Journal of Tropical Forest Science 12(3): 561 – 570

SELECTIVE HERBICIDE APPLICATIONS FOR CONTROL OF LIANAS IN TROPICAL FORESTS

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Received December 1998

FREDERICKSEN, T. S. 2000. Selective herbicide applications for control of lianas in tropical forests. The efficacy of selective herbicide application to control interference from large woody vines (lianas) in managed tropical forests of eastern Bolivia was tested. The efficacy of three chemical formulations (2,4-D, triclopyr and imazapyr) and two methods of herbicide application (cut-surface application and uncut basal stem application) for controlling lianas was compared to the traditional practice of liana cutting with machetes. In addition, costs of herbicide treatments were estimated. For lianas not treated with herbicide, 70% of stems resprouted with a subsequent height growth averaging 140 cm after seven months. Application of 2,4-D to the freshly cut surface of lianas killed 60% of stems after seven months. Basal stem application of triclopyr killed 75% of uncut liana stems and seriously reduced the vigour of another 15% of the stems. Basal stem application of imazapyr killed only 11% of liana stems. Responses to treatments did not vary significantly among major families of lianas. Application of treatments to free commercial species of lianas cost \$1.64 ha^{-1} for cutting without herbicide, \$1.87 ha^{-1} for cut surface application with 2,4-D, \$10.76 ha^{-1} for basal stem application with triclopyr, and \$31.80 ha^{-1} for basal application with imazapyr. While this study provides baseline data on efficacy and cost of treatments, operational feasibility of these treatments will largely depend upon local labour costs, availability of chemicals, and the magnitude of liana interference problems.

Key words: Bolivia - herbicide - interference - liana - tropical forests - vine cutting

FREDERICKSEN, T. S. 2000. Penggunaan racun herba memilih untuk mengawal liana di hutan tropika. Kemujaraban penggunaan racun herba memilih untuk mengawal gangguan pokok kayu menjalar (liana) yang besar di hutan tropika terurus di timur Bolivia diuji. Kemujaraban tiga rumusan kimia (2,4-D, triklopyr dan imazapyr) dan dua kaedah penggunaan racun herba (penggunaan pada permukaan keratan dan penggunaan pada pangkal batang) untuk mengawal liana dibandingkan dengan amalan tradisi iaitu memotong liana menggunakan parang. Di samping itu, kos rawatan racun herba dianggarkan. Bagi liana yang tidak dirawat dengan racun herba, 70% daripada batang bertunas semula dengan pertumbuhan ketinggian secara puratanya 140 cm selepas tujuh bulan. Penggunaan 2,4-D pada keratan baharu permukaan liana membunuh 60% daripada batang selepas tujuh bulan. Penggunaan triklopyr pada pangkal batang membunuh 75% daripada batang liana yang tidak dikerat dan mengurangkan kesuburan sebanyak 15% lagi batang tersebut. Penggunaan imazapyr pada pangkal batang membunuh hanya 11% batang liana. Tindak balas terhadap rawatan tidak berubah dengan bererti di kalangan famili utama liana. Kos penggunaan rawatan untuk membebaskan spesies dagangan liana ialah \$1.64 ha^{-1} untuk keratan tanpa racun herba, \$1.87 ha^{-1} untuk keratan permukaan dengan 2,4-D, \$10.76 ha^{-1} untuk pangkal menggunakan triklopyr, dan \$31.80 ha^{-1} untuk pangkal menggunakan imazapyr. Sementara kajian ini menyediakan data asas mengenai kemujaraban dan kos rawatan, operasi kemungkinan rawatan akan banyak bergantung pada kos buruh tempatan, ketersediaan kimia, dan magnitud masalah gangguan liana.

Introduction

Interference from large woody vines (lianas) has been an obstacle for forest management throughout much of the tropics. Where lianas are abundant, damage during forest harvesting is often excessive because intercrown connections among trees by lianas often results in crown damage or even uprooting of neighboring trees when individual trees are felled (Fox 1968, Appanah & Putz 1984, Vidal *et al.* 1997). In addition, lianas may rapidly envelop tree crowns with foliage, reducing growth or causing mortality (Putz 1984, Hegarty 1991, Pérez-Salicrup 1998). In clearings created by forest harvesting, increased light availability can result in the rapid growth of lianas delaying or preventing regeneration by trees (Fox 1976, Pinard & Putz 1994).

