Sustainable Forest Management

Project No. PN03.3905

Australian Government

Forest and Wood Products Research and Development Corporation

An investigation of a power assisted tool (Electrocoup/Maxicoup) for low pruning of Australian plantations

Part A Literature Review

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An Investigation of a Power Assisted Tool (Electrocoup/Maxicoup) for Low Pruning of Australian Plantations
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Prepared for the

**Forest & Wood Products
Research & Development Corporation**

by

R. McWilliam

The FWPRDC is jointly funded by the Australian forest and wood products industry and the Australian Government.

1.0 Introduction

The focus of this report is on the techniques and tools that have been and are currently used to prune plantation species. Little attention will be given to the development of the actual pruning schedules since these have been the subject of various papers by Sutton (1971), Gerrand *et al.* (1997), and Bird (2000). More important to this project are the techniques and tools used to undertake these schedules and the associated productivity, operator safety, portability and cost.

Mechanisation of pruning is continuously evolving as attempts are being made to find alternatives to manual methods. Therefore the literature review at times draws upon unpublished scientific material. This is necessary as published material that describes mechanised techniques covers only a small proportion of the mechanised equipment available.

The operation of pruning can be divided into distinct parts of the task. In work study these parts are called ‘elements’ and are defined for convenience of observation, measurement and analysis (International Labour Office, 1974). Pruning elements include:

1. Walk and select – includes selecting and walking to the tree to be pruned,
2. Prune – includes the use of pruning equipment to remove desired branches, and
3. Clean – includes the use of small knives or gloves to clean the freshly pruned section e.g. removing needle fasicles or branch buds which may develop after pruning (Hartsough and Parker, 1996).

Each of these elements has “break points” where one element ends and another begins. Kirk and Parker (1996) and Terlesk (1969) noted similar elements.

2.0 Manual Pruning

Pruning of both softwood and hardwood plantations is predominantly a manual operation. The manual methods that are currently used for pruning do not appear to have changed much from the techniques that were explored by the famous forester William Schlich (Schlich, 1910). Currently a range of manual pruning tools exists on the market including various secateurs, loppers, and saws. Good quality secateurs, for example Felco No.4, can be used ‘one handed’ and are efficient at removing small branches that exceed 15 millimetres (Bird, 2000). However, the applicability of these secateurs to forest plantations is limited since branch diameters are rarely less than 15mm at time of pruning, placing unnecessary strain on the secateurs and operators wrist. Workers in vineyards more commonly use single hand secateurs for pruning. There is an increasing desire to design good ergonomic manual hand tools that alleviate physical stresses and reduce the risks of cumulative trauma disorders in the upper limbs (Wakula and Landau, 2001). Prices for secateurs can range from $50 to $100 (Forestry Tools, Non Dated Article (NDA).

Forest pruning more typically requires small handsaws with a fine toothed blade mounted on a metal frame (Wilkes and Bren, 1986). Suitable saws available include the curved blade jack-saw, framed bow saw (Stackpole, 2001), and the D-handled saw (Omule *et al.,* 1994). The prices of saws range from $50 to around $100 (Forestry Tools, NDA). The jack-saw is a particularly good cutting tool due its fine toothed arrangement and is able to cut on both the forward and back stroke (Terlesk, 1969), compared to the conventional curved pruning saw where the cut is only obtained on the back stroke (Bird, 2000).

Terlesk (1969) studied the use of hand saws combined with ladders and pole-mounted saws in New Zealand and discovered that the ladder and saw technique could improve productivity by 50% and attain better quality of branch removal compared with saws on a long pole. Saws are most efficient when the operator's body position is above the branch, which allows the body weight to assist the downward push rather than pull. Saws mounted on long poles therefore suffer the design fault that the operator must pull using only his muscles rather muscles combined with body weight. Pole saws also cause neck strain in the operator after repeated use and greater inaccuracy when removing steeply angled branches or branches in tight whorls (Bird, 2000). However, the vigorous action of sawing from a ladder does raise safety issues, particularly at greater heights. A positive aspect to the use of saws from ladders is that it allows the operator to maintain a free hand, which should be kept above the cutting area, ideally counter balancing the operator's weight. Terlesk's (1969) study resulted in the replacement of pole saws with the saw and ladder combination in New Zealand due to the lower pruning times and therefore greater overall productivity.

