Development and Testing of a Weed Wiper for Roadside Vegetative Control

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ABSTRACT

The objective of the project was to investigate the potential of using the weed wiper applicator as an alternative method to mowing and broadcast spraying for controlling noxious weds, brush and plant growth along roadways. An existing weed wiper applicator used for tax ditch herbicide applications was modified by replacing a flat set of applicators which utilized grit abrasive banded to an aluminum channel with radial applicators. The chemicals Roundup, Rodeo, Touchdown and Arsenal were used. They were applied in concentrated and dilute form or as mixtures. Applications of Rodeo, Roundup and Touchdown at the rate of 0.3 gallons per acre were 50 to 75% effective on 1 to 2 year old sweet gum, tulip popular, sumac, cherry and maple with one application. With the addition of 1 part of applicators concentrate Arsenal added to 40 parts of the other chemicals and applied at 0.25 gallons per acre, vegetation control was over 75% with one application. Even vegetation with extensive root systems was controlled and pine, cedar, willow, phragmites, multiflora rose, black locust, holly and sassafras were also controlled in varying degree with one application.

The total capital cost for a complete three tank applicator system not including the tractor is estimated to be in the $10,500 range. The cost for roadside utility right-a-way and roadside ditch-wood line spraying are in the range of $190 to $200 per mile. This cost includes labor, equipment and chemicals.

INTRODUCTION

Noxious weed, brush and overall control of vegetation next to highways and secondary roads is a major concern to the Delaware Department of Transportation. Noxious weeds and other unwanted plants must be kept under control to maintain right-of-ways, keep channel capacity at design flow rates, reduce costs for future maintenance and comply with the noxious weed law.

Present brush control methods consist of almost entirely mowing. This is very expensive due to the cost of owning and maintaining the mowing equipment. It is also a time intensive process and requires a skilled operator to perform the operation safely. However, mowing provides no long-term control of brush or noxious weeds. It does little to control existing infestation or noxious weeds unless weeds are mowed in a timely manner. Many weeds may require more than one mowing per year and it is likely that the noxious weeds may still set seed.

Chemical brush control has been tried and is effective. However, chemical control of brush and noxious weeds is expensive and herbicide selection is severely limited if the area to be sprayed is over running water. Drift to non-target species is also a serious concern of conventional herbicide application. This is especially true if the material of choice is non-selective. Today reduced chemical costs, lower rates and new products may make this method of control more appropriate. New machines and concepts may also make application easier and more accurate for target areas.

Moore (1995) developed the weed wiper bar for herbicide application as a method for selectively applying the herbicide only to the plants that need control. A project was funded by the Delaware Transportation Institute to evaluate the weed wiper as a cost effective method for controlling weeds and brush along roadsides in Delaware. This report summarizes the results of the project.

OBJECTIVES

The overall objective of the project was to investigate the potential of using the weed wiper applicator as an alternative method to mowing and broadcast spraying for controlling noxious weeds, brush and plant growth along roadways that will be cost effective, environmentally friendly and visually pleasing. The specific objectives of the project were:

1. Modify a weed wiper unit for the purpose of making a cost effective noxious weed, brush and plant growth control unit using an environmentally friendly method.
2. Identify the maximum effective window for noxious weed control and brush treatment on roadsides and ditch banks.
3. Develop costs for the weed wiper method in terms of equipment, labor, chemical and application cost per mile.
4. Compare the weed wiper unit costs for mowing and chemical application methods for controlling weeds.
5. Demonstrate environmental benefits and natural re-growth appearance of this method of noxious weed, brush and plant growth control versus mowing.
6. Investigate alternative chemicals and chemical combinations.

7. Determine if the weed wiper will be an effective herbicide applicator when used to control noxious weeds, brush and plant growth on roadsides, ditch banks and in other sensitive areas.

PREVIOUS RESEARCH

On September 12, 1996, a modified commercially available, rugged, tractor mounted, wiper bar unit was tested on a tax ditch in New Castle County, Delaware. The unit was calibrated to apply 0.40 gallons of a 20:1 Roundup-Arsenal mix per acre at 1.7 miles per hour. The chemicals were applied full strength by use of a 10 foot side mounted boom equipped with a distribution tube on a non absorbent chemical transferring material. The unit passed its first test and was utilized on multiple tax ditches in Kent and Sussex counties during September and October of 1996.

The results of the 1996 demonstration were so promising that an expanded study was started June 1, 1997 on a pilot program with support coming through Kent and Sussex Conservation Districts. The program was continued in 1998 and 1999.

The initial testing started with a 10 foot long side applicator for the ditch slopes and a 10 foot front width for treating the horizontal area. The applicator surface was a rough carpet material attached to an aluminum channel. A distribution tube released the herbicide onto the applicator surface. The actual application was 0.4 gallon per acre when driving the equipment at 1.7 miles per hour. The carpet unit worked well in controlling vegetation but did not hold up well in heavy aggressive brush.

A second set of applicators was installed which utilized industrial grit abrasive bonded to an aluminum channel. A redesigned distributor tube, a front edge scrapped and a wiper brush were other features included in the new unit. This unit proved to be very durable.

The weed wiper unit has been used to treat over 500 miles, exceeding 2000 acres, of tax ditches in Delaware involving a variety of plants and varying degrees of vegetative growth. Some of the results for the tax ditch treatment are summarized in a paper by Kemble et al. (2000).

RESEARCH METHODS

The project was started in the fall of 1998 with modification of the existing weed wiper applicator equipment that was used in 1998 for tax ditch herbicide applications during the fall of

1998 and winter of 1999. For the tax ditch project a flat edge set of applicators which utilized industrial grit abrasive banded to an aluminum channel were used. A pair of radial type applicators were purchased and assembled for use.

In the winter of 1999, 25 potential application sites were selected in New Castle, Kent and Sussex counties for treatment. These were in addition to sites selected for treatment in the fall of 1998. The new sites had various combinations of different types of brush. Some of the sites were along drainage ditches, other of the sites were along roads without drainage ditches.

The experimental treatments with the weed wiper were started in late September of 1998 in Kent County. In May of 1999 treatments were performed on sites selected in the early winter of 1999. A number of treatments were also made during July and August in 1999 but severe drought conditions affected the effectiveness of the herbicides. For the initial treatments in 1998 and 1999, the flat edged set of applicators were used, but for the fall – winter of 1999 treatments the radial type bars were used for slope application. Initially the herbicide treatments of 20 parts Roundup Pro (41%) to 1 part Arsenal (27.6%) were used at an application rate of 0.20 to 0.35 gallon per acre undiluted and 0.40 to 0.70 gallon per acre 50% herbicide and 50% water. In the summer of 1999, a 40 parts Roundup Ultra (41%) to 1 part Arsenal Applicators concentrate (53.1%)was mixed using 25% herbicide and 75% water and applied at a rate of 0.80 gallons per acre. Other sites had the 40:1 ratio applied undiluted at 0.20 to 0.25 gallon per acre and also 50% herbicide and 50% water dilutions at 0.40 to 0.50 gallon per acre.

