4	7.6	7.50	71.4	2273	4752.6	Hit 27 D. fir 23	30.90
24	7.8	7.7	7.75	72.0	2251	4706.6	Hit 27 D. fir 24	31.41
25	5.3	5.0	5.15	43.0	1797	3757.4	Hit 27 D. fir 25	25.61
26	5.0	5.1	5.05	37.1	1602	3349.6	Hit 27 D. fir 26	25.36
27	4.7	4.8	4.75	41.8	1429	2987.9	Hit 27 D. fir 27	24.59
28	4.4	4.5	4.45	38.9	1472	3077.8	Hit 27 D. fir 28	23.80
29	7.3	7.5	7.40	79.1	2338	4888.5	Hit 27 D. fir 29	30.70
30	7.3	7.4	7.35	63.3	2121	4434.8	Hit 27 D. fir 30	30.59
31	7.3	7.0	7.15	67.5	2295	4798.6	Hit 27 D. fir 31	30.17
32	6.7	6.8	6.75	64.1	2121	4434.8	Hit 27 D. fir 32	29.32
33	6.9	7.1	7.00	66.1	2143	4480.8	Hit 27 D. fir 33	29.85
34	7.1	7.2	7.15	57.2	1905	3983.2	Hit 27 D. fir 34	30.17
35	7.1	7.1	7.10	65.1	1883	3937.2	Hit 27 D. fir 35	30.07
36	6.4	6.2	6.30	61.4	1753	3665.4	Hit 27 D. fir 36	28.32
37	5.6	5.4	5.50	39.4	1970	4119.1	Hit 27 D. fir 37	26.46
38	5.8	5.6	5.70	40.4	1753	3665.4	Hit 27 D. fir 38	26.94
39	5.1	5.1	5.10	48.3	1753	3665.4	Hit 27 D. fir 39	25.48
40	5.1	5.0	5.05	44.7	1645	3439.5	Hit 27 D. fir 40	25.36
41	7.0	7.0	7.00	76.5	2251	4706.6	Hit 27 D. fir 41	29.85
42	6.5	6.6	6.55	60.3	1970	4119.1	Hit 27 D. fir 42	28.88
43	6.2	6.4	6.30	51.6	1970	4119.1	Hit 27 D. fir 43	28.32
44	6.8	6.8	6.80	65.4	1970	4119.1	Hit 27 D. fir 44	29.42
45	4.4	4.6	4.50	39.5	1212	2534.2	Hit 27 D. fir 45	23.94
46	4.5	4.4	4.45	38.6	1212	2534.2	Hit 27 D. fir 46	23.80
47	4.6	4.6	4.60	40.6	1407	2941.9	Hit 27 D. fir 47	24.20
48	4.5	4.7	4.60	41.4	1385	2895.9	Hit 27 D. fir 48	24.20
49	4.7	4.8	4.75	33.1	1645	3439.5	Hit 27 D. fir 49	24.59
50	4.9	5.0	4.95	40.2	1624	3395.6	Hit 27 D. fir 50	25.10
51	7.1	7.2	7.15	68.4	2100	4390.9	Hit 27 D. fir 51	30.17
52	6.8	6.9	6.85	60.3	1905	3983.2	Hit 27 D. fir 52	29.53
53	5.4	5.2	5.30	50.4	1624	3395.6	Hit 27 D. fir 53	25.98
54	4.6	4.6	4.60	37.5	1256	2626.2	Hit 27 D. fir 54	24.20
55	2.5	2.6	2.55	13.4	714	1492.9	Hit 27 D. fir 55	18.02
56	2.3	2.3	2.30	10.5	606	1267.1	Hit 27 D. fir 56	17.11
57	2.6	2.5	2.55	9.9	758	1584.9	Hit 27 D. fir 57	18.02
58	2.6	2.5	2.55	16.9	844	1764.7	Hit 27 D. fir 58	18.02
59	1.9	2.0	1.95	12.5	628	1313.1	Hit 27 D. fir 59	15.76
60	2.1	2.1	2.10	10.2	628	1313.1	Hit 27 D. fir 60	16.35
61	1.1	1.1	1.10	4.9	390	815.5	Hit 27 D. fir 61	11.83
62	1.1	1.2	1.15	3.7	303	633.5	Hit 27 D. fir 62	12.10
63	2.3	2.1	2.20	11.3	671	1403.0	Hit 27 D. fir 63	16.74
64	2.4	2.4	2.40	10.0	736	1538.9	Hit 27 D. fir 64	17.48
65	0.9	0.8	0.85	1.0	195	407.7	Hit 27 D. fir 65	10.40
66	0.8	0.8	0.80	1.5	195	407.7	Hit 27 D. fir 66	10.09
67	4.8	4.9	4.85	44.5	1537	3213.7	Hit 27 D. fir 67	24.85
68	4.6	4.6	4.60	35.9	1450	3031.8	Hit 27 D. fir 68	24.20
69	2.9	3.0	2.95	18.7	996	2082.5	Hit 27 D. fir 69	19.38
70	2.6	2.8	2.70	14.2	779	1628.8	Hit 27 D. fir 70	18.54