More recently, the use of saws has been discontinued except where the exceptional large branch occurs. It is more widely accepted that saws produce a rougher cut when compared to loppers and has the major disadvantage of being much slower.

Figure 1. Common jack saw (ForestrySA, 2002).

Genetic improvement in *Pinus radiata* has resulted in smaller and less steep angled branches which in combination with developments in pruning shears has lead to the current adoption of loppers (Knowles, 1992). There are two basic kinds of pruning shear, the bypass and anvil, which range in price from $110 to $235 (Forestry Tools, NDA). The bypass resembles something like a scissor, where instead of having two cutting blades there is only one, which is sharpened on the outside edge. The lower blade does not cut instead it cradles the branch holding it in place while the true blade sweeps down to make the cut. The anvil shears have a different appearance, and they operate on a different principle. Like the bypass shears there is only one cutting blade but it is sharpened on both sides like a knife. The non-cutting blade is a flat surface, called the anvil, which helps cushion the impact of the blade keeping it sharper longer.

Several bypass pruners are available on the market including the popular Prun-off steel bypass loppers, Hit BRC 27 lopper, and the Tom Stone Pruner (Bird, 2000). The Tucano Lopper is an example of an anvil type action pruner that is used currently in plantation pruning. Various sized shears are available, most ranging from 20mm to 50mm cutting capacities, and are available with long handles giving greater mechanical advantage. Both types of pruners are capable of producing good quality work but it is recognised that the bypass loppers have a number of advantages. They are usually stronger, more durable, more manoeuvrable, faster in removing larger branches, and cheaper. Bird (2000) further indicates that they are superior in terms of energy required, peak force needed to operate them, ease of use and cleanness of cut.

Developments in many of the shears have changed the mechanics of their use. Larger loppers have been fitted with a second fulcrum point, which amplifies the physical muscle power being applied to the pruner onto the handles. This transfers much of the cutting power into the shear knives allowing for much larger branches to be removed with considerably less physical force (Kirk and Parker, 1996). A study by Hall and Mason (1988) identified Hit Pruners with modified blades and handles as the best pruners out of seven pruners compared. The study further indicated that there was a clear potential for improvements of "off the shelf" pruners, which would increase the cost effectiveness of pruning operations due to reduced operator fatigue and therefore increased production.

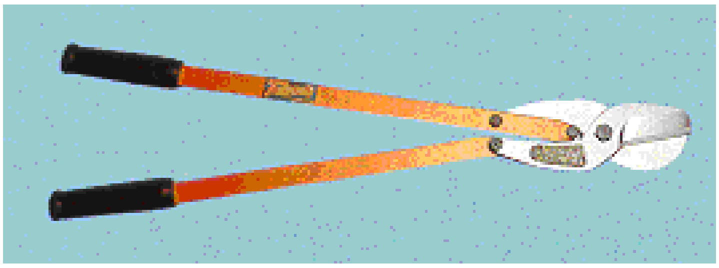


Figure 2. Commonly used Prun-off loppers (ForestrySA, 2002).