Several sites were treated in the fall of 1999 with Roundup, Arsenal and Rodeo and Touchdown and combinations of these chemicals. It was planned to treatment more sites in the fall of 1999, but contact herbicide applicators for the electrical utility company sprayed a number of previously wiper treatment sites and sites selected for application. This spraying was not selective and had a total kill effect on all the vegetation in the wiper treated areas and selected sites. Because of this problem, a six month no cost extension of the project was requested and new sites were selected for treatment.

Starting in April of 2000 and concluding in December of 2000 a number of sites were treated with Roundup, Touchdown, Arsenal and Rodeo in various combinations and rates shown in tables in the appendix. The treatment during early spring bud stage was made in early March of 2001.

The chemical properties of the four herbicides used in the experiments are presented in Tables 1 to 4.

EXPERIMENTAL DESIGN

Factors taken into consideration when developing the experimental design were; vegetation to be treated, chemicals, application timing, applicator design, cost and environmental impact.

In order to determine the overall approach to use in controlling roadside ditch, wood line and right-a-way vegetation an evaluation of the vegetation had to be performed. The type of plants in need of management along roadsides included; phragmites, multiflora rose, virbirnum, sassafrass, birch, willow, sweetgum, pine, red cedar, maple, oak, tulip popular, black locust, button bush, devil's walking stick, wild cherry, honey suckle and Japanese knot weed. The control of this vegetation had to be performed in a manner that would provide cost effective long-term control and also be aesthetically pleasing. Eradication of all the vegetation at one time was not desirable. Selectivity became an issue because of roadside beautification plantings. Because of these considerations environmentally friendly chemical methods would be investigated.

The criteria for the chemicals selected were low to moderate toxicity, systemic herbicides that were non-selective and could be applied over a wide range of time and conditions. The five chemicals that fit this description were Roundup Pro, Roundup Ultra, Rodeo, Touchdown and Arsenal. These chemicals would be applied in concentrated and diluted form and as mixtures. The chemicals would also be applied at different rates to find the lowest volume effective rate.

Applications would take place in all four seasons. This would provide applications to vegetation with and without leaves. In order to have significant transfer of chemical into the plant after leaf drop or before leaf development the chemical would need to be placed beneath the bark layer. Different chemicals and mixtures would be used to determine the optimum application period. The type of application system designed or purchased would need to meet the application timing requirements.

In order to meet the constraints set forth by the type and age of the vegetation, selected chemicals, and application timing a wiper technology approach was selected. Wiping would reduce the volume of chemical applied and through the use of a scraping edge, to break through the outer layer on vegetation, would permit year round application. The unit would need to be strong enough to withstand the effects of three-year-old trees. Uniformity of chemical distribution across the width of the applicator would be critical as rates as low as 0.10 gallon per acre and as high 1.0 gallon per acre were anticipated. Several designs were selected that would meet the overall requirements. One design

was commercially available while the other would be fabricated for the projects needs by the vendor of the commercially available unit.

Cost became a major consideration for the implementation and acceptance of this concept. If the overall operating cost was too high it might negate the benefits. Fixed and variable costs considered for determination of an acre or per mile cost were; equipment, depreciation, maintenance, fuel, labor, transporting, chemicals, safety equipment, insurance, taxes, shelter, and overhead. In order to make accurate appraisals for the overall cost and carry these figures into a commercial operation sufficient treatment area needed to be addressed. Through the treatment of roadside ditches, wood lines, right a ways and tax ditches 700 acres were anticipated for treatment. This would provide the information needed for cost estimating.

Because of the concerns for the environment by Delaware and surrounding states it became significant to evaluate the impact to the soil, water and desirable vegetation this approach of vegetation control would have. Conditions before, during and after treatment would be evaluated to determine if a negative impact was being created. Vegetation controlled or effected would be evaluated through species identification and counts made on randomly selected 100 foot lengths before and after treatment. This practice was also viewed as part of a management package to control undesirable vegetation and promote beneficial varieties.

VEGETATION

Testing for vegetation management was performed on a year round bases. The reasoning behind this was to determine if control or eradication of woody plants could be accomplished during fall and early winter after leaf drop. Application would start in May and continue through March of the next year. Evaluation of the effectiveness of the treatment would be based on the type of applicator, chemical used, chemical application rate, season of treatment, and vegetation treated. In Tables 5 and 6 information is provided on the sites evaluated and the treatment utilized.

The species of vegetation treated included; pine, cedar, willow, verbirnum, button bush, phragmites, multiflora rose, holly, birch, sweetgum, maple, oak, sumac, sassafrass, tulip popular, wild cherry, black locust and Japanese knot weed. All of the vegetation responded to the chemicals applied from May to October. The level or degree of response during this time period was dependent on the chemical used and rate applied. Applications of Roundup, Rodeo, and Touchdown at the rate of 0.3 gallon per acre were 50% to 75% effective on 1 to 2 year old sweetgum, tulip popular, sumac,

cherry and maple with one application. However if these species had extensive root systems from repeated top mowing these chemicals alone were unable to offer acceptable results. When applicators concentrate Arsenal (53.1%) was added at 1 part to 40 parts of Roundup, Rodeo or Touchdown and applied at 0.25 gallon per acre the vegetation control was 75% plus for first time application. Even vegetation with well established root systems from repeated top mowing responded in this range. The addition of Arsenal also extended the range of species effected. Pine, cedar, willow, phragmites, multiflora rose, black locust, holly, and sassafrass were now being controlled in varying degrees with one application. In order to obtain total eradication of the woody species treatment was offered for several years. The second application was performed the following year allowing time for the effected vegetation to deteriorate. In some cases a winter mowing took place the second year permitting treatment of regrowth the following September. On some of the less than year old vegetation a skip year between treatments was permitted to allow for new seed germination.

Two species that proved to be challenging were phragmites and black locust. Late August and September treatments of phragmites were not as good as expected. The heavy dust accumulation within the plants appeared to be effecting transfer of the chemicals. By moving the treatment of phragmites into May, June and July very good control was obtained with the 40:1 mixes at the 0.25 gallon per acre rate. In some cases total eradication was experienced with one treatment, however most cases required a retreat the following year. Well established groves of black locust with extensive root systems required application rates of 0.30 to 0.40 gallons per acre of the 40:1 ratio Roundup – Arsenal mix several years in a row with spot spraying on the third year. Mixes of 20:1 using Roundup or Touchdown with Arsenal improved the effectiveness of control the first year but still required a second year retreat with spot spray follow up. With both of these species results were not immediate because of the spreading type of root system involved.