71	3.5	3.6	3.55	25.5	952	1990.5	Hit 27 D. fir 71	21.26
72	3.4	3.4	3.40	26.8	1104	2308.4	Hit 27 D. fir 72	20.81
73	13.0	12.9	12.95	139.1	3399	7107.0	Hit 27 D. fir 73	40.61
74	12.4	12.2	12.30	141.3	3161	6609.4	Hit 27 D. fir 74	39.57
75	13.0	12.8	12.90	167.6	3788	7920.4	Hit 27 D. fir 75	40.53
76	13.1	13.2	13.15	139.8	3442	7196.9	Hit 27 D. fir 76	40.92
77	14.4	14.4	14.40	183.5	4135	8645.9	Hit 27 D. fir 77	42.82
78	14.0	14.1	14.05	146.1	3637	7604.6	Hit 27 D. fir 78	42.30
79	11.4	11.6	11.50	137.6	3139	6563.4	Hit 27 D. fir 79	38.27
80	11.4	11.4	11.40	127.6	3225	6743.2	Hit 27 D. fir 80	38.10

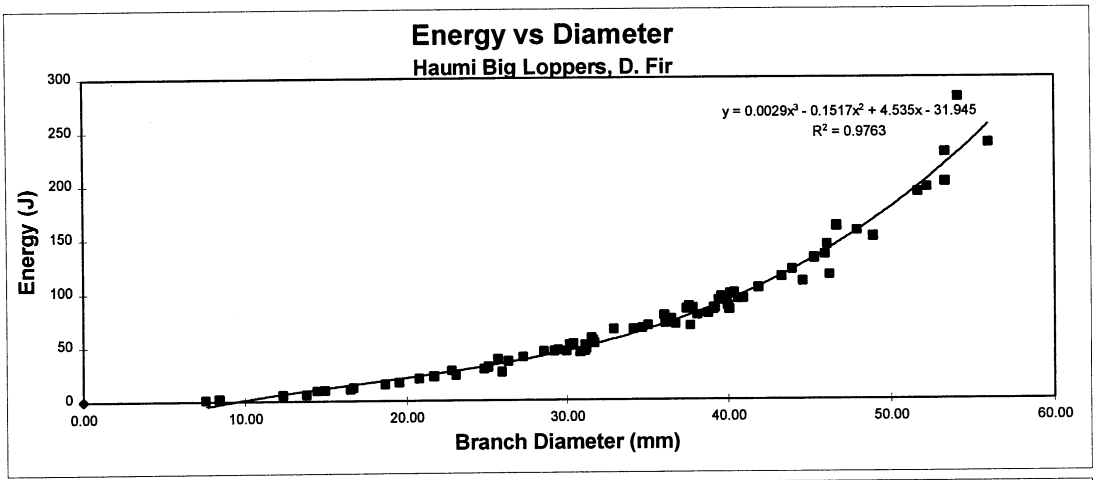


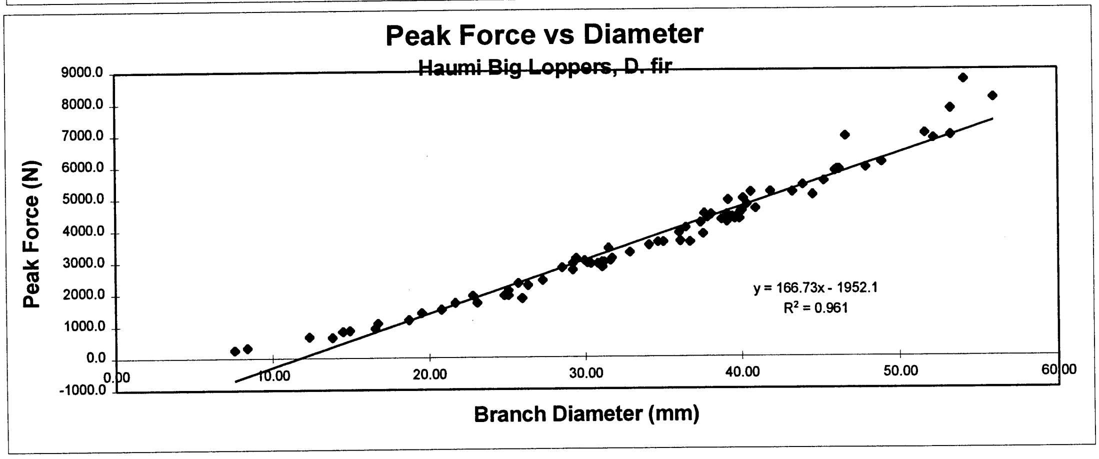


Haumi Big

sample	Planimeter area (cm^2)			Energy (Joules)	Force (N)	Peak Force (N)	Test Works File #	Branch diameter (mm)
	Run 1	Run 2	Average					
1	23.1	22.9	23.00	281.1	5906	8674.4	Haumi Big D. fir 1	54.12
2	22.2	22.4	22.30	229.3	5279	7753.5	Haumi Big D. fir 2	53.29
3	24.6	24.6	24.60	238.2	5517	8103.1	Haumi Big D. fir 3	55.97
4	22.3	22.3	22.30	201.7	4716	6926.6	Haumi Big D. fir 4	53.29
5	21.3	21.5	21.40	196.5	4651	6831.2	Haumi Big D. fir 5	52.20
6	20.8	21.1	20.95	192.2	4760	6991.3	Haumi Big D. fir 6	51.65
7	16.6	16.6	16.60	134.7	3959	5814.8	Haumi Big D. fir 7	45.97
8	16.7	16.9	16.80	115.2	3981	5847.1	Haumi Big D. fir 8	46.25
9	15.7	15.5	15.60	109.9	3440	5052.5	Haumi Big D. fir 9	44.57
10	15.2	15.1	15.15	120.8	3656	5369.8	Haumi Big D. fir 10	43.92
11	16.0	16.2	16.10	131.4	3743	5497.5	Haumi Big D. fir 11	45.28
12	14.7	14.7	14.70	113.9	3505	5148.0	Haumi Big D. fir 12	43.26
13	11.9	12.2	12.05	84.7	3332	4893.9	Haumi Big D. fir 13	39.17
14	11.1	11.2	11.15	68.1	3050	4479.7	Haumi Big D. fir 14	37.68
