ROLLER-WIPER HERBICIDE APPLICATOR: CONTROL OF RIGHT-OF-WAY HARDWOOD BRUSH[1]

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Abstract. The application of herbicides to target plants by using contact method such as wicks or absorbent wipers has several advantages over spraying in many circumstances. Elimination of herbicide drift, conservation of herbicide material, and plant height selectivity are characteristic of most contact application methods. An analysis of the most suitable method of applying translocatable herbicides to woody brush was carried out in field and laboratory tests.

A horizontal, rotating, carpet-covered roller was used in test plots and on utility rights-of-way to treat a wide variety of woody brush using seven translocatable herbicides. An average of over 90% brush control was achieved in these tests. Laboratory testing studied variations in the roller speed, roller diameter, carpet covering, wiper flap pressure, liquid surface tension and liquid viscosity in order to determine optimal levels for these application parameters.

Mathematical models are developed for predicting the behavior of liquid added to the top of the rotating cylinder. More than 86% of the variation in the amount of liquid held on the roller could be attributed to the variables studied. Field studies indicated that the roller-wiper concept of herbicide application is very effective in controlling unwanted woody brush. It was determined that by controlling the proper parameters, an efficient, reliable, safe herbicide applicator could be built using the carpet roller principle.

Controlling woody plants is a problem in many industrial areas. Forest pine plantations require control of hardwood brush during the early years after initial planting to assist the growth on the site from roots and seeds remaining after site preparation that sprout and grow more rapidly than the pine seedlings. The pine growth can be severely retarded by the hardwood brush unless some control method is used on the hardwoods.

On electric utility rights-of-way, (ROWs), hardwood trees also are a problem in that if left unchecked, they will grow into the power lines and disrupt service. In addition, hardwood trees and brush impede service vehicles from inspecting and maintaining the power transmission facilities.

Various methods of brush control are available ranging from hand cutting to aerial spraying of herbicides. Manual cutting methods are slow, hazardous to the worker, and result in resprouting. Aerial application methods are cost-effective for ROW application but are subject to wind drift into non-target plants and ownerships, extensive regulations in some states, and often, public dissatisfaction.

An efficient method of controlling hardwood brush, without the risk of herbicide drift and with minimal impact on non-target plants would be of value to utility right-of-way managers and contract companies, tree plantation managers, and pasture and rangeland managers.

In the beginning of this study, certain constraints were placed on the possible solutions to the problem:

1. The method of controlling hardwood brush must be cost-effective. That is, the resulting method should be competitive with existing methods.
2. Any method devised should only control the brush requiring control and not affect plants and trees on adjacent sites.
3. For erosion control, the method of controlling hardwoods should have no, or minimal, effect on grasses.
4. The method devised should be practical for field use.
5. Any equipment used should be sturdy enough for the rough condition encountered on ROWs, tree plantations, and pasture and rangeland.

Methods investigated. A number of methods of brush control were investigated early in the research and discarded as not having the potential to meet the solution constraints.

Mechanical methods (chopping, rolling and mashing, rotary mower type cutting, and general maceration) were considered to be too energy consumptive and also, require large machines to adequately cut or chop hardwood trees and brush. Stumps and roots would still exist to resprout later unless a herbicide application was included in the system. Application cost would have

1. Presented by Dr. Gibson at the annual conference of the International Society of Arboriculture in Indianapolis, Indiana in August 1983.

increased with the addition of a herbicide applicator. Translocatable herbicides were deemed to be ineffective since the above ground portion of the tree or shrub would not be present to move the herbicide through the internal plant system to the roots.

Solid type herbicides hold some advantages over liquids. Solid pellets tend to stay in place and work over a limited area. Placement is critical, however, and the difficulties of exact placement along with the killing of grasses caused us to move to other methods.

Contact type applicators that apply a liquid herbicide appeared to have a number of features useful in ROW and forestry/range applications. Contact transmission of the herbicide is an exact method of locating the chemical where you want it. Using an applicator with an adjustable height mechanism would permit the grasses to escape but catch the taller hardwood saplings and brush. Some crucial questions remained, of course. How effective would a contact-type applicator, basically designed for weed control in agricultural crops, work on hardwood brush? Could it be designed for the rough service required? Would it be cost effective? Would a treatment that required brush to be no more than three to four years old be useful? Some of those questions have been answered by our research, some remain for additional work.

Preliminary testing used a wick-type applicator, spraying from the ground, a roller-wiper applicator alone and a roller-wiper in conjunction with a scraper bar. The wick type applicator, constructed in a wedge or vee, tended to clog with brush and was considered not feasible for this type of use without major redesign. Spraying by ground equipment worked, but the mist drift problem still remained. The roller-wiper worked well in conjunction with the scraper bar and also without. Further testing was done without the bar.

