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LINE INSERTION TECHNIQUES FOR THE STUDY OF HIGH FOREST CANOPIES

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ABSTRACT. Line insertion is an essential prerequisite for most canopy studies. The height of the lowest branch often precludes the insertion of lines manually; in such cases, the lines must be fired into the canopy. We define the problems associated with this procedure and explain in detail a method for line insertion that we have developed during work on epiphytes growing on the world's tallest rain forest trees (in Sabah, Malaysia). A crossbow proved to be the most effective device for projecting a missile into the high canopy. Branch heights can be measured quickly and precisely using a laser range finder. Significant arrow modifications, including brass tips and a new line attachment system, greatly improved flight performance and accuracy. A high velocity casting reel prevents the line from snapping as it is fired. Low memory line resists the formation of knots and tangles. We conclude with a detailed explanation of a technique for repositioning the line from the ground.

Key words: canopy access, line insertion, tropical rain forest, crossbow, Malaysia

INTRODUCTION

The engines of propulsion were laid aside, having effected little beyond scattering cords which stretched through the clearing from their points of entanglement like the natural ropy lianas of the canopy

(Major R.G.W. Hingston in Mitchell 1986)

The ability to insert lines into tall trees is an essential prerequisite for many scientific studies of the canopy, especially if the researcher is unable to free climb. Moreover, since forest canopies are complicated structures, these lines must be inserted with some precision if useful data are to be collected. Although the fogging techniques pioneered by Erwin (1982, 1983) can sometimes be used without actually lifting anything into the trees, in most canopy studies either equipment or people or both must be transported into the canopy itself. Line insertion is usually necessary to facilitate the following activities: erecting aerial sticky traps (Compton et al. 2000) and aerial netting (Munn 1991); building permanent platforms, bridges, and canopy walkways (Lowman & Bouricius 1995, Reynolds & Crossley 1995); inserting portable platforms (Nadkarni 1988); fogging tall trees (Stork & Hammond 1997); and for allowing individuals to climb into the canopy to make detailed observations and collections (e.g., Moffett & Lowman 1995).

Other methods exist for transporting people and equipment into the canopy. These include "high-tech" methods (Barker & Sutton 1997, Barker 1997), such as cranes (Parker et al. 1992), booms (Ashton et al. 1995), dirigibles (Hallé 1990), and towers (Inoue et al. 1995). Such methods are costly and, where mobility or relocation is difficult, can create problems of replication. Alternative "low-tech" methods of canopy access include loops (Donahue & Wood 1995, Brockelman 1997), tree-gripping apparatus (Mori 1984), and chains (Reid et al. 1987). These techniques, although cheaper, can be arduous and slow, again potentially causing problems of replication. The canopy access techniques that require line insertion are generally inexpensive, swift, and versatile; and they are likely to remain the most useful for many years to come. In this paper we discuss general techniques of line insertion and some problems associated with them and outline a widely relevant method that we have developed in Borneo in recent years.

Line insertion can be exceptionally difficult. The chief problem is the height of the trees and, in particular, of their lowest branches. This is a global problem. Douglas firs in temperate forests can reach heights of more than 70 m, with their lowest branches higher than 20 m above the ground (Denison 1973). The tallest tropical trees in the world, which are in the lowland forests of southeast Asia, can reach heights of more than 60 m (Richards 1996); more importantly, their lowest branches are often as high as 40 m above the ground. If lower branches were available, it would be easy to climb from the ground, perhaps with the help of a throw bag (Dial & Tobin 1994). Where first-branch heights exceed 20 m, however, it is extremely difficult to climb and

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TABLE 1. The relative merits of various line insertion tools.

Technique	Range (m)	Accuracy (m)	Operation	Safety	Cost
Throwbag	15	±5	Easy	Very Safe	Low
Pole catapult	40	±10	Moderate	Unsafe	Medium
Hand catapult	25	±5	Easy–Moderate	Safe	Low
Line gun	80	±2	Difficult	Hazardous	High
Crossbow	65	±1	Difficult	Hazardous	Medium–high

insert lines manually. The only realistic option is to throw or fire a line using an insertion tool—an instrument designed to launch a projectile attached to a thin line into a tree.