After frost and leaf drop Roundup, Rodeo and Touchdown alone at the 0.30 gallon per acre or lower rate produced less than a 30% effective over winter kill of one to two year old woody vegetation. However the addition of Arsenal to these chemicals as used in the summer applications (40:1) and applied at the 0.30 gallon per acre rate provided 50 – 75% overwinter kills in applications through December. Sheltered areas treated in January and February demonstrated equal results. The after frost treatments proved significant when applying in areas of tall grasses. The dormant grass tops were not susceptible to the chemicals so lower on the trunk applications to woody vegetation

could be performed. This increased the effectiveness of the chemical in controlling the entire woody plant.

Treatment in late February, March and April demonstrated poor response. Application of chemical combinations with and without Arsenal had limited immediate effects. However the trees treated with combinations containing Arsenal, although not killed, were stunted and diseased during the coming growing season. This provided a skip year in the mowing cycle without the concern about the vegetation getting out of control. To further the work with stunting treatments using 0.20 gallon per acre rate of a 40:1 Roundup – Arsenal mix were applied in late fall and winter. This was performed to investigate the potential for chemical pruning. Undesirable branches could be treated and killed or stunted without killing the main plant. This proved effective and beneficial in areas of encroaching and overhanging vegetation.

MAIN FRAME

The main frame requirements were evaluated by the weed wiper team. A design was developed and a search was started to determine if something was available commercially that could be utilized as is or modified. The unit eventually purchased was intended for low lying plants, including trees, of not more than one year of age. Modifications to strengthen the main frame and side boom were performed to accommodate trees up to three years of age. The two-side boom pivots were reinforced by increasing the surface and support area of the joints. The front boom was increased in rigidity by adding a 10-foot length of 2-inch box tubing. Weak or failure points were built as part of the redesign. The straps attaching the applicator bars to the main frame and side boom were designed to bend or break free before major damage could be transferred to the main unit.

The 10-foot front unit was designed to move up and down and could treat material as short as 4 inches, Figure 1. The side boom could bend down a ditch slope or be raised and brought back parallel to the tractor to treat a wood line. The side boom could also be lowered to rub the soil or raised to a horizontal height of over 5 feet, Figure 2. This allowed for treating a diversity of plant varieties and ages at various heights. All movement of the booms was through the use of hydraulic cylinders and control valves connected to the tractors hydraulic remote valves.

With the unit being front and front side mounted the ability to work corners and tight places was greatly improved over a rear mounted unit. A disadvantage to this mounting orientation was increased weight over the front axle. In wet conditions and poor ground cover this resulted in leaving

excessive wheel tracks. Larger diameter, floatation tires or front wheel assist would overcome this issue.

The performance and durability of the unit was good. However there were times when the unit was operated in conditions beyond its designed strength to determine levels for failure. In all cases, even with failures, it performed beyond the level of expectation.

APPLICATOR ASSEMBLY

During the fall of 1998 treatment was started using an existing wiper applicator bars purchased by the conservation districts, Figure 3. These bars were constructed using a 5 foot length of 2.25 by 5 inch aluminum channel with industrial grit abrasive bonded to the entire outside surface of the channel. The frontal area consisted of a 2 inch strap of perforated aluminum installed over the grit along the entire length. This served to protect the leading edge and provide scraping cuts on the vegetation. The front upper edge of the five foot applicator was equipped with a liquid distributor consisting of a 0.5 x 0.5 x 0.093 inch wall thickness aluminum channel containing a cross-grained polyester ribbon wedged in place by a 0.344 inch diameter PVC tubing having 0.125 inch holes spaced 12 inches apart. This unit was placed inside a 0.75 x 0.5 inch aluminum channel for attachment purposes. The distributor tube allowed the chemical to flow uniformly across the entire bar length down to the scraper edge. At the scraper edge chemical was applied directly into the cut made to the trunk of the vegetation. The chemical not applied at the scraper edge flowed back across the grit and was applied to other scratched areas of the vegetation. A 3 inch long wiper brush was located on the rear edge to aid in wiping the chemical across a broader area of the plant. Such areas treated included the underside of leaves prior to leaf drop in the fall, while leaf buds were treated prior to leaf formation in the spring. The bars were mounted on a 20 degree angle from front to rear with the rear being lower than the front. Two 5 foot bar sections were mounted on the front and two 5 foot sections were mounted on the side boom. This unit was used unmodified throughout the fall of 1998 and into 1999.

During mid-winter of 1999 the front edge on the side bar was made more aggressive through the use of 0.50 inch standard expanded metal. The expanded metal went from the distributor tube down the front and bent around the scraper edge and 1 inch across the bottom surface. This not only made the front edge more aggressive but also reduced the wear on the grit behind the original scraper

edge. The rear edge of the bar was modified by replacing the 3 inch long wiper brush with a 3 inch piece of nylon carpet. The carpet had greater capacity for retaining surplus chemical that migrated to the rear of the bar. The advantage of this became apparent when going through short sections of dense vegetation. The need to increase system flow rate was eliminated because of the reserve in the carpet. This design was used until the end of the summer treatments in September of 1999.

A new bar design that was developed in a cooperative effort with Weed Sweep Inc. and University of Delaware Bioresources Engineering researchers was first used September 28,1999. This style bar replaced the outer two 5 foot sections of the side treatment boom, Figure 4. Each applicator consisted of a 5 foot length of 6 inch schedule 40 aluminum pipe. The front and bottom area was covered with a 12 inch coarse grit belt secured in place by stainless steel flatten expanded metal bands. These bands covered the entire length and circumference except for the attaching area at the top of each 5 foot section. This combination of grit and expanded metal provided a much greater abrading and application surface than did the original 5 inch channel bar. The distributor tube was the same style used on the channel bar as it performed well. This was mounted 30 degrees forward from the top of the vertical center of the 6 inch tube. This positioning prevented tree trunks from striking and damaging the distributor. The tube was mounted on the expanded metal to take advantage of flow paths for the chemical. This proved to be beneficial in maintaining uniformity across the bar when operating in positions other than horizontal.

During June of 2000 the two 5 foot channel front applicator bars and the side 2 foot channel applicator bar were replaced with 6 inch round pipe applicator bars. These units were the same as the 6 inch round pipe bars installed in the fall of 1999. The entire wiping system was now equipped with the new style pipe bars.