For these reasons, liana cutting has been employed in many areas of the tropics to reduce logging damage or to control competition. However, many liana species resprout aggressively and regrowth is often rapid (Appanah & Putz 1984, Putz 1991, Pinard & Putz 1994), being supported by root systems left intact after cutting. Cutting may also stimulate the sprouting from several points of a cut liana stump, or even severed pieces of liana stems (Appanah & Putz 1984), thus increasing the actual number of stems per rootstock.

One potential solution to reducing liana interference is the use of selective herbicide applications to cut surfaces of lianas. Appanah and Putz (1984) found that applications to cut surfaces with 2,4,5-T kept resprouting below 6% compared to 32% for untreated stems. Applications of herbicide directly to the basal portions of uncut stems may also provide control of lianas without the necessity of cutting. Similar applications have worked effectively in controlling interference with crop trees from small-diameter woody trees and shrubs (Loftis 1985, Zedaker *et al.* 1987, Groninger *et al.* 1998) in temperate forests. However, such techniques have yet to be tested on lianas. If effective, these treatments may provide a more efficient and more lasting means of controlling logging damage and competition from lianas.

The objective of this study was to evaluate the efficacy of several herbicide formulations (2,4-D, triclopyr and imazapyr) and methods of application (cut surface vs. basal stem application) in managed tropical forests in eastern Bolivia. These herbicide treatments were compared to the traditional practice of machete cutting of lianas. Costs of applying these treatments were also estimated.

Methods

Study areas

Las Trancas is a seasonally dry tropical forest within the Lomerío region located south of Concepción in eastern Bolivia (16°13'S, 61°50'W). Seasonal mean temperature in the region averages about 24.3 °C with a mean annual precipitation of about 1100 mm. Most of Las Trancas is upland forest with the canopy stratum becoming mostly deciduous during a 6–7 month dry season. A second site, Oquiriquia is a forest concession located in the Bajo Paraguá Forest Reserve (14°45'S, 62°00'W). The forest is also a semi-dry seasonal tropical forest with an average annual rainfall of 1300 mm. Mean annual temperatures range between 20 and 25 °C. Both study areas have an abundance of lianas. In Las Trancas, vine stem density > 2 cm diameter averaged 3876 stems ha^{-1} (Killeen *et al.* 1998); while in Oquiriquia vine density > 2 cm diameter at breast height (1.4 m) averaged 2741 stems ha^{-1} (Pérez-Salicrup 1998). Major liana families and genera in Las Trancas include Apocynaceae: *Foresteronia*; Bignoniaceae: *Arrabidaea*, *Macfadyena* and *Tanaecium*; Combretaceae: *Combretum*; Malpighiaceae; Sapindaceae: *Serjania*; and Trigoniaceae: *Trigonia*. Major liana families and genera in Oquiriquia include Apocynaceae; Bignoniaceae: *Tanaecium*; Combretaceae: *Combretum*; Dilleniaceae: *Doliocarpus*; Malpighiaceae; Papilionaceae; and Sapindaceae: *Serjania*.

Field experiments

Experiment 1 – Efficacy of rate and method of application of 2,4-D for liana control

A total of 100 single-stemmed lianas ranging 2–8 cm in stem diameter (measured at 50 cm from their origin in the soil) were tagged in July 1998 at Oquiriquia. Care was taken to ensure that liana stems did not share root systems with other nearby stems. Lianas were randomly assigned one of five treatments resulting in 20 replicates. Treatments included:

1. Machete cutting lianas 1 m above from the ground.
2. Machete cutting followed by application of a 10% aqueous solution of 2,4-D in amine formulation (applied as Fenomine) to the freshly cut surface. Herbicide was applied in a thin stream (1 mm) with a 0.5-l plastic squirt bottle. The entire cut surface was coated to the point of runoff and then repeated after 10 seconds to assure herbicide uptake and coverage. Quantity of solution applied varied with liana diameter but ranged approximately 10–50 ml per liana.
3. Same as treatment 2, but using a 25% solution of 2,4-D.
4. Application of a 25% solution of 2,4-D (amine formulation) in vegetable oil (to facilitate bark penetration) to uncut liana stems 1 m above the ground. Herbicide was applied with a squirt bottle as in previous treatments encircling the stem with solution until a 15 cm length was completely wetted. The herbicide solution was shaken vigorously before application to facilitate mixing of herbicide and oil carrier. Amounts of solution applied averaged 50–100 ml per liana.
5. Same as treatment 4, but using a 50% solution of 2,4-D.

Responses of lianas to treatments were rated in September 1997 using a four-point response scale which differed for cut-surface vs. uncut stem applications.

For cut-surface applications:

1. No control = vigorous resprouting from cut stems without apparent effect of herbicide applications
2. Minor control = slightly weakened resprouting with minor herbicide response evident including foliar yellowing, epinasty
3. Major control = severely weakened resprouting with severe foliar yellowing or epinasty (abnormal twisting of the stem)
4. Total control = no resprouting

For uncut-stem applications:

1. No control = no visible crown injury (leaf browning, defoliation) or injury to stem near area of application (tissue necrosis, bark loss)
2. Minor control = minor crown injury (<25% of canopy discoloured or defoliated) or injury to stem (minor tissue necrosis or bark loss that was unlikely to significantly affect vascular transport or cambial activity)
3. Major control = major crown injury (>25% of canopy discoloured or defoliated) or major injury to stem near area of application (extensive tissue necrosis or bark loss that is likely to result in significant disruption of vascular transport or cambial activity)
4. Total control = mortality of liana

For this experiment, another rating of liana responses to treatment was to be made after one year. However, poor road conditions prevented access to the study site.

Experiment 2 – Efficacy of herbicide formulation and application technique for control of lianas

Ester formulations of triclopyr (applied as Garlon 4E, ®-DowElanco, Indianapolis, IN) and imazapyr (applied as Chopper, ®-American Cyanamid Company, Wayne, NJ) were applied as 50% solutions in vegetable oil to determine their relative efficacy for stem applications without cutting. Also included was a 10% cut-surface application of 2,4-D and a cut-only treatment. The study was installed at the Las Trancas study site in January, 1998. A total of 80 lianas were selected using the criteria of previous experiments and randomly assigned to four treatments for a replication level of n=20. Treatments were applied and response data collected in the same manner as the previously-described experiment. In addition, the height of the largest sprout was measured for resprouting lianas. Liana responses to treatments were observed in April 1998 and again in August 1998. For the August rating, all lianas receiving the basal stem application treatments were cut to determine whether liana stems were live or dead. The stump portion of lianas receiving the other cutting treatments that had not resprouted were also examined to determine whether they were live or dead.

Experiment 3 – Operational feasibility of liana control treatments

In April 1998 at the Las Trancas site, six 0.25-ha (50 × 50 m) plots were delineated and randomly assigned one of three treatments: machete cutting (at 1 m height) of all liana stems (> 2 cm dbh) growing on the stem or within the crown of commercially valuable tree species, cutting followed by cut surface application of water, or basal application of vine stems (without cutting) with vegetable oil. Thus, each treatment had two replicates. Herbicides were not used in these trials to avoid unnecessary exposure to workers not yet trained in the application of herbicides. Formulations contained only the carrier solutions. It was assumed that not using actual herbicides in the mixture solution would not significantly impact the time required to administer treatments. Solutions were applied with a 0.5-l plastic squirt bottle by three local labourers who were highly skilled with the use of machetes and were able to identify commercial forest tree species. The time required for treatment application and the amount of solution used was recorded. Labourers were instructed in the application of treatments and the general purpose of the experiment, but did not know they were being timed. Local labour wages at the time of treatments were 25 bolivianos (US$4.46) for a 7-h workday. Cost of chemicals were: 2,4-D:($5.5/l), triclopyr ($15.40/l), imazapyr ($50.00/l).