A further problem is that lower parts of trees are often obscured by vegetation. Preparations and groundwork preceding line insertion are often severely restricted, the most suitable branches can become obscured, and the insertion equipment can be impossible to handle effectively. Lines easily become entangled in understory vegetation, a problem made worse by the need for long lines because the trees are tall.

Unless fired at a very steep angle, the arrow will return to the ground at considerable distance from the tree. A final set of problems is associated with bringing the ascending and descending sides of the line together. If the arrow flies off course before hitting the ground, the ends of the rope will be even further apart. When hoisting equipment into the canopy or using the arborist climbing technique (sensu Dial & Tobin 1994), allow both sides of the rope to hang vertically and meet at the base of the tree. If not possible, however, use the split tail technique (Jepson 1997) to negotiate intervening branches. Although the single rope technique (SRT) does not require both sides of the rope to meet under the tree (Perry 1978), the original line, nevertheless, must be inserted with precision, because of the difficulty of moving it once the climb has started.

The difficulties of line insertion are exacerbated by the common occurrence of both living and dead plant material on the branches, especially on the older, larger, and therefore more suitable, support branches. Even a small amount of debris on a branch can prevent the line from sliding over, and with dense epiphytic mats, inserting lines can become almost impossible (Nadkarni 1981). This is a problem throughout the forests of the world, including those of the Nearctic (Denison 1973), Palaearctic (Stork & Hammond 1997), Neotropical (Nadkarni 1984, Freiberg 1997), Oriental (Floren & Linsenmair 1999), and Australasian regions (Kitching et al. 1993).

At least five kinds of line insertion tools are available, and each has its strengths and weaknesses (TABLE 1). Throwbags (Dial & Tobin 1994) are inexpensive and safe but have a very limited range and can be difficult to use in a confined space. Catapults (Nadkarni 1988) can be used to launch projectiles, with lines attached, to heights of up to 30–35 m. Even at these heights, tangling can occur, depending on the type of reel and line used. Line-throwing guns are powerful but costly and dangerous, since they use explosive charges, and legal complications can make them difficult to import. Crossbows have the greatest accuracy, although they also are relatively dangerous to use and can be difficult to import.

MATERIALS AND METHODS

Over several years, we developed line insertion techniques and equipment, while studying epiphytic ferns in lowland dipterocarp rain forest at Danum Valley, Sabah, Malaysia. Working in these forests is particularly challenging. The trees are very tall; dense, tangled vegetation hinders movement; and equipment deteriorates rapidly in the hot, wet climate. Techniques robust enough for these conditions should work in any environment.

The primary criterion for selecting a site within the canopy should be its relevance to the study, not its accessibility or convenience (Barker & Pinard 2001). The canopy site, therefore, should be selected before choosing an optimum firing position, rather than the other way round. The point from which the line is eventually fired should afford a reasonably clear view of the branch, although most projectiles can be fired through light vegetation. After a target site is selected, precise target heights are essential, so that the method of line insertion and the type of missile used can be matched to the range required. The easiest and most accurate way to measure branch heights is with a laser range finder. We use a Bushnell Yardage Pro™ 400, from Bushnell Sports Optics Worldwide, Kansas, U.S.A. This instrument records distances instantly, and many measurements can be made in a few seconds.

From our own experience in southeast Asian rain forest, we have found that the crossbow is