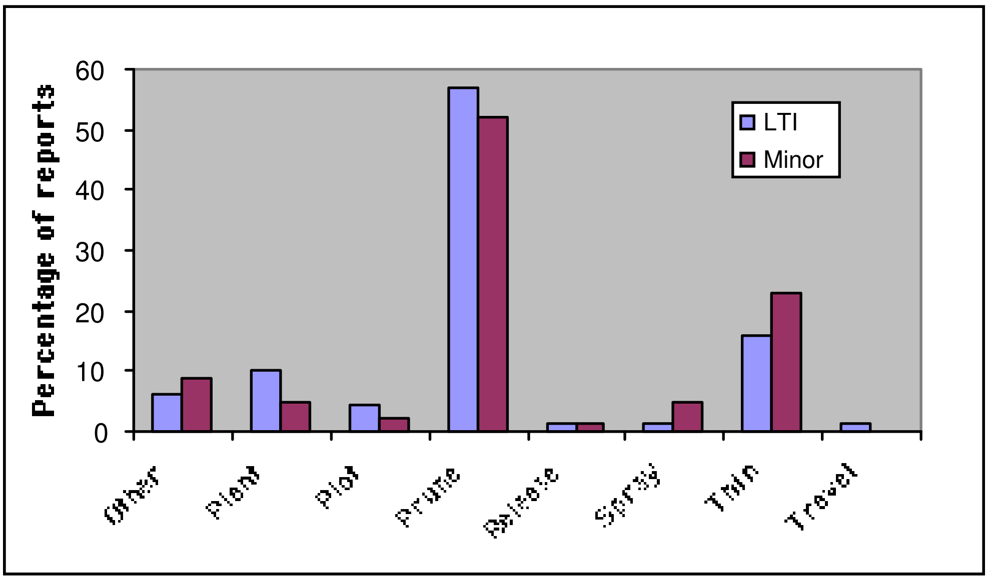
It is well recognised within the industry that loppers are more efficient overall and provide cleaner cuts. However, the use of ladders for second and third lifts in combination with loppers raises safety aspects. Unlike saws, the operation of loppers requires the use of both hands, removing any potential for the operator to stabilise their body weight during cutting. Safety harnesses are used by some contractors (Bird, 2000), which enable the operator to keep both feet on the ladder and allow the operator to lean away from the tree. But, especially when payment is based on production, harnesses are regarded as an impediment to productivity and efficiency, since substantial time is spent setting and releasing the harness. The majority of pruning contractors witnessed seem comfortable with the technique of wrapping one leg around the tree trunk for support, which allows for the operator to lean back slightly from the tree. This inherently places continuous strain on the lower and upper back. The Centre for Human Factors and Ergonomics, New Zealand (Ashby *et al.,* 2001) produced a report that summaries the accidents that occurred during 2000 due to forest silviculture. The report identified pruning activities as accounting for the largest proportion of lost time injuries (LTI) at 57% and 24% of minor injuries. The report contains a definition of silviculture that excludes harvesting. Only the operations presented in Table 1 and Graph 1 below are defined as silviculture practices in this report.

Table 1. Lost time injuries by silviculture operation (Ashby *et al.*, 2001).

Activity	Reported LTI	Total days lost	Average days lost
Release	1	5	5
Travel	1	6	6
Spray	1	30	30
Plot	2	11	5.5
Plant	5	13	2.6
Thin	8	102	12.8
Prune	**28**	**263**	**9.4**
Other	3	27	9

The report further identifies the causes of injuries, and reveals significant facts about pruning. 39% of all injuries were initiated by branches flicking back into the face of the operator or where the branch was cut under tension and sprung back at the operator. This percentage also includes those where operators were hit and cut by loppers. A further 5% of injuries involved shoulder and elbow pain, which developed during pruning with hand tools for two hours continuously (Ashby *et al*., 2001).

Generally, most manual pruners carry all their equipment in holsters. These are very handy as they keep all equipment together and readily accessible. Also holsters allow both hands to be free when moving through the stand, which becomes even more important when the pruner is required to carry a ladder. Commonly, holsters will carry shears, a jack saw and a knife to remove needles and epicormic branches.



Graph 1. Reported LTI and minor injuries by operation (Ashby *et al.*, 2001)

3.0 Mechanised pruning

The viability of mechanised pruning was analysed by Sutton (1971). He reported several key factors that limit the application of mechanisation to pruning. These factors included the need to prune in several lifts rather than one large lift, requiring the same device to be brought to the same stand several times. Another limitation is the power supply for the device. Ideally the power supply needs to be small and light weight and does not produce continuous noise, toxic fumes or excessive vibrations. Due to the terrain of many plantations in Australia the equipment needs to be easily transported between trees if mechanisation is to improve on current manual methods. Dannatt (1966) cited by Sutton (1971) recognised that any method of mechanical pruning would require an output of up to three and half times that of normal pruners to be competitive on a cost basis. Operator safety was also identified as an important factor. The factors described by Sutton remain the dominant features of the success of any mechanised pruner today.