APPLICATOR EVALUATION

In order to test the different bar configurations for longevity and performance treatment areas included roadside ditches, utility right-a-ways, wood lines and tax ditches.

The first bar used for the 1998 season to mid January of 1999 was used as purchased with out modification. This bar performed well for metering chemicals and creating cuts in the vegetation. By mid January the lower frontal edge of the bonded grit paper had been worn through. This interfered with the rearward movement of chemicals across the grit towards the rear mounted brush. The chemicals migrated along the front edge towards the lowest end of the bar. This resulted in a non

uniform application across the 10 foot width, two 5 foot sections, of the side bar when operating on slopes. The front bars, which were maintained in a horizontal position, still performed satisfactorily even with the front grit edge rubbed through. Up until January of 1999 these bars had covered 500 acres of vegetation and performed over 270 treatment miles. After January 1999 the front bars were maintained as purchased, however the side bars were modified and evaluated with the expanded metal front edge and nylon carpet on the rear edge. This change on the side bars restored the performance to the level before the grit was eroded. The expanded metal worked well for cutting into the vegetation and provided channels for the chemical to travel uniformly from the distributor tube. This eliminated the majority of the side migration of chemicals when operating on slopes. The carpet proved to provide a reserve of chemicals for short treatment areas of dense vegetation. Evaluation of die down of these treatments areas showed no difference from surrounding less dense areas. One of the drawbacks to the 5 inch channel bar was the location of the distributor. Because of its location it was susceptible to being rubbed by heavy vegetation. This would create flexing and working of the tube resulting in a loosening of the attaching machine screws. When loose, contact with the 5 inch channel was not consistent resulting in a non uniform distribution of chemicals across the treatment surface. If the unit was checked on a daily bases and kept tight the unit performed well. A second issue was the wearing of the grit on the leading edge. This was corrected with the expanded metal covering. For the 1999 testing season the front bars were used with no modifications and treated 348 acres and 287 treatment miles. The modified side bars, expanded metal on leading edge, treated 282 acres and 194 treatment miles. Overall the 5 inch channel performed very well for the 1998 and 1999 testing periods.

The concept of using expanded metal to skin the bark on trees and shrubs was tried on a small scale in the fall of 1998. It was the success of this trial that initiated the changes to the side bars in early 1999. It was also a factor in the redesigning of the applicator bar to a 6 inch aluminum schedule 40 pipe. This style was first used on the side boom September 28, 1999. The applicator, for a 5 foot section, provided 424 square inches of contact area verses 300 square inches on the 5 inch channel bars. This is a 30% increase in the area that makes contact with the vegetation. Not only is the area increase significant for improved chemical transfer but this entire area also has grit and expanded metal for improved abrading of the plant. The round bar also facilitates backing through an area. With bushy plants this provides treating both sides of the plant.

The round bar proved to be highly effective in providing uniform distribution of chemicals across the bars length even when the bar was operated at various angles. This can be attributed to the chemical tracking the expanded metal and flowing into the grit surface. The location of the distributor tube on the applicator bar also offered more protection from tree damage when compared to the channel bar. This resulted in maintained tightness within the metering unit eliminating unwanted leaking and non uniform distribution across the length of the application bar. A very important feature on this bar was the ability to replace the abrasive grit paper. This could be accomplished by loosening the expanded metal straps, removing the old 12 inch wide grit paper, install new grit paper and retighten the expanded metal straps. In comparison the grit paper on the channel bars was bonded which made the expense for replacement exceed the cost of a new bar.

One initial concern about the round applicator was weight. At approximately 7 pounds per foot this unit was 2.5 times the weight of the 5 inch channel. During testing this proved to cause slow response at low engine idle. However when wiping vegetation the tractor's operating idle was always above this, so operation was normal. Although the weight didn't effect the hydraulic response it may have contributed, along with the increased aggressive nature of this bar, to several pivot joint failures on the main frame. These sections were reinforced and no more problems were experienced.

During the fall 1999 season the outer 10 feet of the side bar treated 135 acres and 93 treatment miles. For the 2000 year the entire 22.5 foot, 10 foot on front and 12.5 foot on the side, treatment width utilized the round applicator. The treatment of 613 acres and 337 treatment miles was accomplished during this period.

All three configurations of applicator bars worked well for vegetation management. The channel bars were less expensive initially but became throw away items when the grit wore through. Removing the old grit and rebonding new became more costly than replacement of the applicator bar. Because of the positioning of the distributor on the 5 inch channel it received a lot of abuse from objects contacting the front of the applicator bar. Trees, brush, fence posts, line markers and whatever would constantly make contact with the outer channel of the distributor causing it to become shifted or loose. This resulted in poor uniformity of chemical distribution across the length of the applicator. Daily routine maintenance was sufficient to keep the distributor aligned and tight. When these bars were retired they had treated over 550 miles for an initial investment of $ 44.00 per foot of applicator length. This resulted in less than $1.00 per mile replacement cost for the 12.5 foot of side applicators.

The round applicator bars, being a prototype, performed above expectation. At $60.00 per foot of applicator length the initial cost was higher than the 5 inch channel bars. However with replaceable grit, expanded metal and distributor tube the round unit proved to be the most cost effective. By not having to replace the main tube but just replace the items require it became an issue of parts and labor verses total replacement and labor. During the testing period the side mounted round applicator was utilized for 430 treatment miles. During this time it required very little maintenance. The original grit and expanded metal has held up very well and is not in need of replacement. At this time a cost per mile replacement cost cannot be calculated for the round applicator. With the components replacement features it is however expected to be lower than the 5 inch channel applicator. When all the factors, of the three configurations tested, the round applicator bar became the unit of choice.

CHEMICAL APPLICATION SYSTEM

The original chemical application system was purchased from Chemical Containers, Inc. This unit was designed to supply soaker type carpet applicators. Chemical mixing ratios recommended were 20% chemical and 80% water. The unit included a 35 gallon cone bottom tank, 12 volt diaphragm pump and timer circuit all mounted on a three point hitch carrier. To this unit were added a pressure gage, three electronically controlled solenoid valves, three balancing orifices and three rotometers with flow metering valves. Master control switches were mounted on the tractor dash to control the pump and solenoid valves. Through the use of the solenoid valves the supply system was divided into three sections. Side unit delivery, left front and right front were all controlled independent of each other. The three sections were calibrated to supply 0.30 gallon per acre of undiluted chemicals. This was performed using the pump on-off timer circuit. The on-off controller was set at 0.5 seconds on and 3.5 seconds off. This combination supplied the 0.30 gallon per acre while maintaining the line pressure low at 40 pounds per square inch and the high at 55. The systems supply of chemicals was based on the timing circuit with the orifices and metering valve used to balance the systems three areas. This system worked well through October with warm and mild days. When cold weather application began recalibration was performed to account for viscosity changes in the concentrated chemicals. As the viscosity increased flow rate decreased, requiring the off time on the timer to be decreased to 2.5 seconds. To reduce the effects of viscosity a 50/50 chemical – water mixture was tried. This worked well and extended the original timer setting treatment period through

November without having to make timer adjustments. Winter treatments in December, January and February still required reducing the off time to 2.5 seconds. One thing important to mention at this point is the lack of freezing of the chemicals either in the concentrated form or as a 50/50 chemical – water mixture. This becomes significant for two reasons. If the chemicals were to freeze it could result in an inability to treat but more critical is the potential loss of equipment, chemicals and environmental safety due to breakage.