The roller-wiper has been an effective method of applying herbicides to weed plants in agronomic crops, such as the control of volunteer corn in soybeans or Johnsongrass control in cotton or soybeans. This method utilizes the height differential between crop and weed plants to apply low volumes of highly concentrated solutions as opposed to dilute, high volume spray applications used in conventional treatment methods. The roller-wiper permits longer time intervals between tank refills; an advantage in remote areas. Since only target plants are contacted by the roller, a properly adjusted roller-wiper applies herbicide solution according to brush density.

No herbicide drift occurs with a roller-wiper. This allows treatment near sensitive crops and human habitations. Because there is no spray solution to drift, public acceptance of the application method is enhanced. The roller-wiper permits selectivity for vegetative species by choice of herbicide as well as selectivity by vegetative height differences. Treatment of the taller woody plants is possible without killing low growing shrubs and lesser vegetation.

Successful application of herbicide with the carpet roller-wiper was dependent on the proper selection of several physical design parameters. The diameter of the roller cylinder was important because it determines the total amount of contact area available on a roller of fixed length. An increase in surface area helped reduce the rate at which the carpet wore out and provided a larger herbicide reservoir which was especially useful in dense weeds. The speed at which the roller rotates must be maintained within a given range to achieve optimal herbicide holding capacity on the carpet. This speed depended on the roller diameter and the type of herbicide that was being used. The type of carpet that was used on the roller-wiper to transfer herbicide to the target plants was a vital parameter. The carpet must be durable, have good liquid holding capacity, have the proper physical characteristics, and be chemically compatible with all types of herbicides which might be used. Generally, a rubber flap was used to spread the herbicide onto the roller to help equalize carpet wetness along the entire length of the applicator. The pressure which this flap exerted on the carpet was of interest since it helped determine the amount of liquid the carpet would hold. Various combinations of these parameters interact to determine the overall performance of the roller-wiper. Physical and chemical properties of the herbicides and additives used for weed control also affect the operation of the roller-wiper applicator.

The roller-wiper herbicide applicator is similar to a wick or a paint brush. Capillary action and liquid surface tension are important in regulating liquid transfer from the roller to any other object. The rolling motion of the carpet-covered cylinder allows a super-saturated operating condition compared to an immobile cylinder. Contact with an object transfers liquid from the saturated fiberous carpet covering to the contacted object. The total amount of liquid available on a carpet roller depends on the speed at which the roller is rotating, the absorbency of the carpet material, and the physical properties of the liquid.

Roller speed. According to instructions which accompany the roller applicator from Rockey Manufacturing Company (RMC), the roller speed should be set at the slowest rotational speed at which no herbicide loss occurred. The roller must revolve continuously to prevent dripping from the carpet. A variety of speeds have been used satisfactorily, ranging from 20 to 60 RPM (10, 6, 12, 5). Slower speeds were possible, but only as carpet wetness decreased from saturation.

Ground speed. The rotating principle permits faster equipment ground speeds than with other methods of applying contact herbicide. Application ground speeds of 3.2 to 7.2 km/hr have proven to be satisfactory in field tests with woody weeds at Purdue (4). Hardwood saplings, ranging from 1.3 to 8.9 cm in diameter at a height of 0.6 m, were treated with herbicides controlling 75 to 95 percent of plant growth. The lower ground speeds (3.2 km/hr) were necessary due to the light structural framework of the roller-wiper.

Herbicides and herbicide concentrations. At present, glyphosate (Roundup) and picloram (Tordon) are the only chemicals for which much data exist in conjunction with the roller-wiper. Schepers and Burnside (10) initially used 1 to 5 percent solutions of glyphosate in water. Later experiments with 5 to 10 percent concentrations of glyphosate proved more satisfactory in field crops.

World Crops (11) reported that a mixture of Roundup and water, with a small amount of Admongel added a thickening agent and applied with a roller was effective in controlling weeds in sugar beets. A mixture of 5 liters of Roundup in 20 liters of water was used.

The Roundup Herbicide Usage Guide recommends two rates of Roundup-water mixtures for use with roller-wipers. One liter of Roundup diluted to 20 liters with water is suggested for use with relatively easy-to-control weeds; one liter of Roundup diluted to 10 liters with water for weeds that are harder to control. A wide range of Roundup concentrations are being used in conjunction with rollers for controlling weed escapes in soybeans; 1:5 to 1:40 (1).

Maintaining carpet wetness. Opinions differ on the wetness at which the carpet should be maintained. RMC suggests that 19 to 26.5 liters of mixed chemical will be required to fully saturate a 4.6 meter carpeted roller. The carpet is kept saturated by visual appearance; i.e., carpet color, herbicide foaminess, and carpet matting. Irons and Burnside (6) showed extensive (95%) soybean injury because of excessive herbicide solution on the roller with resultant dripping onto the plants when conducting their tests with a saturated roller.

The Roundup Herbicide Usage Guide (9) suggests that roller saturation be maintained at all times with the herbicide concentrations that they recommend. Special care should be taken on sloping ground when the roller is saturated or severe dripping will occur.