15	11.3	11.5	11.40	78.6	3029	4448.8	Haumi Big D. fir 15	38.10
16	11.8	11.8	11.80	80.2	2921	4290.2	Haumi Big D. fir 16	38.76
17	10.6	10.6	10.60	70.1	2445	3591.1	Haumi Big D. fir 17	36.74
18	10.3	10.2	10.25	71.1	2466	3621.9	Haumi Big D. fir 18	36.13
19	9.4	9.5	9.45	66.6	2445	3591.1	Haumi Big D. fir 19	34.69
20	9.2	9.1	9.15	65.7	2380	3495.6	Haumi Big D. fir 20	34.13
21	7.9	7.8	7.85	55.5	2055	3018.3	Haumi Big D. fir 21	31.61
22	8.4	8.6	8.50	65.5	2228	3272.4	Haumi Big D. fir 22	32.90
23	13.1	13.2	13.15	94.0	3159	4639.8	Haumi Big D. fir 23	40.92
24	12.5	12.7	12.60	83.8	3115	4575.2	Haumi Big D. fir 24	40.05
25	12.6	12.5	12.55	86.8	3094	4544.3	Haumi Big D. fir 25	39.97
26	12.4	12.6	12.50	92.5	3050	4479.7	Haumi Big D. fir 26	39.89
27	12.0	12.0	12.00	85.4	2877	4225.6	Haumi Big D. fir 27	39.09
28	11.2	11.0	11.10	86.9	2618	3845.2	Haumi Big D. fir 28	37.59
29	12.6	12.7	12.65	98.2	3375	4957.0	Haumi Big D. fir 29	40.13
30	12.1	12.3	12.20	92.3	2986	4385.7	Haumi Big D. fir 30	39.41
31	12.1	11.9	12.00	83.7	3029	4448.8	Haumi Big D. fir 31	39.09
32	11.3	11.2	11.25	85.1	2964	4353.4	Haumi Big D. fir 32	37.85
33	11.0	11.0	11.00	84.3	2856	4194.8	Haumi Big D. fir 33	37.42
34	10.4	10.5	10.45	75.0	2748	4036.1	Haumi Big D. fir 34	36.48
35	10.2	10.2	10.20	78.2	2639	3876.0	Haumi Big D. fir 35	36.04
36	9.5	9.8	9.65	69.2	2445	3591.1	Haumi Big D. fir 36	35.05
37	7.8	7.8	7.80	57.5	2315	3400.2	Haumi Big D. fir 37	31.51
38	7.9	7.9	7.90	52.9	2099	3082.9	Haumi Big D. fir 38	31.72
39	7.6	7.7	7.65	47.8	2034	2987.4	Haumi Big D. fir 39	31.21
40	7.6	7.6	7.60	50.8	1925	2827.3	Haumi Big D. fir 40	31.11
41	13.0	12.9	12.95	93.7	3506	5149.4	Haumi Big D. fir 41	40.61
42	13.7	13.8	13.75	103.7	3517	5165.6	Haumi Big D. fir 42	41.84