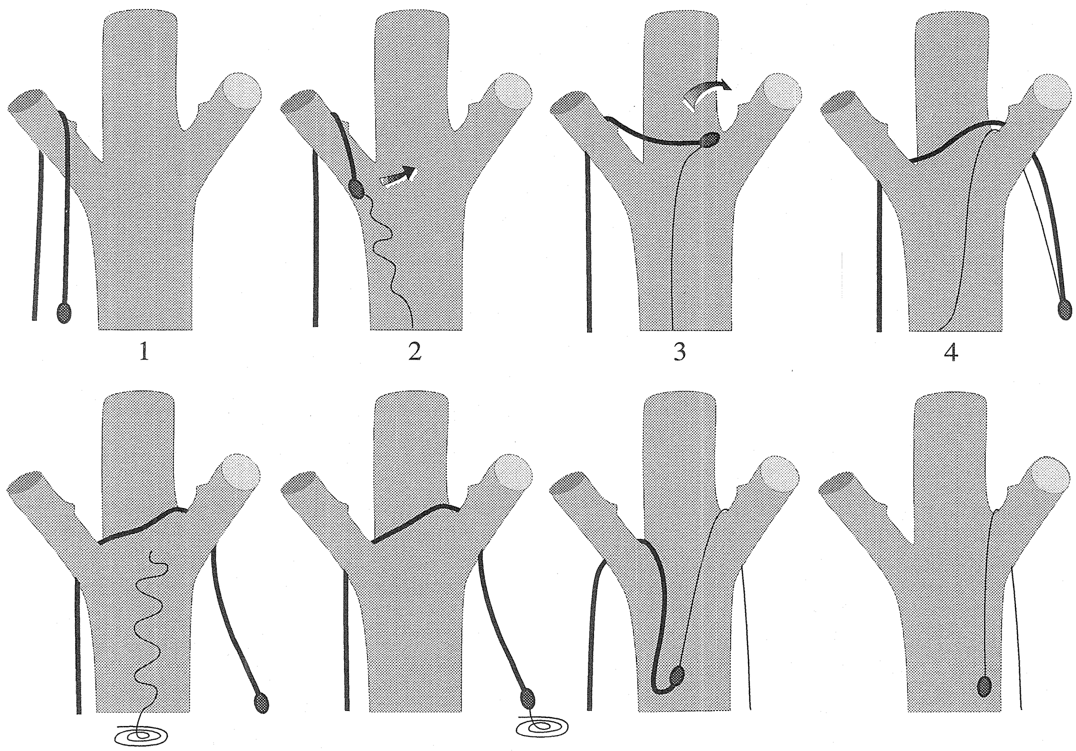

FIGURE 1. A ground based method for repositioning lines in trees. A smooth weight attached to a thin line should be fastened to the thick line and pulled up to within a few meters of the left hand side (LHS) branch (1). Oscillations in the thin rope cause the weight to act as a pendulum and eventually to swing over the right hand side (RHS) branch (2, 3). At this point (4) the weight is released and it falls, pulling both lines over the RHS branch. The thin line is pulled out of the tree (5) and re-tied to the weight (6), which is pulled back over the second branch (7). The weight, with both lines attached, falls down between the two branches, leaving the thick line over the LHS branch and the thin line over the RHS branch (7). The thick line can either be removed or left in the tree (8).

the best instrument for line insertion. Throwbags (Dial & Tobin 1994), pole catapults (Munn 1991), and hand catapults (Nadkarni 1988), although easy to transport internationally, simple to use and versatile, were not powerful enough to reach even the lowest branches. Even where low branches are available, researchers unfamiliar with rope techniques will be unable to reposition the line significantly higher in the tree and therefore will still require a powerful insertion tool. We have developed a way of repositioning lines without having to climb (see FIGURES 1 and 2). Although the line can be moved higher with these techniques, they would be impractical for covering large vertical distances. In studies where climbing is necessary, firing lines into the highest branches makes the initial climb much easier. Line throwing guns (Stork & Hammond 1997) are powered by explosive charges or gas canisters. This not only makes them relatively dangerous but difficult to transport from one country to another. Crossbows, on the other hand, are capable of firing lines high up into even the tallest trees, yet they can be dismantled and transported as component parts.

Firing an arrow with a line attached over a branch up to 65 m high requires a large, high velocity (ca. 76 m s^{-1}) crossbow. We use a Panzer II crossbow, purchased from Barnett International, Wolverhampton, U.K. Although detachable limbs make it possible to adjust the range of some crossbows, this process can be difficult and time-consuming under field conditions. Greater flexibility can be achieved by using arrows with a range of tip sizes (TABLE 2). Our arrow shafts are 40 cm long and weigh 16 g before the brass tips are attached. Although we decided to attach the brass tips permanently, it would be simple to design a screw-on tip that could be changed in a matter of seconds, thus