Furrer (1) found that the roller-wiper method of applying herbicides in soybeans was gaining acceptance. The report also showed that 86% of the farmers surveyed reported equipment problems with their units. Problem areas were listed in the following order of importance: sensors, carpet, rate adjustment, and the herbicide pump.

Uses of the roller-wiper in woody brush. Lym and Messersmith (7) tested the roller-wiper technique for use in leafy spurge control. The roller was used to reduce the amount of picloram applied while maintaining satisfactory weed control. In dense leafy spurge stands, the roller applicator applied 47 to 70% less herbicide than a broadcast sprayer. Control was similar with the roller and broadcast application methods when evaluated one and two growing seasons after treatment.

Mayeux and Crane (8) have found that levels of control of honey mesquite have generally been far higher when using the roller-wiper than those usually resulting from foliar sprays of the same herbicides. Treatments can be applied with the roller at any time during the growing season whereas, in Texas, sprays must be applied to honey mesquite during late May and June to be most effective.

Objectives of this Study

The purpose of this research was threefold; to analyze, evaluate, and improve a method of controlling unwanted woody brush. Initial studies focused on selection of a practical, environmentally safe method of applying herbicides to unwanted brush in tree plantations, rights-of-way, and pastures. Subsequent studies were designed to determine the dependability, ruggedness, and effectiveness of the methods chosen. Further testing was conducted to developed a better understanding of the chosen concept. Theoretical modeling of the application method was needed to identify important operational parameters.

The objectives were: selection of a herbicide applicator, testing to determine suitability over a wide range of conditions, formulation of a mathematical model of the fluid behavior on a rotating, horizontal, carpet-covered cylinder, and application of the theoretical model to herbicide applicator design.

Procedures

Field experiments on small brush. Investigatory field experiments were carried out in two phases. The first year's tests were structured to test the mechanical feasibility of three methods of herbicide application; spraying, rope wicking and carpet rolling. Preliminary testing of several herbicides was also accomplished in the initial field testing. Testing in the summer of 1982 focused on the use of the carpet roller-wiper in realistic field conditions. Improvements in machinery and operating techniques were made during the second summer's tests.

Small plot machinery-herbicide tests. The first year test plots were located in Purdue University's Martell Forest Laboratory near West Lafayette, Indiana. Martell Area I was a three-year-old planting with 16 species of hardwood trees, brush, and pine. Martell area II was an old field with natural invasion of hardwood species. Herbicides were applied in July 1981 along with an optimal scraper bar in front of the roller. Data were collected in early October 1981 before leaf color change and again in late June 1982.

Two prime movers were used in this experiment. A Ford 4000 gasoline tractor was used for most of the wick and sprayer applications and some of the roller applications. All treatment combinations using the scraper blade were done with a Ford 8000 diesel tractor modified and shielded for this type of work (see Figure 1).

Three basic applicators and a large scraper blade were chosen to implement the treatments desired. A hand-held sprayer, a carpet roller, a nylon rope wick, and a veneer blade scraper were combined in different configurations. Records were kept relating to reliability, weak points, apparent effectiveness, and general suitability of each component.

The sprayer in the experiment was a hand-held gun with a variable stream control. Label directions were followed for all spray combinations.

The wick apparatus used was a design referred to as a Wedge-Wick by its manufacturer, Porter Mfg. Co. This was a pressurized wicking system with a manually controlled manifold pressure. There were several disadvantages to this system for use in forestry applications. The wick to manifold couplings were weak and consequently leaked. The wick, due to its wedge design, was an excellent collector of plant materials, especially vines. Debris collection lowered the wick's effec-

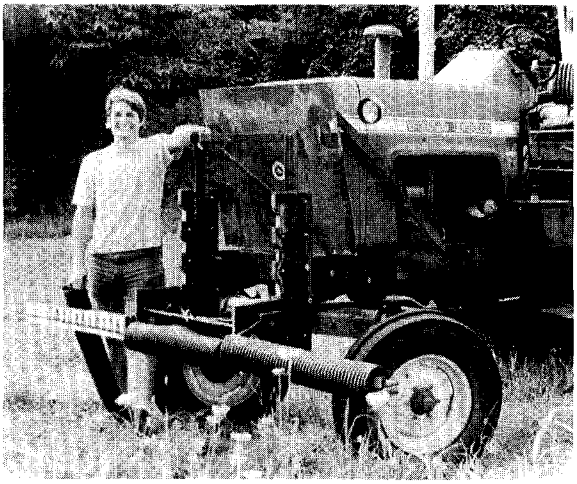

Figure 1. Adjustable scraper bar used to debark brush (1981).

tiveness considerably since the accumulated plant parts shielded the wicks from further plant contact. At speeds of approximately 3.3 kph or higher, even the highest manifold pressure gave insufficient flow rates in thick growth.