Once treatments were applied, the plot was systematically searched for all lianas, which were then tagged to facilitate counting. The following information was recorded for each liana stem > 2 cm dbh: liana family, host tree species, liana treatment status (treated or not treated), and liana diameter at breast height.

Statistical analysis

Contingency table analyses were used to test whether responses differed among treatments. Differences in the responsiveness of major liana families to treatments in general (all treatments combined) were also tested for both experiment 1 and experiment 2. Student's *t*-test was used to test for difference in the growth of liana resprouts between cut-only and cut-surface herbicide application treatments. Regression analysis was used to test for the significant relationships between liana diameter and resprout growth. An alpha level of 0.05 was used to test for significant differences between treatments or for the significance of relationships.

Results

Experiment 1 – Efficacy of rate and method of application of 2,4-D for liana control

Two months after application, both rates of cut-surface application had successfully prevented resprouting of all liana stems (Table 1). For cut lianas not subsequently

Table 1. Percentage of liana stems by response class to liana control treatments in Oquiriquia, Santa Cruz, Bolivia. Responses were recorded two months after treatment. See text for full definition of treatments and treatment responses.

Treatment	Response			
	No control	Minor control	Major control	Total control
Cutting only	55	0	0	45
Cutting followed by 10% solution of 2,4-D	0	0	0	100
Cutting with 25% aqueous solution of 2,4-D	0	0	0	100
Basal stem application with 25% oil solution of 2,4-D	50	35	15	0
Basal stem application with 50% oil solution of 2,4-D	40	20	40	0
No treatment	100	0	0	0

treated, 55% of stems had resprouted. Basal stem applications appeared to have affected (but not killed) 50% of liana stems receiving the low rate of 2,4-D and 60% of stems receiving the high rate of application. No mortality was observed for control stems. No significant differences in responses were observed among liana families when combining responses of all treatments. However, lianas in the families Apocynaceae, Connaraceae and Sapindaceae tended to be most responsive to treatments, while lianas of Dilleniaceae and Papilionaceae tended to be the most difficult to control (Table 2).

Experiment 2 – Efficacy of method of application of three chemicals for liana control

Four months after application, more than half of cut liana stems had still not resprouted (Table 3). Treatment of cut lianas stems with 2,4-D further decreased

Table 2. Percentage of stems for major liana families by response class to all liana control treatments combined (cutting only, cutting with herbicide application, and basal stem application) in Oquiriquia, Santa Cruz, Bolivia. Responses were recorded two months after treatment. See text for full definition of treatments and treatment responses. Responses did not differ significantly among liana families (χ^2 = 17.9, df = 20, p = 0.47).

Treatment	Responses			
	No control	Minor control	Major control	Total control
Apocynaceae	0	0	20	80
Bignoniaceae	50	0	0	50
Connaraceae	12	12	12	64
Dilleniaceae	50	50	0	0
Papilionaceae	38	25	12	25
Sapindaceae	11	11	11	67

Table 3. Percentage of liana stems by response class to liana control treatments in Las Trancas, Santa Cruz, Bolivia. Responses were recorded four and seven months after treatment. See text for full definition of treatments and treatment responses. Responses differed significantly among treatments at four months (χ^2 = 101.8, df = 12, p = 0.0001) and at seven months (χ^2 = 40.9, df = 9, p = 0.0001).

Treatment	Responses							
	No control		Minor control		Major control		Total control	
	4 mth	7 mth	4 mth	7 mth	4 mth	7 mth	4 mth	7 mth
Cutting only	30	70	5	0	10	0	55	30
Cutting followed by 10% solution of 2,4-D	10	40	0	0	5	0	85	60
Basal stem application with 50% oil solution of triclopyr	35	5	35	5	25	15	0	75
Basal stem application with 50% oil solution of imazapyr	67	67	22	22	11	0	0	11

Table 4. Percentage of stems for major liana families by response class to all liana control treatments combined (cutting only, cutting with herbicide application, and basal stem application) in Las Trancas, Santa Cruz, Bolivia. Responses were recorded seven months after treatment. See text for full definition of treatments and treatment responses. Responses did not differ significantly among liana families (χ^2 = 6.37, df = 12, p = 0.90).