In the spring of 2000 an electric 12 volt metering pump was installed along with a 15 gallon cone bottom tank, 3 electric solenoid control valves, electric by pass valve, 3 rotometers with flow metering valves and a by pass pressure regulator. This system was mounted to the left of the original system. A sprayer control module containing 3 solenoid control switches, a master switch, electric by pass switch and a pressure gage was mounted on the tractor dash. The main difference of this metering system and the original was the type of pump used. This pump was a positive displacement diaphragm pump with stroke and timer control features as part of the pump. At 100% stroke and time the pump delivered 44 gallons per day. With this pump the need to readjust for temperature changes was eliminated. The system performed well with concentrated chemicals and 50/50 chemical-water dilutions. Changes made to increase volume outputs for 50/50 mixes were made using the stroke rate and percent stroke controls. This was a much easier system to calibrate because of the type of pump and controls.

A third system was also added in the spring of 2000. To the right of the original system a 15 gallon cone bottom tank was mounted. This system was used for spot spraying a 1.5% Rodeo-water mix with a hand held spray gun. A 12 volt rotary diaphragm transfer pump operating at 55 pounds per square inch pressure delivered 1.8 gallon per minute to the spray gun. This system was only operated for summer and fall applications. After leaf drop in the fall the system was drained and RV antifreeze installed to protect the pump, valves and handgun from freezing.

With three systems in operation more flexibility for chemical mixes was provided. The original system was operated at 0.60 gallons per acre with a 50/50 ratio of chemical-water. In very dense vegetation this gave better dispersion of the mix across the vegetation. The system with the variable stroke rate pump utilized concentrated chemicals applied at rates of 0.15 to 0.30 gallons per acre. When needed both systems could be operated at the same time for hard to control vegetation. Even when operated together the output of chemicals was still in the low to midrange application recommendations by the chemical manufacturer. The spray gun system, utilizing chemicals approved

for over water, worked well for spot spraying vegetation out of reach of the applicator bars. The entire system proved to be reliable with each of the three units complementing each other. Figures 5, 6 and 7 illustrate the pump and solenoid control switches, flow meters and three tank arrangement.

COSTS

The cost evaluation can be broken down into three sections. The cost of the wiping equipment, cost of the chemicals, and cost for a commercial operation.

The costs involved for equipping a tractor with a manufactured unit varies depending on whether the unit will have one or multiple systems. These costs are itemized for clarity in Table 7. A single system set up can be obtained for less than $8000. Adding a flow meter for each of the three zones would increase the cost by $200 to $700 depending on the quality of the flow meter chosen. A reasonable price for three flow meters would bring the system cost up to $8525. The addition of a second tank system would increase the cost by another $1000. With the optional flow meters the second system would add $1525 to the original system cost. The installation of a third tank system for hand spray applications would add another $425 to the initial cost. When all of these costs are put together for a three tank system the total would be $10,475. This price is actually on the high side. By utilizing a variety of equipment suppliers, as indicated in Table 8, this price can be reduced. A recent co-operative effort with the Maryland Department of Agriculture to equip a private operator with a wiper unit has resulted in prices below $10,000. This included all the components to assemble a system equal to or better than the one currently used by the Delaware conservation districts.

The purchase price of chemicals used during the time period of testing from 1998 to spring 2001 remained constant. The cost of these chemicals and various application rates are summarized in Tables 9 to 15. The most expensive chemical used during this period was Arsenal at $1481 for a 2.5 gallon unit. Fortunately this chemical was normally added at only 1 part to 40 parts of other less expensive chemicals. The other chemicals used varied in price according to the unit size available. For example Roundup Pro, 4 pound concentrate, purchased in 2.5 gallon containers was $64.40 per gallon. Roundup Ultra, which contains the same ingredients and concentration, was purchased in bulk, 30 gallon shuttle junior, for $30.99 per gallon. This was a considerable savings at less than one half the per gallon cost by purchasing in bulk. Touchdown in bulk form and a 5 pound concentrate was priced higher at $39.95 per gallon. However because it was a 5 pound concentrate the application

rate per acre cost when adjusted to a 4 pound concentrate was slightly less than the bulk Roundup Ultra Rodeo, which is approved for spraying over water, in a 5.4 pound concentrate was $102 per gallon bulk rate. Because the wiper unit applied directly to selected plants through applicator contact and did not put chemicals into water bodies this was not a required chemical in the wiper units and because of cost was used on a limited bases. However Rodeo did become the primary chemical for use in the spray gun because of over water treatments. The combining of chemicals increased the price per gallon but also made for more effective results. When looked at long term the combination was more economical. Roundup Pro at 40 parts to 1 part Arsenal cost $77.28 a gallon compared to Roundup Ultra and Arsenal in the same formulation at a cost of $44.68 per gallon. Both worked equally well so the lower cost formulation was used in the later tests. Touchdown at the 5 pound concentration level in a 40:1 ratio with Arsenal equaled $53.41 per gallon. Another mix was tested using Roundup Ultra and Arsenal in a 20:1 ratio. The cost for this ratio was $57.72 per gallon. This mix was utilized on plants that were well established and had extensive root systems, such as black locust groves and phragmites.

The combination of chemicals also resulted in lower application rates, 0.15 to 0.30 gallons per acre to obtain the same results as using 0.30 to 0.50 gallons per acre of Roundup, Touchdown or Rodeo alone. Application rates of Roundup Ultra and Arsenal in a 40:1 mix at a 0.25 gallon per acre rate cost $11.17. To obtain similar vegetation control with just Roundup Ultra 0.35 gallon per acre had to be applied at a cost of $10.85. Even at the increased rates pines, holly and black locust were hard to control with just Roundup. In areas where these trees were abundant the mix containing Arsenal proved to be very effective.