The roller-wiper was considered to be the most promising of the three applicators from the outset. It has the advantage of a relatively larger contact surface area and a more durable construction than the wick. The carpet roller (see Figure 2) was manufactured by Rockey Manufacturing Co. of Hiawatha, Kansas. It is 2.4 m wide and has a 25 cm diameter carpet covered steel drum. The roller was hydraulically powered and the speed regulated by a priority valve and a bypass valve. A small electrically powered pump supplied herbicide mixture to the top of the roller via distribution manifolds. A 200 liter drum provides adequate volume for chemical mixing and storage. Although the durability of the test carpet was not acceptable, it was felt that durable carpet could be located which would result in satisfactory performance.

The scraper blade (see Figure 1) was built from a 2.4 meter section of a steel veneer blade. An adjustable mount was constructed for a Ford 8000 tractor. The mount permitted manual adjustment of both the height and angle of the veneer blade.

Initially the blade was mounted at a height of 0.6 meters above ground level and in a plane parallel with the ground. We adjusted the blade so that it would penetrate the tree stem to a depth of approximately 12 to 18 mm and then proceed to remove a strip of bark and wood, along with the

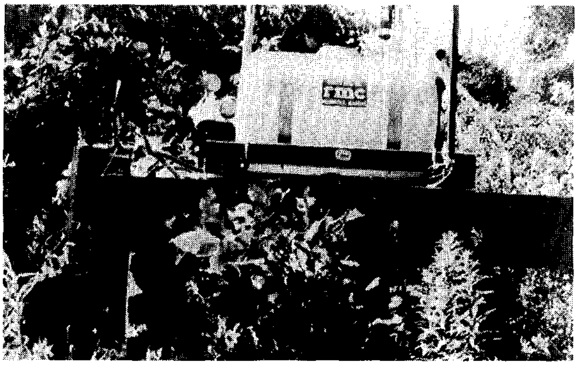

Figure 2. Rear mounted roller-wiper on agricultural tractor (1981).

limbs, all of the way to the top of the tree. In practice, adjustment of several parameters was required to realize the desired effect. When properly adjusted, this technique was a very efficient and economical way to damage brush species in order to allow better herbicide penetration into the cambial layer.

Brush control on utility rights-of-way. The land used in the second year field testing was located in the south central portion of Indiana near Bloomington. The forests there are primarily hardwood, with oak, maple, and sassafras being the predominant species. Most of the area had been mowed two years previously with a large hydraulically powered rotary mower. Larger stems had been hand cut, leaving stumps up to 1 m (3 ft.) high. As might be expected with these treatments, hardwood species which are predisposed to root or stump sprouting had formed dense clumps of new growth. Six and one-half hectares of land were treated, with plot sizes ranging from approximately 1/10 hectare to nearly 7/10 hectares. Plots were marked off so that a uniformity of brush density existed within the boundaries of each plot. Topography varied from nearly level to moderately sloping (up to 15% slope).

Machinery operators were previously untrained in operating either the roller or the prime mover which was used. Since training essentially occurred as treatments progressed, some variability in herbicide application rate and the area of land covered per unit of time may be attributed to operator familiarity.

The method of treatment varied slightly depending on topography and obstacles, but generally a back and forth parallel path was followed. Turning time was of major importance in small plot testing. In the smaller plots, the time spent turning the equipment was a very significant portion of the total treatment time.

Seven widely used herbicides (see Appendix B) which are effective against woody brush were applied to the various plots. Two herbicide adjuvants (Emphasizer and Cide-kick) were also incorporated into selected treatments. Weather conditions, machinery breakdowns, and operator comments were recorded. Plots were evaluated after full spring leafout in the year following the summer of treatment. Both top kill and root sprouting were considered in the evaluation of treatments.

The equipment used consisted of a modified agricultural carpet roller mounted on a Bombardier high-speed, low-ground pressure, crawler tractor (see Figure 3). Front mounting of the roller-wiper allowed herbicide contact with plants before they had been pushed down by the prime mover. Operation of the machine was also easier with the front mounted arrangement since the operator never had to turn around to look at the roller.

The prime mover is well suited to the variability of terrain and soil conditions to be expected in treating brushy areas and utility rights-of-way (see Figure 4). The rubber cleated tracks result in low ground pressure with minimal soil compaction and disturbance. The Bombardier Muskeg (68 kW) was found to more than adequate for treating all situations encountered in these tests. The narrow width of this machinery makes it suitable for treating brush in tree plantations with row spacings of greater than 2.4 m.

Laboratory tests of carpet roller. Problems encountered in the field, during two years of testing, caused us to begin laboratory testing to determine the important factors related to retention and dispensation of liquid chemicals from carpet covered rollers. The main factors studied were: roller size, carpet type, flap (a flap mounted on a carpet roller to disperse fluid) setting, centrifugal acceleration, surface tension of the liquid and liquid viscosity. Statistical tests were included to establish the importance of these factors. Laboratory equipment was designed and built to simulate field conditions. The end result of this work was to be regression equations that would predict the performance of the roller applicator.