Treatment	Responses			
	No control	Minor control	Major control	Total control
Apocynaceae	33	0	0	67
Bignoniaceae	48	4	4	44
Combretaceae	33	0	0	67
Malpighiaceae	38	0	0	62
Trigoniaceae	67	7	7	26

resprouting by over 50%. After seven months, 70% of lianas had resprouted with the largest sprout averaging 140 cm in length. Resprouting vigour at seven months was not related to liana diameter (r^2 = 0.04, p = 0.73). Much less control was observed with the basal application treatments, although triclopyr achieved a higher control rate than imazapyr. However, after seven months, lianas treated with basal applications of triclopyr had the highest liana mortality rates (75%) with an additional 15% of treated lianas displaying major negative effects from the application (Table 3). Cut-surface applications of 2,4-D following cutting prevented resprouting of 60% of the liana stems treated, a 100% improvement over cutting alone. Height growth of sprouts on lianas treated with 2,4-D was not significantly different from sprouts of untreated lianas (t = 0.98, p = 0.48). Imazapyr had a limited effect with only 11% mortality of treated lianas. Responses among major liana families to treatments in general did not differ significantly (Table 4). However, lianas in the families Apocynaceae, Combretaceae, and Malipighaceae tended to be most responsive to treatments, while lianas in the family Trigoniaceae tended to be most difficult to control.

Experiment 3 – Operational feasibility of liana control treatments

In the six plots used to determine operational feasibility of treatments, average liana density was 504 stems ha^{-1} > 2 cm dbh, 73% of which were hosted by commercial tree species. After four months, the largest of the sprouts on resprouting lianas averaged nearly 80 cm in length. Costs varied dramatically, ranging from \$1.64 ha^{-1} for cutting alone to \$31.80 ha^{-1} for basal stem treatment with imazapyr (Table 5). Cutting treatments had higher labour costs than basal bark applications, but were much less expensive overall because of the higher price of herbicides used in basal bark applications (Table 5).

Table 5. Costs ($/ha) of liana control treatments in Las Trancas, Santa Cruz, Bolivia. Each treatment cut only, stem application following cutting, and basal application without cutting was replicated twice. Only carriers (water or vegetable oil) were used to prevent herbicide exposure to local workers not yet trained with the use of herbicides. Chemical costs were estimated based on the amount of carrier solution used. See text for full definition of treatments and treatment responses.

Treatment	Labour	Chemical	Total cost
Cutting only	1.64	0.00	1.64
Cutting with 10% solution of 2,4-D	1.61	0.26	1.87
Basal stem application with 50% oil solution of triclopyr	0.45	10.31	10.76
Basal stem application with 50% oil solution of imazapyr	0.45	31.35	31.80

Discussion

Responses of lianas to treatments and treatment costs varied greatly. However, the inadequacy of liana cutting for prolonged liana control was demonstrated by this study. After seven months, 70% of cut liana stems resprouted with an average height of 140 cm. If the objective of liana cutting is only to prevent damage caused by intertree liana connections during felling, the rate of resprouting is not important and herbicide application is unnecessary. However, if post-harvest interference by lianas with tree regeneration is a concern, herbicide treatments may be used to reduce damage by lianas during felling while simultaneously improving post-harvest tree regeneration success. For example, Appanah and Putz (1984) found that six years after harvesting trees with lianas, more than 50% of lianas were resprouts from nearby fallen climber stems.