43	12.9	12.7	12.80	99.0	3246	4767.6	Haumi Big D. fir 43	40.37
44	12.9	12.7	12.80	97.9	3246	4767.6	Haumi Big D. fir 44	40.37
45	12.5	12.5	12.50	91.6	2943	4322.5	Haumi Big D. fir 45	39.89
46	12.3	12.3	12.30	95.4	2943	4322.5	Haumi Big D. fir 46	39.57
47	17.0	17.2	17.10	160.9	4696	6897.3	Haumi Big D. fir 47	46.66
48	18.8	18.8	18.80	151.3	4133	6070.3	Haumi Big D. fir 48	48.93
49	16.8	16.6	16.70	143.5	3982	5848.6	Haumi Big D. fir 49	46.11
50	18.1	18.0	18.05	156.7	4025	5911.7	Haumi Big D. fir 50	47.94
51	6.9	6.7	6.80	46.7	2099	3082.9	Haumi Big D. fir 51	29.42
52	6.7	6.7	6.70	45.7	1861	2733.3	Haumi Big D. fir 52	29.21
53	6.5	6.3	6.40	45.2	1904	2796.5	Haumi Big D. fir 53	28.55
54	5.8	5.9	5.85	39.8	1645	2416.1	Haumi Big D. fir 54	27.29
55	5.4	5.5	5.45	36.2	1536	2256.0	Haumi Big D. fir 55	26.34
56	5.2	5.2	5.20	38.1	1580	2320.6	Haumi Big D. fir 56	25.73
57	7.4	7.5	7.45	44.7	1991	2924.3	Haumi Big D. fir 57	30.80
58	7.1	7.2	7.15	51.2	2013	2956.6	Haumi Big D. fir 58	30.17
59	7.2	7.3	7.25	52.0	1991	2924.3	Haumi Big D. fir 59	30.38
60	6.6	6.8	6.70	45.4	1991	2924.3	Haumi Big D. fir 60	29.21
61	4.9	5.0	4.95	31.0	1428	2097.4	Haumi Big D. fir 61	25.10
62	4.9	4.8	4.85	29.4	1320	1938.8	Haumi Big D. fir 62	24.85
63	4.1	4.1	4.10	27.5	1320	1938.8	Haumi Big D. fir 63	22.85
64	4.2	4.2	4.20	24.1	1169	1717.0	Haumi Big D. fir 64	23.12
65	3.8	3.6	3.70	22.5	1169	1717.0	Haumi Big D. fir 65	21.70
66	3.4	3.4	3.40	20.4	1017	1493.7	Haumi Big D. fir 66	20.81
67	3.0	3.0	3.00	17.1	952	1398.3	Haumi Big D. fir 67	19.54
68	2.8	2.7	2.75	15.2	801	1176.5	Haumi Big D. fir 68	18.71
69	2.3	2.1	2.20	12.4	736	1081.0	Haumi Big D. fir 69	16.74
70	2.2	2.1	2.15	10.1	628	922.4	Haumi Big D. fir 70	16.55