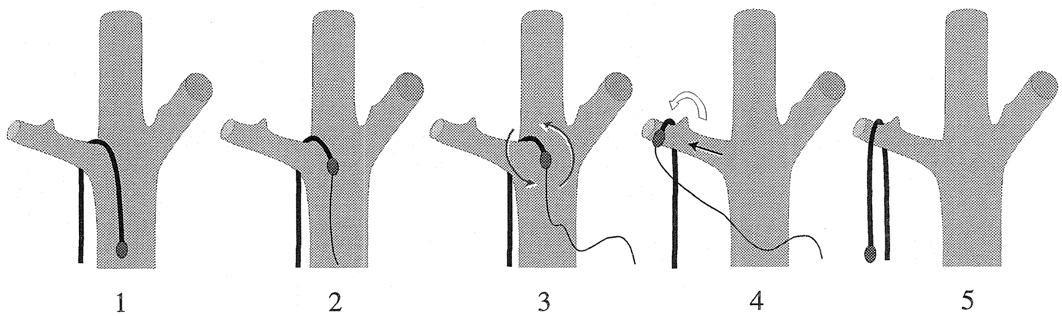

FIGURE 2. A ground based method for moving a line along a branch. A weight is raised to the branch (1, 2) as in FIGURE 1. Instead of oscillating the thin line, however, it is whirled around, causing the weight to move with a rapid circular motion (3). The momentum of the weight can be used to lift the line and place it further along the branch (4). The line can be lifted over stumps and other obstructions, including branches, using this technique (5).

reducing the number of arrows required. By mastering all the techniques described in this paper, researchers will find that loss of an arrow becomes a rare phenomenon. Our rate of arrow loss before we began using the equipment and techniques detailed here, was ca. three arrows per line. Since that time, however, we have inserted more than 100 lines and lost only eight arrows. The arrows are standard and can be purchased from Barnett International.

The crossbow should never be loaded until one is in position and ready to fire. At this point, the line can be screwed into the back of the arrow (FIGURE 3), and the crossbow loaded. The reel should be held in the hand that supports the weapon, such that the spool is free to unwind as the arrow exits the bow. Once loaded, the crossbow should be raised, aimed, and fired without delay. Indecision or hesitation at this stage may result in a negligent discharge, which could cause serious injury. The crossbow and reel must be held in the firing position until the arrow has stopped moving, otherwise the line will snap or tangle.

The height to which the arrow ascends is determined by the weight of its tip. We have found that four sizes provide adequate flexibility (TABLE 2). Although lighter arrows are required for high branches, they must be heavy enough to pull the line over the branch and down the other side. The arrow design is fundamental to the accuracy of this system. For example, if the line is not attached directly behind the shaft of the arrow, the latter will fly off course (FIGURE 3).

TABLE 2. Dimensions, weight, and range of arrow tips.

Size	Tip dimensions (mm)	Tip weight (g)	Total weight (g)	Range (m)
1	60 × 15	74	90	30–40
2	50 × 15	54	70	40–50
3	40 × 15	44	60	50–60
4	40 × 12	24	40	60–65

The arrow's flight should be monitored using binoculars to confirm whether the shot was successful. In the case of a misfire, knowing the arrow's last heading will facilitate its retrieval. Assuming that the line is not seriously tangled, the arrow should fall smoothly back to earth. If not, and if the arrow is suspended out of reach, it may be necessary to give the line a series of short, sharp flicks. In most cases, this will cause the line to slip and the arrow will drop. If the arrow has travelled an excessive distance past the target branch, it can be reeled back gently and allowed to drop vertically closer to the base of the tree.

Only thin lines can be successfully fired at high speeds, and they need to be smooth to reduce friction over the branches. Instead of nylon fishing line, braided line should be used because it has very low 'memory' and will not tangle as easily. It is essential to use low memory line, especially with a high velocity weapon such as a crossbow. If the line twists, it will snap immediately, and the arrow will be lost. The breaking strain should be high enough to be effective but not so high as to prevent breaking an arrow that becomes entangled. For these purposes, 14 kg is sufficient. The line should be at least twice the height of the tree, in case the arrow travels further than the target branch.