Results and Discussion

Small plot comparisons — herbicides and methods. The first year's data indicate that certain herbicides were well adapted to use with the roller-wiper. Translocatable herbicides appeared to be very effective at application rates well below recommended spraying coverage rates. Paraquat, a herbicide which kills on contact, was used to test herbicide coverage. The paraquat treatment indicated that the roller-wiper contacted a large part of the available leaf surface. Some shielding of plants did occur in very thick brush. The potential problems associated with plant shielding may well be compensated by the high concentration of active ingredients in the mixture that can be used with the roller. The roller should always rotate so that the contact surface of the cylinder is moving in the same direction as the prime mover. This motion provides a lifting action to the foliage which results in a better application of herbicide to the undersides of leaves; an application site which is more favorable for herbicide uptake by the plant.

The data in Table 1 suggest that both Roundup and Garlon were suitable herbicides for use in conjunction with the herbicide roller-wiper. Higher concentrations of a herbicide generally gave quicker kill rates, but it appeared that the lower concentrations used also work well. The herbicide treatments tested were consistent both in repeatability and in their final results. Little difference was found between the final average woody plant control values in these treatments. These data suggested that the most cost effective rates of application may not have been reached and that more herbicide may be saved on an ac-

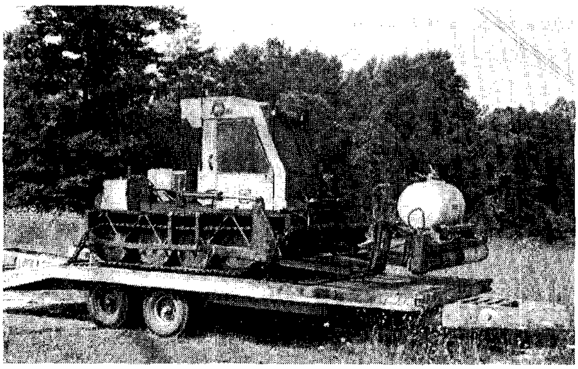

Figure 3. Roller-wiper mounted on crawler tractor (1982).

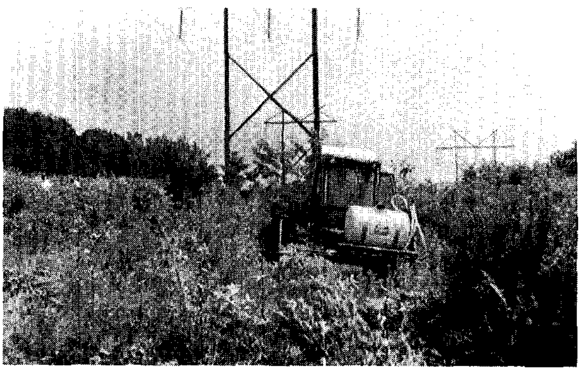

Figure 4. 1982 Right-of-way test in progress.

tive ingredient per hectare basis.

Right-of-way plots — application rates and economics. Tables 2 through 5 indicate several of the parameters which were deemed important in analyzing the practicality of the carpet roller. It appears that the roller-wiper was capable of a wide range of application rates, most of which were below total material application rates for foliar spraying. Variability in terrain accounts for much of the variation in the rate of treatment. Estimated cost figures are based on early 1982 utility prices for one firm in Indiana. The average total cost of brush control for one utility company in Indiana ranges from $210/ha to $370/ha depending on treatment method.

The average values for liters of mixture per hectare and hectares per hour showed interesting trends. As would be predicted, the herbicide application rate increased as brush density increased. This occurred because the roller contacted more leaf and stem surface area. The relatively high variations in the treatments (as shown in Tables 4 and 5) indicate that further quantification is needed in this area. The rate of treating a given area of land was dependent on the density of brush encountered. Land treatment rates almost doubled for moderate brush and tripled for light brush when compared with plots having heavy brush densities.

It was noted that higher concentrations of a herbicide generally give quicker kill rates, but that adequate control was obtained with reduced application rates. Within two to three weeks of herbicide application, all plots showed clear evidence of having been treated.

The percentage kill data in Table 6 were collected in late May and early June, 1983. Nineteen species of native woody brush (see Appendix A) were evaluated for mortality and sprouting. Stem counts and associated defoliation data were accumulated over three 0.0004 hectare plots randomly laid out within each test plot. All nineteen woody species were not found in each of the subplots.

Table 1. Small plot test results with herbicide applied with the rolling carpet or sprayer.