3.1 Motor manual pruners

A motor manual pruning method refers to the operator holding a small powered cutting unit, which may be a circular saw, a chainsaw, or shears. The cutting unit may or may not carry its power source (Wilkes and Bren, 1986). Various power sources are available including petrol engines, hydraulics, batteries, or air compressors.
In the past small chainsaws were a popular form of mechanised pruner in Australia and New Zealand, particularly for first lift pruning (Wilkes and Bren, 1986). The saw’s bar is usually around 300mm in length powered by a small petrol engine. This type of saw has also been popular for urban forestry work. However, there are several aspects of chainsaws that have lead to the demise of their use in plantation forests. Firstly, the control of the cut is often difficult, particularly since it is desired to have the branch cut nearly flush with the branch collar. Small branches also pose problems and may cause kickback or the saw to operate at excessive speeds. Secondly, for reasons of safety and accuracy of cut the operator needs to be at the same level or above the cut, and this requires the use of ladders above the first lift (Bird, 2000). The portability of chainsaws (6-7kg in weight) up and down ladders is not easy and implies frequent stopping and starting of the motor. Also, like loppers, the saw requires the operator to use both hands to control the saw while cutting increasing the potential for the operator to lose balance. Thirdly, the small fuel capacity of the motor requires a number of

refuelling stops throughout the day, decreasing productivity. An average price for a small chainsaw is around $600 (Stihl Products, NDA).

Because of the safety implications high pruning tools have been designed which use small chainsaw motors as the power source and transfer power to the cutting head via long poles. Like manual pole pruning mentioned above, the applicability of pole mounted chainsaws is limited for the same reasons. Using chainsaws raises the issues of noise production, vibrations and operator fatigue created by the power source.

Figure 3. A small chainsaw used for pruning (Left) and a telescopic pole mounted with a small chainsaw (Right) (Stihl Products, NDA).

In South Australia, ForestrySA make use of a specially rigged trailer unit with pneumatic pruning shears, complete with 4 air lines on rectangle reels, for strip pruning. It is reported that this device reduces fatigue and risks of repetitive strain injury (RSI) (Bleby, personal communication, 2 September 2002). Stackpole (2001) also reports that pneumatic secateurs powered by a compressor mounted on a trailer with leads up to 15 metres in length can be used to prune stands. The major disadvantage with such devices is the portability of the power supply, which must be able to negotiate the variable terrain found in forests and the debris which results from previous pruning and thinning operations. It is also important to note that some air compressor models may need time to repressurise after cutting numerous large branches (Johnstone, 2002), affecting productivity.

Attempts have been made to design a pruner that removes the need for a bulky trailer-mounted power source. Innovative Machinery International designed a hand held pruner, the Power Prune 250, that ran off a small bottle of butane gas. The gas bottle is designed to be attached to the operator’s belt and weighs approximately 1.5kg at maximum capacity. A tube around 1metre long supplies the required gas to the cutting hand piece. The hand piece weighs around 1kg but importantly the weight of the pruner is focused on the front. This places quite a lot of strain on the operator’s wrist and this would pose problems for repeated use. The cutting device is shaped like a hook that is placed over the branch. The trigger features a two-stage function, where the trigger half pressed fills the combustion chamber and further pressing fires and activates the cutter. The exhaust gas is released via the exhaust ports on the top surface of the hand piece. This description comes from inspection of the device.

No published material related to the Power Prune 250 has been located, but it is thought that the device would be unsatisfactory due to its unevenly balanced hand piece, limited supply of power, the jolt and noise that the device would create during cutting, and the emission of hot exhaust gas.

Figure 4. The Power Prune 250

Pole mounted and hand held circular saws have been used in the past both in the USA and New Zealand (Wilkes and Bren, 1986). These have proved to be unsatisfactory for a number of reasons. The depth of cut is limited due to the size of the guard used to protect the tree from damage. This gauge also limits the access to whorls with heavy branching. Another problem associated with circular saw cutting devices is that as the blade accelerates the unit tends to rotate requiring the operator to resist this force. This provides for uncomfortable working conditions for the operator (Wilkes and Bren, 1986).