While equipment and chemical costs for wiping technology are very reasonable they need to be incorporated into the overall costs of a commercial operation. These costs can than be compared to spraying and mowing costs to aid in making vegetation management decisions. By first comparing chemical costs for wiping and spraying of the same area an initial appreciation for the saving of wiping can be seen. The chemical costs for wiping using just Roundup Ultra at the 0.35 gallon per acre rate would be $10.85 compared to spraying 3 quarts per acre of the same chemical would equal $23.25. This difference becomes significant when viewed as acres per mile of treatment area. On a roadside ditch system 2.66 acres per mile would potentially be treated. This equals $28.86 for chemicals to wipe one mile verses $61.85 to spray the same mile using only Roundup Ultra. Knowing Roundup Ultra alone is limited in controlling some vegetation Arsenal is also added to the

formulation to give broader species control. When a 40:1 formulation of Roundup Ultra and Arsenal is applied at the 0.25 gallon per acre rate through wiping the per acre cost is $11.17. To spray this 40:1 formulation using a 3 quart roundup per acre recommendation would cost $34.36. To treat the same mile by spraying versus wiping would triple the cost of the chemicals. The past two examples were assuming the area wiped and sprayed was not over water during the application period. With spraying drift can be a significant problem around water. When water exists the chemicals for spraying must be labeled for use over water. Rodeo is such a chemical that can be sprayed around and over water without causing environmental health problems. The wiping technology eliminates drift and water contamination thus allowing the safe use of Roundup around water. Both of these chemicals, when applied at label rates, are equally effective however there is a significant cost difference. To treat one acre with a wiper at the 0.35 gallon per acre rate would cost $10.85 compared to $38.25 for spraying the same area with Rodeo. Expanding this to one mile of treatment would cost approximately $29.00 for chemicals applied through wiping verses $102.00 for spraying.

Up to this point only chemical costs have been compared. However in order to gain a better perspective other costs such as; equipment, depreciation, insurance taxes, shelter, repair, maintenance, fuel, lubricants, labor safety items, administrative and overhead needed to be determined. The base cost for wiping, without chemical cost included, to travel one mile of treatment area was $104.00. With a base established the treatment costs can be determined according to area treated and type of chemical applied. A full treatment width for one mile using a 40:1 formulation of Roundup Ultra and Arsenal, at the 0.25 gallon per acre rate would cost $29.71 for the chemicals and $104 for the base or $133.71 for the cost of application.

Costs for roadside utility right-a-way and roadside ditch-wood line spraying are in the range of $190 to $200 per mile. This cost includes equipment, labor and chemicals. Broadcast spraying of right-a-way and tax ditch areas involving treatment over water are in the range of $1000 per running mile. This includes treatment on both sides of a ditch or wet area. Chemical cost alone can exceed $500 per mile when treating these areas. In comparison the total cost for treating these areas with the wiper unit has been $250 per mile. Helicopter application including chemicals exceeds $900 per hour of operation. Spot spraying of vegetation for utilities and right-a-ways costs $40 per hour plus the cost of chemicals used. From the costs presented the economic advantage of wiping verses spraying to manage vegetation becomes more apparent.

Another method used for vegetation management has been mowing. Mowing provides a clean appearance but offers little in the way of long term control of undesirable vegetation. Repeated mowing in areas of woody vegetation has proven to create greater density by the vegetation putting out multiple shoots to replace the one that was removed. This dense covering of woody vegetation soon canopy's and crowds out the grasses and other low lying plants that prove beneficial to stability of the area. Most systems require mowing at least every two years to maintain control. Some areas are being maintained through mowing every year to provide a pleasing visual appearance. The cost of mowing is in the range of $275 to $550 per mile depending on width of area mowed and age of vegetation. Most systems that have been maintained on a routine bases are in the cost range of $300 to $325 per mile. These costs are at least $50 greater per mile than wiping and offers only short term results. In comparison a wiping treatment at $250 per mile and treated again the next year or after a skipped year with extended treatments on a 3 to 5 year bases as needed will create considerable financial savings. The observations of test areas on ditches can be used to demonstrate this. One section of a system that was treated, mowed and retreated as part of a 4 year evaluation averaged $200 per year per mile for maintenance. Another section of the same system averaged $225 per mile per year for only mowing. Approaching 6 years since initial treatments on both sections of the system began the wiped section is maintaining itself through low lying vegetation while the mowed section is in need of another mowing. This will add a cost of $300 per mile for the mowed section while the wiped will not need treatment at this time so no cost is incurred to this part of the system. Through this comparison it can be seen that there are short term financial benefits but the substantial savings will be made over time.

Time is another factor involved in mowing as related to the age and density of the vegetation. One year growth can be mowed readily and is limited within the recommended mowing speed more by the surface condition of the right away than the power requirements of mowing the vegetation. Two year and certainly three year growth requires a slower ground speed, higher power demand and full throttle engine speed to perform an effective cutting and shredding of the woody vegetation. High engine speeds, increased fuel use and lower ground speeds are to be expected with vegetation of this age. Reasonable ground speeds for this operation would be between 1.5 to 2.5 miles per hour. These are also the same speeds used for operation with the wiping applicator. Once application requirements have been determined and a speed selected that speed can be maintained whether the vegetation is 1 or 3 years old. As wiping only requires moving the applicator through the vegetation

the power requirement is relatively low. A low engine idle in the 800 to 1200 revolutions per minute range is used depending on the hydraulic response needed for the applicator boom. Fuel use is based on this low load-low idle mode of operation. This also reduces the maintenance requirement on the tractor. Because the wiper unit has no rotating shafts or gear boxes to repair or replace as mowers do another cost savings is possible in equipment repair.

There are secondary savings created through wiping verses mowing or spraying. These costs have not been totally investigated at this point but need to be mentioned. When wiping vegetation the dying and decaying plants fall in place and are surrounded and secured by the underlying still living vegetation. The underlying vegetation secures the soil surface to prevent silting in of drainage areas requiring less clean out maintenance. Also significant is the prevention of loose vegetation getting into the water channel. Mowing deposits debris into the channel, which during heavy rain events can cause plugging and eroding of pipes and culverts. Repairing washed out areas can add considerable expense to a systems maintenance over and beyond the vegetation mowing cycles. Wiping to establish dense low-lying vegetation has demonstrated the ability to eliminate plugging problems associated with mowing.

CONCLUSION

After an in depth review of the information collected during field research from the period of the fall of 1998 to March of 2001 some conclusions on the wiping technology can be presented.

- The wiper method of managing vegetation has proven effective in the establishment and acceptance of non-woody buffer zones.
- Wiping demonstrates selectivity in vegetation management. Drift is not an issue to non-target species as in spray applications.
- The optimum vegetation control window is June through the end of October. However, some plants respond well in May and others in November and December. Management for species control is important.
- Winter treatments are effective for pruning or stunting activities.
- Very good control of phragmites was experienced with May, June and July treatments. Total eradication was experienced with a single treatment in May.