Herbicide	Applicator	Water:herbicide	Plots	Average woody plant control 10/81 %	6/82 %
		Martell I			
Garlon 3A	Roller-wiper	1:1	3	87	91
Garlon 4	Roller-wiper, scraper blade	2:1	3	84	92
Roundup	Roller-wiper, scraper blade	3:1	2	52	86
Roundup	Roller-wiper	20:1	2	58	88
Roundup	Sprayer	20:1	2	59	92
		Martell II			
Garlon 3A	Roller-wiper	1:1	2	92	90
Garlon 4	Roller-wiper, scraper blade	2:1	2	93	90
Roundup	Roller-wiper	3:1	1	92	92
Roundup	Roller-wiper, scraper blade	3:1	1	76	85
Roundup	Roller-wiper	20:1	1	91	94
		Averages for all test sites.			
Garlon 3A	Roller-wiper	1:1	5	89	91
Garlon 4	Roller-wiper, scraper blade	2:1	5	88	91
Roundup	Roller-wiper	3:1	1	92	92
Roundup	Roller-wiper, scraper blade	3:1	3	60	85
Roundup	Roller-wiper	20:1	3	69	90
Roundup	Sprayer	20:1	2	59	92

* Average woody plant control is determined by the percent defoliation. Evaluation was made in September, 1981 and June, 1982. In general, the percent kill increased over the longer time.

Table 2. Cost data (1982).

		($/hectare)	
	Minimum	*Average*	*Maximum*
Light brush	143	214	289
Moderate brush	101	345	790
Heavy brush	140	516	1444

Table 3. Treatment rate (1982).

		(hectares/hr)	
	Minimum	*Average*	*Maximum*
Light brush	0.43	0.52	0.65
Moderate brush	0.18	0.34	0.65
Heavy brush	0.14	0.18	0.34

Table 4. Herbicide application rates (1982).

		(L/hectare)		
	Minimum	*Average*	*Maximum*	*Standard deviation*
Light brush	8	12	15	5
Moderate brush	5	23	43	14
Heavy brush	14	36	89	22

Table 5. Total mixture application rates (1982).

		(water plus herbicide, L/hectare)		
	Minimum	*Average*	*Maximum*	*Standard deviation*
Light brush	140	206	280	100
Moderate brush	140	261	458	103
Heavy brush	150	337	654	138

Overall, control of most species appears to be acceptable. Some species, notably red maple and aspen, exhibited considerable resistance to low concentration applications of the herbicides tested. Sassafras, red oak, red elm, and shagbark hickory exhibited limited sprouting in plots treated with low concentrations of the herbicides. Figures 5 through 6 show typical plots one year after treatment.

A wide range of cost and effectiveness was noted in this study. Actual herbicide costs varied from 100 to 1444 dollars per hectare. Percentage kill ranged from 50 to 100% with the average around 90%. No direct relationship appeared to exist between cost and effectiveness; although particularly inexpensive treatments do tend to result in lower plant kill.

No one treatment appears to excel the others in either effectiveness or cost solely on the basis of herbicide. All herbicides tested had the potential to perform well when applied by the roller-wiper applicator. Generally speaking, high concentrations of all of the herbicides except Banvel performed relatively poorer than low concentrations of the same herbicide primarily due to the high cost of the mixtures. Since carpet wetness was not regulated in these tests, the results which were obtained would be expected.

Garlon 4 gave fairly consistent kill rates over all treatment combinations except for the 65% kill reported at the 5.6% concentration level. This was apparently due to the very low cost, low volume application of the mixture. High concentrations of Garlon 4 (14.3%) are prohibitively expensive and do not improve treatment efficiency. The addition of Cide-Kick or Emphasizer did not noticably affect kill rates for Garlon 4.

Garlon 3A performed consistently, giving good brush control at a reasonable cost. The addition of the surfactants improved the overall performance by reducing the amount of material that was required for treatment. Cide-kick may have had a slightly detrimental effect on the percentage of all species killed.

Roundup, in general, gave excellent brush control. Treatments of Roundup alone gave 100% brush control. A difference in effect was noted between the additional effects of the two adjuvants; Emphasizer decreased brush control while Cide-kick tended to show little influence on percent kill. As with Garlon 4, high concentrations of Roundup are not required, nor are they advisable, due to the costs of the treatments. Roundup concentrations of 5% appear to give consistently good results.

Banvel 720 was used at a high concentration and was the only herbicide to perform economically alone at that concentration. Brush control was above average in dense brush. Treatment costs were reasonable at high herbicide concentrations because of the relatively low cost of the herbicide material.

Combinations of herbicides gave slightly higher than average brush kill rates. Treatment costs were based on the herbicides used and mixture concentrations. Expensive herbicides appear to give best results when the combined herbicide concentration is near 5%. Less expensive herbicides can be mixed and applied at up to 20% concentrations with economical results.

In addition to herbicide costs, a complete brush management program must also consider machinery and labor costs. As brush density increases, the rate at which herbicide can be applied to a given area of land decreases. Fixed and variable costs for machinery and labor are thus increased as the size and density of the brush increases. When all cost factors are taken into account, the roller-wiper method of herbicide application compares favorably with all current methods of woody brush control.