The design specifications of the reel are of paramount importance. Standard fishing reels will not work when used with high velocity projectiles. It is impossible for the line to unwind quickly enough and it will snap. The use of reels with a shallow aperture, such as casting or spin-

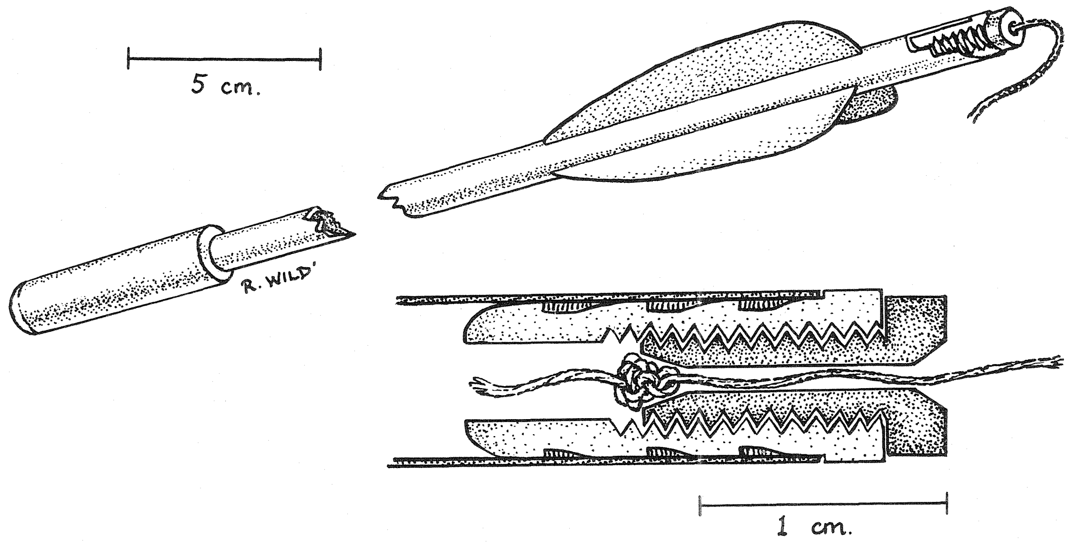

FIGURE 3. Upper drawing shows modified brass arrow tip and line attachment system. Lower drawing is an enlarged longitudinal section showing the knot running centrally through the threaded brass rod, which is screwed into the end of the aluminium arrow shaft.

ning reels, is essential. We use a Daiwa Emblem spinning reel and Fox Pike System™ braided low memory line with a breaking strain of 14 kg.

The arrow can be slowed at any point from the moment of firing by applying friction to the line as it exits the reel. Some fishing reels have an adjustable clutch for this purpose. Once the arrow is over the branch, its descent can be controlled using the same principle. The arrow should be lowered gently to eye level; if allowed to fall to the ground, it becomes harder to locate. As the arrow is removed from the fishing line, a slightly thicker (ca. 5 mm) line should be attached in its place. This "intermediate" line can then be pulled up into the canopy as the fishing line is wound back onto the reel. Finally, a heavy-duty line (ca. 10 mm) should be pulled over the branch (FIGURE 3). This line can be used to haul climbing ropes or equipment into the crown and can remain there indefinitely. If lines are left in a tree for long periods, however, they may become choked with vines or lianas. They should be checked, therefore, approximately every 3–6 months.

It is often necessary to move lines between branches (FIGURE 1) or along them (FIGURE 2). To do this from the ground, a smooth piece of wood weighing ca. 10 kg should be tied to a heavy-duty line and pulled up into the tree. This weight also should be attached to a slightly thinner line running back to the ground. Once in the tree, the weight can be moved back and forth by swinging the thinner line. By appropriate control of the movement of the weight, the line can be moved either to a new branch (FIGURE 1) or to a new position on the same branch (FIGURE 2). These techniques are easier to perform, if the branches are clearly visible. The alternative is to fire another line although; if the branches are obscured, this option may be less desirable than persevering with the original line.

DISCUSSION

Inserting lines into tall trees with speed and precision can be a complicated and daunting task. With the techniques described here, however, we have been able to use the inserted lines in a range of applications, including the positioning of aerial sticky traps (Compton et al. 2000), placing ropes for climbing, removing large epiphytic ferns, lifting foggers and fogging trays into the canopy, inserting data-loggers, and hoisting construction materials for the building of canopy platforms (Workman 2000). Although developed in a tropical rain forest, these techniques should prove useful and relevant anywhere in the world.

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