- Applications to trees after frost permitted lower contact heights as the dormant tops of the underlying vegetation was not susceptible to the chemicals.
- Application during February, March and April demonstrated poor response with or without the addition of Arsenal.
- Applications of Roundup, Rodeo and Touchdown were effective up to 75% on one to two year old trees. However trees with extensive root systems and evergreens did not respond well to these chemicals used alone.
- The introduction of Arsenal in the ratio of 1 part to 40 parts Roundup, Rodeo or Touchdown reduced the application rate, broadened the species affected and increased the percentage of control.
- Application rates of 0.20 to 0.30 gallons per acre of a 40:1 Roundup, Rodeo or Touchdown to Arsenal mix applied in concentrated form 0.40 to 0.60 gallon per acre 50% chemical – 50% water provided 75% plus control on targeted vegetation when applied during the appropriate window for that species.
- The flat bar with the right angle contacting edge or the expanded metal over the right angle created deeper wounds on the woody vegetation.
- The deeper wounds of the flat bar may have accounted for the increased vegetation response during winter applications versus applications made by the round bar.
- The use of expanded metal across the frontal edge of the flat bar created very good abrasions and prolonged the life of the grit paper.
- The round applicator proved more effective during the treatment window of June through October. This may be partially attributed to the round applicator providing 30 percent more contact area for transferring chemicals to targeted vegetation.
- The round applicator provided greater maintenance potential and should prove to be the most economical in the long term.
- The round applicator was consistent in uniformity of chemical distribution on the wetting front when operated at various angles after 400 plus treatment miles.
- The positive displacement diaphragm pump with stroke and timer control features provided exceptional flow stability throughout the treatment period. This pump in conjunction with flow meters and a pressure relief valve can provide uniformity of flow rate to multiple applicator sections.

- Wiping is less expensive and longer lasting than mowing. It has short term and long term economic and environmental advantages.
- Plugging of pipes and culverts needs to be a consideration when making recommendations for vegetation management on drainage areas.
- Cost of management of drainage ditches needs to be viewed not only as the cost to control vegetation but also long term in respect to stability of the slope and right-a-way. Operations to remove the sediment from the bottom of ditches to maintain flow can be very expensive and the management of vegetation needs to address the issue of filling the ditches with debris.

These conclusions may also serve as recommendations where appropriate or raise questions for further discussion and research.

REFERENCES

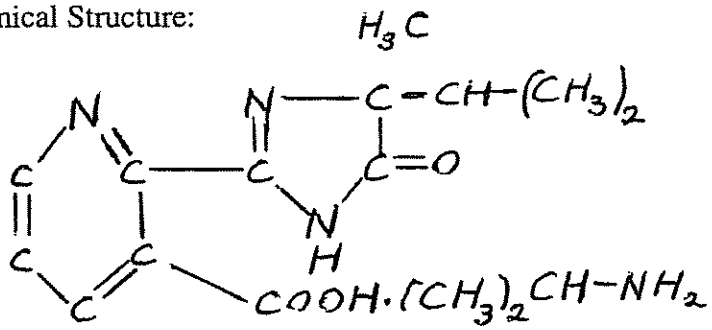
1. Kemble, L.J., W.F. Ritter and P. Krishnan. 2000. A weed wiper for drainage ditch brush control. In: Proceedings of ASCE Watershed Management Conference, June 20-24, 2000. Fort Collins, CO. CD-ROM.

2. Moore, J.C. 1995. Weed sweep sprayless herbicide applicator, U.S. Patent No. 5, 388, 369, Feb. 14th, 1995.

APPENDIX

Table 1. Properties of Arsenal [a]

Chemical Structure:



Chemical Composition: 2 – (4-isopropyl – 4 – methyl – 5 – oxo – 2 – imidazolisa – 2yl) – nicotinic acid.

Action: Nonselective, broad-spectrum systemic herbicide with residue

Use: Controls most annual and perennial grasses, broadleaf weeds and woody species in noncropland uses.

Solubility: Miscrible in water

Formulation: Aqueous liquid with wetting agent.

Toxicity: (Rat): Oral LD_{50} 75000 mg/kg. Rabbit: Dermal $LD_{50} > 2148$ mg/kg.

[a]Trade name

Table 2. Properties of Rodeo [a]

Chemical Structure:

$HO - C - CH_2 - NH - CH_2 - P - OH$

Chemical Composition: esopropylamine salt of N – (phosphono – methyl) glycine.

Action: Nonselective, postemergence herbicide.

Use: Controls many annuals and perennial grasses and broadleaf weeds plus many trees and woody brush species in cropland and noncropland sites. May be used over water.

Formulation: Water soluble liquid and nomonic surfactant.

[a]Trade name

Table 3. Properties of Roundup[a]

Chemical Structure:

$HO - C - CH_2 - NH - CH_2 - P - OH$

Chemical Composition: Isopropylaminc salt of N – (phosphono – methyl) glycine.

Action: Nonselective, postemergence herbicide.

Use: Controls many annuals and perennial grasses and broadleaf weeds plus many trees and woody brush species in cropland and noncropland sites. May not be used over water.

Formulation: Water soluble liquid.

[a] Trade Name

Table 4. Properties of Touchdown [a]

Chemical Structure:

$HO - CO - CH_2 - NH - CH_2 - P - (CH_3)_3\ S$

Chemical Composition: N – phosphonomethyl glycine trimethylsufforium salt.

Action: Nonselective postemergency systemic herbicide.

Use: Controls broad range of annual and perennial grass and broadleaf weeds and certain woody perennials.

Solubility: In water .430g/100 m.

Formulation: Water soluble liquid

Toxicity (Rat): Oral LD_{50} 750 mg/kg.