Results from lab testing of carpet roller. Lab tests of equipment used to evaluate a carpet roller for chemical retention and dispensation, indicated the important factors to be used in designing carpet rollers for hardwood brush use. Surface tension of the liquid (herbicide and water or herbicide, water and adjuvant) was the most important factor in retaining the most herbicide on the carpet roller. Flap setting was the second most important factor. The flap, or rubber dam, adjusted to contact the carpet roller at different tensions, proved to be an important factor in liquid retention.

Table 6. Summary of 1982 herbicide test plots.

				Cost** ($/ha) at		
*Material**	*Herb. conc.*	*% kill*	*Cost per liter of mixture*	*206 L/ha*	*261 L/ha*	*337 L/ha*
G4	.143	91	2.06	434	553	711
G4	.056	65	0.81	170	217	279
G4	.048	90	0.69	146	185	240
G4	.038	87	0.55	116	148	190
G4+E	.056	90	0.81	170	217	279
G4+C	.056	89	0.81	170	217	279
G3A	.071	97	0.77	163	207	267
G3A+E	.071	95	0.77	163	207	267
G3A+C	.071	80	0.77	163	207	267
R	.125	99	2.00	422	538	692
R	.063	100	1.01	212	269	348
R	.048	100	0.77	163	207	267
R+E	.048	85	0.77	163	207	267
R+E	.038	50	0.61	128	163	210
R+C	.056	88	0.90	188	240	306
R+C	.048	100	0.77	163	207	267
B	.200	94	0.76	161	205	262
TK+F40+W	.158	98	0.93	195	249	319
R+G4	.133	100	2.03	427	543	699
R+G4	.058	90	0.88	185	237	304
R+G4	.051	99	0.77	163	207	267
R+G4+C	.051	84	0.77	163	207	267
R+G3A	.111	90	1.49	314	400	514

* List of herbicides and adjuvants:

G-4 - Garlon 4	B - Banvel 720	W - Weedone 2,4-DP
G3A - Garlon 3A	TK - Tordon K	C - Cide-kick
R - Roundup	F40 - Formula 40	E - Emphasizer

** Based on average application rates for light brush (206 L/hectare), medium brush (261 L/hectare), and heavy brush (337 L/hectare).

The third factor in importance was acceleration forces. Roller diameter was fourth in importance. Other factors of lower importance were analyzed, such as interaction of these four factors. They are fully explained in Gaultney, 1983.

Basically, fluids with higher surface tension are retained in larger quantities on a carpet roller. Flap setting should be light to retain maximum fluid and rotational speed of the roller (acceleration) should be set at different RPM for different roller sizes, but, in general, at the point where dripping losses do not occur, but less than the critical "slinging" RPM. Larger roller diameters hold more fluid, as might be expected. The reader interested in specific details on this should consult Gaultney (2).

Summary and Conclusions

The roller-wiper concept of applying herbicides to woody brush was feasible and economical. Experience indicated that several improvements to the current roller-wiper were needed. Some of the design changes are purely mechanical, intended to increase the durability of the machine, while others deal with carpet type, flap setting, roller diameter, and roller speed.

Strengthening of the frame and incorporation of a shock absorbing system are the major mechanical changes to be made to the experimental roller-wiper. The shock absorbing system would consist of incorporating a relief valve and a hydraulic accumulator into the hydraulic lift system. The relief valve would be set to maintain a predetermined downward resistance on the roller in order to assure adequate contact with the plants to be treated.

It is important, in choosing a carpet, to consider several parameters in order to arrive at a suitable combination for a roller-wiper. A good carpet should have moderate pile depth. Insufficient pile reduced the amount of liquid that was immediately available for herbicide application. A long fiber length tended to lead to increased matting and subsequently to decreased application efficiency. Fiber packing density appeared to affect both wear characteristics and the total liquid held per unit area. Generally, the denser the pile, the better the carpet has worn, and the more available liquid it has retained. Carpet resilience was important, and is due primarily to a combination of fiber material, thickness and length. A moderate resilience was desired, since a limp fiber was ineffective in retaining liquid and tended to mat, and a highly resilient fiber tended to contribute to high slinging and flipping losses. Neither of these extremes was desirable. Satisfactory service appears to depend mostly on carpet design with regard to the pile to backing interface. As long as the pile and backing are interwoven and the general suggestions presented previously are followed, the carpet should perform satisfactorily.