3.2 Semi automated pruners

One step close to full mechanisation was the introduction of the ‘Sachs Tree Monkey’ power pruner. The pruner is semi automated and operators are only required to transport the device between trees and set the device up. The pruner consists of a hinged tubular steel frame, which embraces the tree and carries a vertical chainsaw (Cremer and de Vries, 1970). The unit is clamped to the base of the tree and inclined wheels cause the unit to spiral up the tree after the petrol engine is started and the forward gear is engaged (Wilkes and Bren, 1986). Cremer and de Vries (1970) trialed the ‘Tree Monkey’ in Australia. They suggested that this machine would reduce labour requirements and total costs of pruning under very restricted circumstances only. The main criticisms of the ‘Tree Monkey’ were that the machine was too heavy, weighing approximately 47kg, requiring considerable effort in handling. When the machine descended it did not stop automatically increasing the danger to operators (Sutton, 1971). A major problem was that the unit tended to cause excessive stem damage as the sensing system was unable to differentiate between swellings and branches, causing bark removal over nodal swellings (Wilkes and Bren, 1986). This resulted in trees being ‘ring barked’ in the pruned zone and hence killed. Another limitation was that the bottom wheels of the unit had to be placed above the main butt swell, meaning that the tree had to be manually pruned to around breast height (Cremer and de Vries, 1970). The unit also had traction problems associated with wet bark and tended to stall where branches exceeded the maximum size for that species (Sutton, 1971).

Generally, as reported by Cremer and de Vries (1970), and Sutton (1971) the ‘Sachs Tree Monkey’ unit is not suited to low or first pruning and is not suited to a multi-lift schedule. Basically the speed, costs and quality of pruning were inferior to manual pruning. Experience with the ‘Sachs Tree Monkey’ illustrates all of the difficulties inherent in attempts to completely mechanise pruning operations.

3.3 Pruning platforms

More recently some growers have sought to develop new methods of high pruning. These are not yet reported in scientific literature. Ladders are generally regarded as unsafe work platforms, particularly when inexperienced low skilled operators are using manual loppers. A common type of equipment utilised by orchard growers and arboriculturalists are mobile elevated work platforms (sometimes referred to as ‘cherry picker’s’ or ‘squirrel’s’) (Johnstone, 2002). This equipment has the ability to be used in plantation in conjunction with manual or mechanised pruners. The platforms are usually driven by a compressor or a combustion engine and controlled by foot pedals leaving the hands free to prune (Johnstone, 2002). The advantages of this equipment are that the platform is stable and allows the operator to move around to avoid falling branches. However the disadvantages of traction loss on steep or moist surfaces and difficulties with debris or irregular ground surfaces poses problems (Bird, 2000). Also the equipment requires row widths to be wide enough to allow easy access without causing damage. Where level ground exists and stand permits machine movement this equipment offers potential for high pruning.

3.4 Self mobile mechanisation

The Paterson Pruner was the first known attempt at self mobilised mechanical pruning which was further developed by the CSIRO Division of Forest Research (Wilkes and Bren, 1986). The machine consisted of a boom which could be tilted in both directions to align with the tree, attached to a small wheel based prime mover. Unlike the ‘Sachs Tree Monkey’ this equipment had a leaf spring in the base of each of the six chisel knives keeping its cutting edge a prescribed distance away from the stem until it engaged a branch (Wilkes and Bren, 1986). A constant hydraulic force kept the knives clamped to the stem. This was reported as one of the major problems which caused excessive stem damage. The possibility of using low-pressure pneumatic tyres to align the boom with the tree and so allow lower knife clamping forces would decrease the equipment’s ability to cause damage. No published material was found relating to machine productivity or quality of pruning. It is however suggested that productivity would be high with great increases in operator safety.

4.0 The Electrocoup

The Electrocoup is a battery powered pruning tool which was first invented in France in 1985. It was originally designed for use in vineyard pruning. Today it is used in many countries world wide mainly for vineyards and orchards, but increasingly other pruning reliant industries have expressed interest (INFACO, NDA). One study, by Fassola (2001) has documented the productivity and efficiency of the Electrocoup when used to prune stands of *Pinus taeda* in Argentina. Limited sections of this paper have been translated from Spanish to English for the purpose of this report. A video of the Electrocoup in use in Argentina has also been viewed. The device is used without difficulty for all three stages of pruning, whether ground or ladder based.