71	1.7	1.8	1.75	9.8	584	857.8	Haumi Big D. fir 71	14.93
72	1.7	1.6	1.65	9.0	563	826.9	Haumi Big D. fir 72	14.49
73	1.2	1.2	1.20	5.4	454	666.8	Haumi Big D. fir 73	12.36
74	1.5	1.5	1.50	5.8	433	636.0	Haumi Big D. fir 74	13.82
75	0.5	0.6	0.55	1.8	216	317.3	Haumi Big D. fir 75	8.37
76	0.4	0.5	0.45	1.3	173	254.1	Haumi Big D. fir 76	7.57
77	5.4	5.2	5.30	26.6	1255	1843.3	Haumi Big D. fir 77	25.98
78	5.0	4.9	4.95	30.7	1320	1938.8	Haumi Big D. fir 78	25.10
79	7.0	7.1	7.05	45.2	2056	3019.8	Haumi Big D. fir 79	29.96
80	7.6	7.6	7.60	45.7	2034	2987.4	Haumi Big D. fir 80	31.11

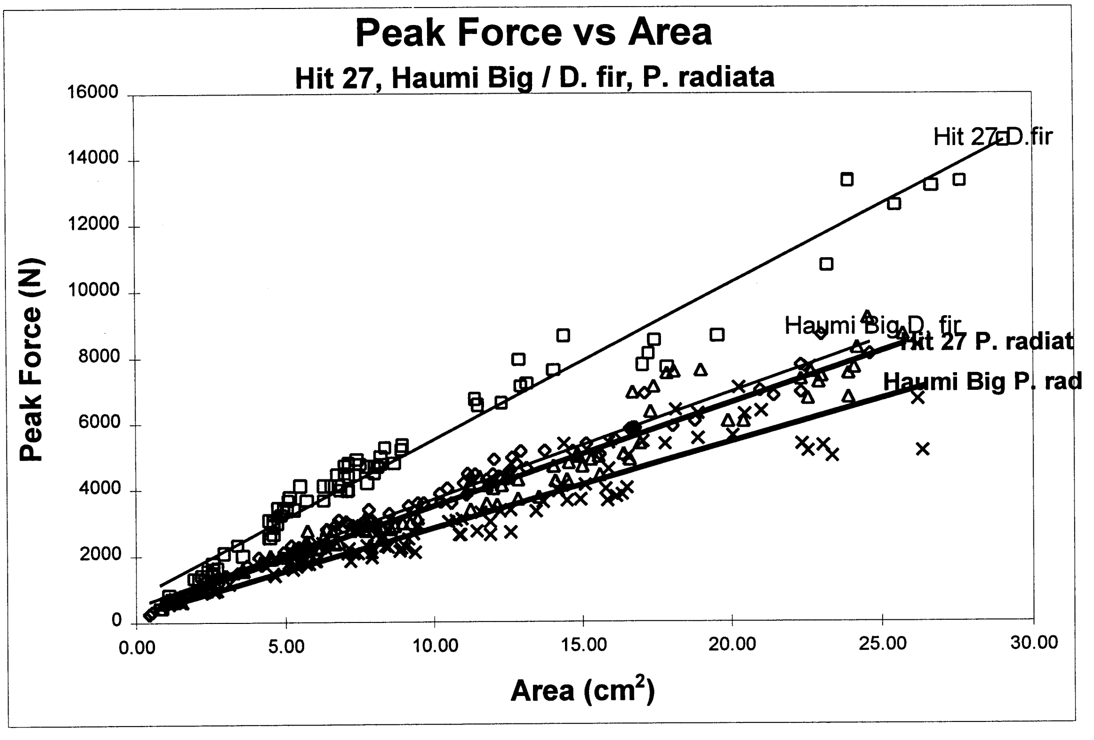


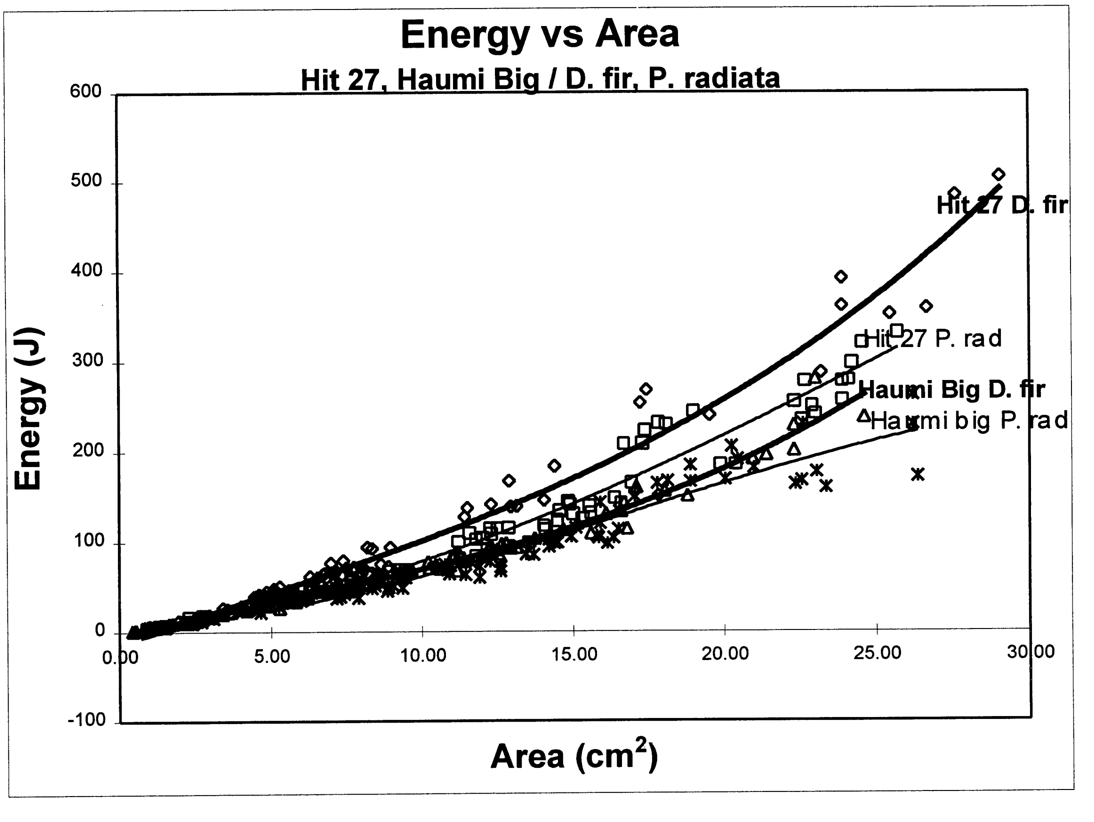


Appendix 7 - Comparison of Douglas fir and Pinus radiata Results

A comparison of the Douglas fir and the Pinus radiata results is given in this appendix.

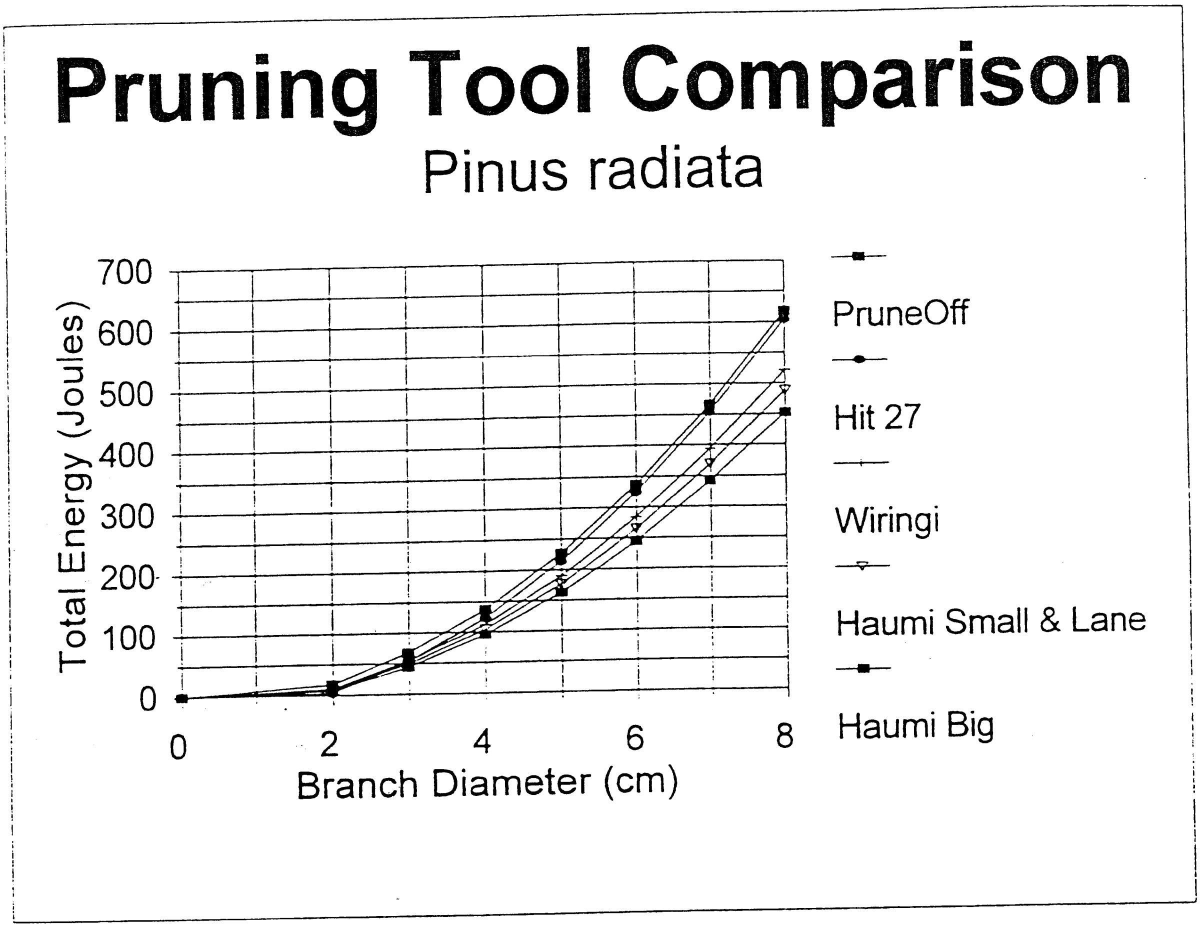
Comparison of Douglas fir and Pinus radiata Results