In the short term (3–4 months), cutting followed by application of 2,4-D to the lower cut surface of lianas provided near complete control of resprouting. Appanah and Putz (1984) observed similar effective short-term (3 month) control of lianas with the herbicide 2,4,5-T in Malaysia. However, the treatment in my study only delayed resprouting of many lianas, since many lianas had sprouted after seven months. Moreover, the growth of resprouts was not significantly reduced compared to that of resprouts of lianas not receiving treatment. Still, this treatment represented a 100% increase in resprout control compared to cutting alone after seven months. After three months, response of lianas did not differ between the 10% and 25% rates of application. The low labour cost of this treatment is attractive, being similar to cutting alone. The herbicide 2,4-D is also the most inexpensive of the chemicals tested. However, other more expensive chemicals, such as imazapyr, triclopyr and glyphosate should be tested to determine if greater control can be achieved without substantially increasing costs. Resprouting from the untreated upper surface (hanging) portion of lianas was uncommon (3% of all vines cut) and mostly limited to one species (*Psiguria ternata*, Cucurbitaceae). Given this small percentage of resprouts from the hanging portion of lianas, it is probably not cost-effective to treat both cut surfaces.

Triclopyr provided the most effective control of lianas after seven months. Although much more costly than 2,4-D, this chemical can greatly reduce the density of liana stems in harvested areas. One advantage of basal stem treatments is their relatively low labour costs, approximately 25% of the costs of liana cutting treatments. Additional cost savings may be obtained through additional trials to determine if efficacy is similar at reduced rates of application with this chemical.

Although the results of this study provide efficacy and cost comparisons of application methods and chemicals, operational feasibility of treatments in other tropical forests will depend on local conditions including labour costs, chemical costs, the magnitude of liana infestations, the resprouting ability of species, and their individual susceptibility to chemical treatments. For example, Vidal *et al.* (1997) determined that the cost of cutting all lianas in Brazilian forests averaged \$16 ha^{-1}, an order of magnitude higher than in eastern Bolivia. To control costs, they proposed species-specific cutting of only the most aggressive liana species, although more detailed response data on individual liana species responses would be necessary. Although treated liana species in this study were not identified to species, some liana families appeared to be more difficult to control than others. However, it may be unrealistic to expect labourers to distinguish individual liana species that are often difficult to differentiate by trained botanists.

Cutting only those lianas hosted by commercial tree species is another method for reducing costs. For example, only 73% of trees in plots at the Las Trancas site were considered to have commercial value, theoretically reducing treatment costs by over 25%. However, Vidal *et al.* (1997) found that lianas connected the crowns of 3–9 individual trees, indicating that it may be rare to find lianas that only infest non-commercial trees within a given area. Given the interconnections of lianas among trees, it may be more expedient to control only those lianas, regardless of liana species or the commercial value of the tree bole supporting them, that are most vigorous and/or large in size. These lianas are likely to cause the most damage when commercial trees are felled and will also be the most vigorous competitors with regeneration in logging gaps. In addition to economic reasons, it may also be detrimental to cut all lianas since they provide many important ecological functions within forests, such as substrates for insects (Davies 1998), food for various species of wildlife (Sainz 1997), and travel corridors for many arboreal animals (Montgomery 1978). The selective nature of these applications, as well as the relative low toxicity of the chemicals used, will unlikely be problematic in terms of damage to non-target organisms, including humans. However, it is important to add that the application of these treatments should always be made by personnel who are well-trained in the safe use of herbicides.

In summary, some selective herbicide applications can provide more long-lasting control of lianas than traditional vine-cutting. Further research is necessary to increase the efficiency of applications and to determine which other chemicals and/or rates provide the best control:cost ratio. It will also be important to develop guidelines for selecting which liana stems are to receive treatment in forest stands. Finally, the cost and effectiveness of controlling lianas prior to harvesting should be compared to post-harvest control of lianas in logging gaps.

Acknowledgements

This study was funded by Proyecto BOLFOR, a USAID-funded sustainable forest management project in Bolivia. I would like to thank Laura Carse, Bonifacio Mostacedo, Daniel Nash, John Nittler, Shep Zedaker and two anonymous referees for their reviews of this document. I also thank Shep Zedaker for his material and technical assistence to this project as well as Jack Putz for his initial guidance. Finally, I thank Nell Fredericksen and Lizzy McDonald for their assistence with field work and Bonifacio Mostacedo, Diego Perez and Marisol Toledo for their assistence in liana species identification.

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