The Electrocoup has potential to be an efficient tool for mechanical pruning of plantations. Several different hand pieces have been designed by INFACO including the latest F3002 and the Maxicoup hand piece. Both are lightweight and designed for ergonomic efficiency. The blade is tin coated and the trigger system features a safety lock. There is a range of blade apertures available from 40mm to 60mm. The Maxicoup has a capacity of 60mm, which would be most favourable to the larger branching of forest plantations. The hand piece allows for instant stopping at any time during the cut, which is controlled by an Automatic Safety Control Mechanism. During a heavy cut the hand piece has an automatic switch off to avoid overloading and eventual burnout. The blade is activated after a second once the trigger is pressed several times. The hand piece is also constructed of heavy-duty materials and is entirely waterproof.

Figure 5. Photo of the Electrocoup hand piece, battery, safety gloves, holster and hand saw.

The power source is an electric battery which weighs 2.3kg designed to sit around the operator's waist. This battery is a re-chargeable metal hydride type allowing for 8 hours of operation before re-charging. The batteries can be re-charge from a 200-250V power supply. A coiled cable lead is attached to the hand piece from the battery to supply the power. The coiled nature of the cord means it retracts after use and thus avoids catching on obstructions.

The charger has the positive feature of negating any battery memory that remains after a day’s operation. Therefore the battery can be charged at any time, eliminating the need to run the battery flat before re-charging. It is noted that it takes approximately 5 hours to fully charge the battery. The Electrocoup unit contains a holster to carry the cutting head thus increasing safety and efficiency.

4.1 Perceived benefits of the Electrocoup unit

None of the mechanical devices that have been designed in the past has led to wide acceptance of mechanised pruning in forest plantation for the reasons discussed by Sutton (1971). However the new technology that has been designed into the Electrocoup has the potential to solve many of the problems identified by Sutton (1971). It is perceived that the Electrocoup will be less fatiguing to the operator. Compared to manual pruning the Electrocoup requires only the pressing of a trigger to activate an efficient cutting mechanism. The Electrocoup does not produce loud noises, continuous vibration or have outputs of toxic smoke like so many of the other attempts at mechanisation. The battery pack has also been ergonomically designed so that the weight will be carried on the pelvis (i.e on the skeletal frame rather through muscular effort).

It is expected that gains in productivity will be minimal in low or first lift pruning but substantial increases may be attained on high lifts or towards the end of the day’s work. Fassola (2001) reported that pruners using manual shears were fatigued after 6.5 hours of work and that their productivity decreased compared to the ‘end of day’ productivity increases shown by workers using electric pruners after 7.5 hours. It was also reported that overall daily productivity for low pruning increased by 12.8% when the electric shears were used compared to manual shears.

Since the Electrocoup shear is operated with only one hand this would enable the operator to have one hand free to hold the ladder or tree branch increasing safety at greater heights. The Electrocoup secateurs are also more easily used by workers who are ambidextrous.

Currently manual pruning is carried out by a workforce that is fit and predominantly male. Use of the Electrocoup shears may widen the current age range and gender of the work force. It is perceived that less physically capable workers will be able to prune with this equipment. Also, since the Electrocoup is currently being used in orchards and vineyards in Australia, there is potential for workers in those areas to extend the range of work currently available by pruning in forestry. Unlike orchard pruning, plantations can be pruned in winter, spring and summer providing for a continual employment all year round. This may also help offset the high initial capital cost (around $3000) of the equipment, which is one of the negative attributes of the pruner.

A safety concern exists regarding the non-operating hand. A secateur which can cut a 60mm branch is clearly able to remove a finger. The video of workers in Argentina shows that all operators who are low pruning hold a saw in the non-operating hand. This keeps their fingers well clear of the cutting blade and provides a tool for cutting exceptionally large branches. Chain male gloves or a glove of similar nature may also be required to protect the operator. When pruning the second or third lifts, the operators used ladders for support and their free hand to grasp the tree for stability. It is thought that this will be a safer method of working than the current method with manual shears. The worker will stand on the ladder with both legs in a normal posture and, because one hand is free, will still be safe while climbing without needing to use a safety belt.

5.0 Summary

The pruning tools currently used have not altered significantly from those outlined by Schlich nearly one hundred years ago (Schlich, 1910). This review has described the design of numerous mechanical pruners and results of field tests where applicable. Attempts to mechanise pruning have so far had little or no success. The Electrocoup has much greater potential since its design overcomes many of the factors listed by Sutton (1971) that limit full or partial mechanisation. As a result of this analysis the Electrocoup will be field tested in Australia.

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