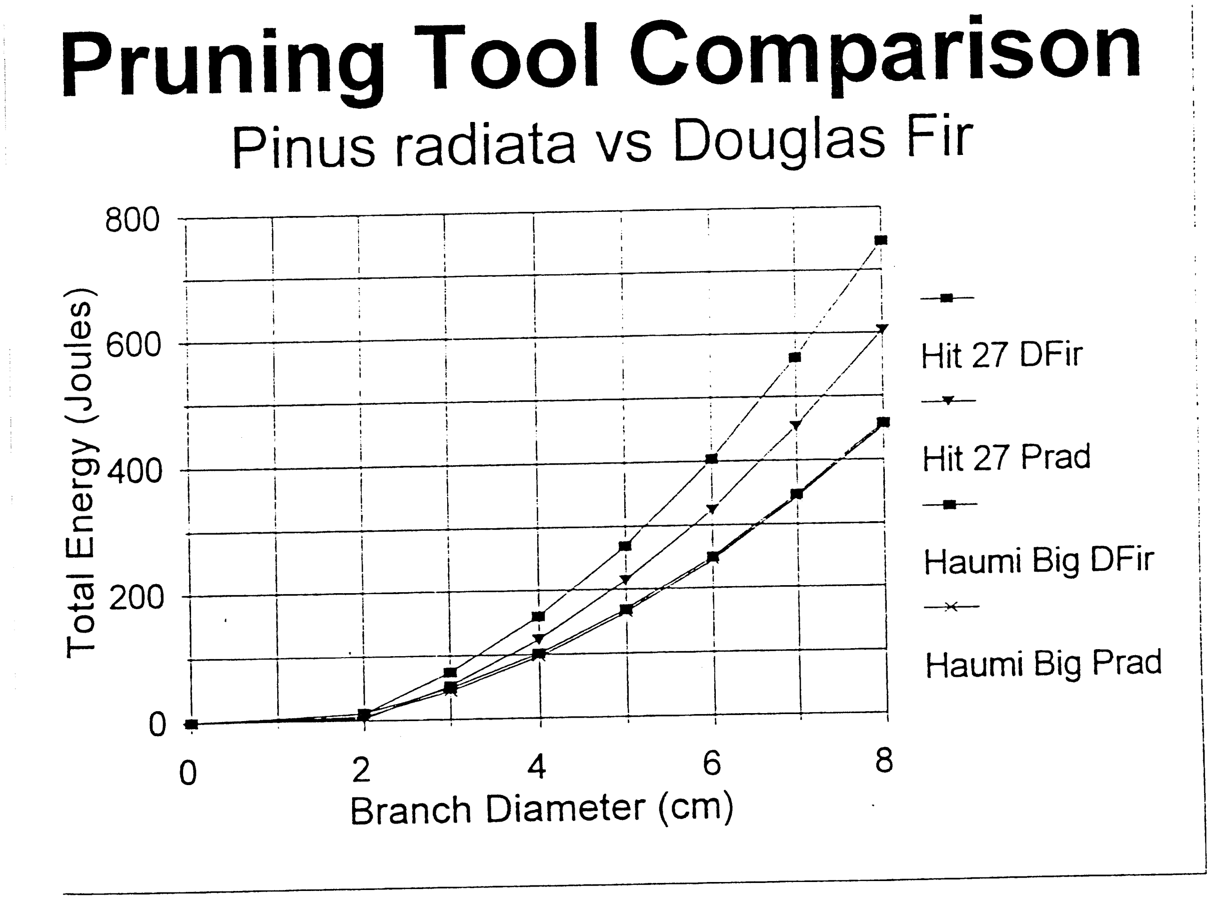




Appendix 8 - Minitab Results

The energy results from all the tests, including the Douglas fir tests, were entered into the statistical analysis program, "Minitab." This was done to confirm the statistical relevance of the results. This analysis was only done for the energy results as they are considered to be the governing parameter when comparing loppers.


Pruning Tool Comparison
Pinus radiata
Total Energy (Joules)
700
600
500
400
300
200
100
0
0
2
4
6
8
Branch Diameter (cm)
PruneOff
Hit 27
Wiringi
Haumi Small & Lane
Haumi Big


Pruning Tool Comparison
Pinus radiata vs Douglas Fir
Total Energy (Joules)
800
600
400
200
0
0
2
4
6
8
Branch Diameter (cm)
Hit 27 DFir
Hit 27 Prad
Haumi Big DFir
Haumi Big Prad

ENERGY REGRESSION EQUATIONS

The following regression equations apply to the minitab analysis carried out for the lopper tests for Pinus radiata and Douglas fir.

1. Pinus radiata

Haumi Big	$E = -23.11 + 9.476 \times A$
Haumi Small	$E = -23.11 + 10.198 \times A$
Pruneoff	$E = -23.11 + 12.739 \times A$
Lane	$E = -23.11 + 10.198 \times A$
Hit-27	$E = -36.60 + 12.739 \times A$
Wiringi	$E = -23.11 + 10.849 \times A$

2. Douglas Fir

Haumi Big	$E = -17.90 + 9.476 \times A$
Hit-27	$E = -36.60 + 15.561 \times A$

NOTE: E = energy (J)
A = area (cm^2)

Appendix 9 - Approximate Area to Diameter Conversions

This table converts the area of a branch from cm^2, to its corresponding diameter in mm. This conversion assumes the branches are circular.

Area (cm^2)	Diameter (mm)
1	11
2	16
3	20
4	23
5	25
6	28
7	30
8	32
9	34
10	36
11	37
12	39
13	41
14	42
15	44
16	45
17	47
18	48
19	49
20	50
21	52
22	53
23	54
24	55
25	56
26	58

Appendix 10 - Comment on Twisting Action Adopted by Pruners

It is common practice for a pruner to twist his/her loppers when removing a reasonably large branch. Why does this twisting action make pruning easier?

This question has been raised to me by several foresters. My theory on this is that twisting the loppers will slightly increase the total energy required due the extra movement which introduces greater friction along the side of the cutting blade, but it will reduce the peak force required as it is not cutting along the same length of blade, hence lowering the resistance to shearing force.

It is common practice for a pruner to twist his/her loppers when removing a reasonably large branch. I agree that it is easier in practice to do this. I think the reason it is easier is because it is physically easier for a person to use their own weight to twist the loppers in order to reduce the peak force required than it is for them to apply extra force by squeezing the loppers together harder. It must be noted that the effect of twisting the loppers applies energy to the cutting head and changes the force distribution at the cutting point. It must also be noted that it is the same cutting blade shearing the branch and it is the same size branch being sheared so the total resistance to this cutting blade, excluding friction, will be exactly the same whether it is being twisted or not. Therefore the action of twisting the loppers when cutting a large branch is easier as the twisting action lowers the peak force required. However, it still requires approximately the same amount of energy as cutting the branch by squeezing the handles only.