From experience, a roller diameter of approximately 0.35 meters appears to be the best size for a roller-wiper that is to be used in woody brush control. A reduced carpet wear rate should result due to the larger total, and instantaneous load bearing surfaces available on a larger roller. Even though the amount of liquid available per square

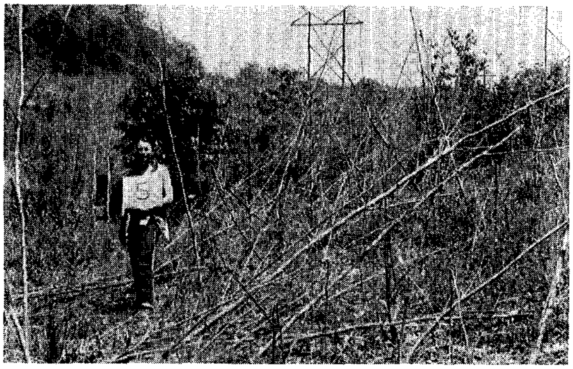

Figure 5. Typical heavy brush plot 10 months after treatment.

Figure 6. Typical light brush plot 10 months after treatment.

meter of carpet decreases as roller diameter increases, the increase in total available liquid would be desirable in cases of high brush density.

Flap setting and roller speed can be combined with a liquid recycling system to give good performance and almost no risk of unwanted liquid loss. A moderate flap setting with a roller speed sufficient to create approximately 4 m/sec^2 acceleration appeared to be ideal for brush treatment. Since this combination of flap and speed created a reservoir of liquid behind the flap, it allowed rapid recharge of the carpet when high herbicide demands were made on the roller-wiper. Collectors mounted at the ends of the roller would be used to catch and recycle all excess liquid. Little, if any, dripping and slinging losses would occur along the length of the roller other than at the ends.

The roller-wiper concept of herbicide application is a practical and feasible method of controlling woody brush because it: 1) minimizes herbicide drift, loss, and non-target impact, 2) is effective with currently available herbicides, 3) is simple to operate (few adjustments are needed to maintain efficient herbicide application, 4) is safe for the operator and the environment, 5) is easily adaptable to varying brush conditions, and 6) was mathematically modelled to predict the influence of changing of application parameters.

Suggestions for Further Study

The major topics for future studies should include carpet classification, machine improvements, and herbicide application economics. Further understanding in these areas would allow optimization of chemical application, operator and environmental safety, and applicator dependability.

Several mechanical improvements can be made to the current applicator which would significantly affect its efficiency and durability. A suspension system should be designed which would limit shock loading on the roller while maintaining adequate contact with the target plants. Overflow collectors mounted at the ends of the roller and used in conjunction with a properly adjusted flap would reduce herbicide waste to a minimum. Simple sensors such as those tested in this study could provide an indication of carpet wetness and signal any malfunction of the fluid distribution system. A panel of red lights in the operator's line of view would be sufficient to warn of inadequate carpet saturation.

The third topic for further study concerns the formulation and application of herbicides in the field. Two primary modes of herbicide metering exist in the operation of the roller applicator, the herbicide may be metered by controlling carpet saturation, or by allowing full carpet saturation and reducing herbicide concentration. Reducing carpet saturation allows the use of a more concentrated solution of the herbicide and provides for longer intervals between tank refills. Implementation of this approach requires constant monitoring of carpet wetness and somewhat sophisticated sensors and controls. It is also possible to use the rubber flap to control carpet wetness given proper applicator design. This alternative would probably be more suitable and cost effective. The second mode of herbicide metering, using a fully saturated carpet, would require minimal control sophistication but would result in relatively frequent tank refills. The key to the whole issue is determining how much total active ingredient of a given herbicide is needed to give adequate control on a specific area of land. Since the roller is in a sense self-metering based on brush density, the problem is resolved into one of the two aforementioned approaches.

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Appendix A. Species of woody brush considered (1982).

Sassafras	Redbud	Black Locust
Black Cherry	Aspen	Juniper
Ash	Dogwood	Hazelnut
Sumac	Tulip Poplar	Sugar Maple
Shagbark Hickory	Elm	Red Maple
Butternut Hickory	White Oak	Scotch Pine
Red Oak		

Appendix B. Herbicides used in 1982 brush control plots.

Product name	*Common name*	*Manufacturer*
Garlon 4	triclopyr ester	Dow
Garlon 3A	triclopyr amine	Dow
Roundup	glyphosate	Monsanto
Banvel 720	dicamba	Velsicol
Tordon K	picloram	Dow
Formula 40	2,4-D	Dow
Weedone 2,4-DP	dichlorprop	Amchem

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ABSTRACT

SANTAMOUR, F.S, JR. 1983. **How good is monarch birch for American landscapes?** Am. Nurseryman 157(3): 79.

Monarch birch (*Betula maximowicziana*) has been a problem tree. Five years ago, Dr. Frederick G. Meyer and I warned nurserymen of the many improperly identified specimens in nurseries and arboreta. We also told how to identify true monarch birch. During our investigations, we attempted to obtain monarch birch seed from any part of the world in which the true species, or supposed true species, was being cultivated. We obtained four true-to-name seed lots and grew progenies for testing. Our data indicate that monarch birch is generally inferior in juvenile survival and growth to most of the other birches used in landscape planting. Whether some of these shortcomings could be eliminated by increased cultural care is unclear.