(Rabbit) Dermal $LD_{50} > 200$ mg/kg

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[a] Trade name

Table 5. List of Application Sites For Kent County and Flat Applicator Type [a]

Year	Season	Town	Rd. number	Chemicals	Treatment	
1998	Summer	Harrington	300	Roundup Pro	40:1	
				Arsenal	.35 g/ac.	
1998	Fall	Vernon	455	Roundup Pro	40:1	
				Arsenal	.18 g/ac.	
1998	Fall	Andrewville	304	Roundup Pro	40:1	
				Arsenal	.32 g/ac.	
1999	Summer	Willow Grove	54	Roundup Ultra	40:1	50/50
				Arsenal	.25 g/ac.	.50 /ac.
1999	Summer	Willow Grove	54	Roundup Ultra	40:1	50/50
				Arsenal	.25 g/ac.	.50 g/ac.
1999	Summer	Farmington	311	Roundup Ultra	40:1	50/50
				Arsenal	.25 g/ac.	.50 g/ac.
1999	Summer	Farmington	311	Roundup Ultra	40:1	50/50
			312	Arsenal	.25 g/ac.	.50 g/ac.
				Roundup Ultra	8:1	50/50
				Touchdown	.23 g/ac.	.46 g/ac.
				Roundup Ultra		50/50
					.28 g/ac.	.57 g/ac.
				Touchdown		50/50
					.25 g/ac.	.50 g/ac.
1999	Summer	Vernon	14	Touchdown	40:1	75/25
				Arsenal	0.17 g/ac.	.229 g/ac.
1999	Summer	Brownsville	59	Roundup Ultra	40:1	50/50
				Arsenal	.25 g/ac.	.50 g/ac.
				Insure GL	50:1	

Table 5. continued

Year	Season	Town	Rd. number	Chemicals	Treatment
1999	Fall Early	Hazlettville	215	Roundup Pro Arsenal	20:1 .20 g/ac.
1999	Fall Early	Wyoming	52	Roundup Ultra Arsenal	20:1 50/50 .30 g/ac. .60 g/ac.
1999	Fall Early	Vernon	4	Roundup Ultra Arsenal Touchdown	40:1 50/50 .43 g/ac. .86 g/ac. 3:1
2000	Summer	Wyoming	52	Roundup Ultra Arsenal	20:1 50/50 .20 g/ac. .40 g/ac.
2000	Summer	Hazlettville	216	Roundup Ultra Arsenal	20:1 50/50 .25 g/ac. .50 g/ac.
2000	Summer	Greenwood	13	Roundup Ultra Arsenal	40:1 50/50 .18 g/ac. .36 g/ac.
2000	Fall	Harrington	290	Roundup Ultra Arsenal	40:1 50/50 .16 g/ac. .32 g/ac.

[a] Round Application Type Used in 2000

Table 6. List of Application Sites For Sussex County [a]

Year	Season	Town	Rd. number	Chemicals	Treatment	
1998	Summer	Staytonville	36	Roundup Pro	40:1	
				Arsenal	.14 g/ac.	
1998	summer	Owens	611	Roundup Pro	40:1	
				Arsenal	.21 g/ac.	
1999	Spring	Laurel	509	Roundup Pro	40:1	
				Arsenal	.25 g/ac.	
1999	Fall	Redden	42	Touchdown	.97 g/ac.	
1999	Fall	Owens	611	Roundup Ultra	40:1	50/50
				Arsenal	.337 g/ac.	.67 g/ac.
1999	Fall	Laurel	24	Roundup Ultra	40:1	50/50
	Late			Arsenal	.19 g/ac.	.38 g/ac.
1999	Winter	Laurel	503	Roundup Ultra	40:1	50/50
	Early			Arsenal	.12 g/ac.	.24 g/ac.
2000	Fall	Bridgeville	404	Roundup Ultra	40:1	75/25
				Arsenal	.25 g/ac.	.334 g/ac.
2000	Fall	Bridgeville	36	Roundup Ultra	40:1	75/25
				Arsenal	.25 g/ac.	.33 g/ac.
2000	Fall	Georgetown	113	Roundup Ultra	40:1	50/50
				Arsenal	.205 g/ac.	.41 g/ac.
2000	Fall	Laurel	24	Roundup Ultra	40:1	50/50
				Arsenal	.19 g/ac.	.38 g/ac.

Table 6. continued

Year	Season	Town	Rd. number	Chemicals	Treatment
2000	Fall	Laurel	503	Roundup Ultra	40:1 50/50
				Arsenal	.35 g/ac. .70 g/ac.
2001	Winter Late	Laurel	503	Roundup Ultra	40:1 50/50
				Arsenal	.20 g/ac. .40 g/ac.
2001	Winter	Laurel	504	Roundup Ultra	40:1 50/50
				Arsenal	.20 g/ac. .40 g/ac.

[a] Flat applicator type in 1998 and Spring of 1999. All other applications were within the round applicator type.

Table 7. Equipment and Cost

Required	Description	Cost
1	10 ft. front mounted wiper with hydraulic angle and height adjustment	$2950.00
1	Ditch bank wiper with horizontal tilt and angle adjustment	$3075.00
1	Complete control valve, 12 volt pump system with timer and 36 gal. cone bottom tank	$ 750.00*
1	3 way control valve kit	$ 239.00*
1	8 inch hydraulic cylinder	$ 64.99
2	Spool valves pairs (2 valves per unit) Total of 4 spool valves	$ 320.46
6	Hydraulic hoses and fittings	$ 175.00
	Basic unit subtotal	$7574.45

*These two items can be replaced with marked items in second tank option to utilize the Pulse feeder pump.

Second Tank Option

1	Pulse feeder pump (requires by pass)	$ 450.00*
1	16 gal. poly tank, cone bottom	$ 68.00*
1	Frame for 16 gal. poly tank	$ 55.00*
1	3 way control valve kit	$ 239.00*
	Misc. hose fittings & valves	$ 150.00
	Second tank option subtotal	$ 962.00

Table 7. continued

Required	Description	Cost
1	12 volt chemical pump	$ 75.00
1	16 gal. poly tank, cone bottom	$ 68.00
1	Frame for 16 gal. poly tank	$ 55.00
1	3 way control valve kit	$ 239.00
	Misc. hose fittings & valves	$ 150.00
	Second tank option subtotal	$ 587.00
	Third Tank Option	
1	12 volt chemical pump	$ 75.00
1	16 gal. poly tank, cone bottom	$ 68.00
1	Frame for 16 gal. poly tank	$ 55.00
1	Hand gun	$ 64.00
1	Single control valve	$ 69.00
	Misc. hose fittings & valves	$ 75.00
	Third tank option subtotal	$ 406.00
	Optional flow meters	
3	Flow meters @ $228.00 For primary tank to service three separate boom sections (does not need to be this quality, units are available for less than $100/each)	$ 684.00
	Replacement Wiper Bars	
1	5 ft. section @ $ 44.00 per ft. Flat bar applicator	$ 220.00
1	5 ft. section @ $ 60.00 per ft. Round bar applicator	$ 300.00

Table 8. List of Equipment Suppliers

1. Weed/Sweep Systems, 555 Riviera Drive, Naples, FL 34103
   Ph: 914-261-1098. James E. Moore.

   Wiper bars, mounting systems, and metering – control system

2. Agri Supply Co., Garner, NC 27529
   Ph: 1-800-345-0169

   Solenoid valves, remote controls, pumps, spray guns and fittings

3. Grainger, 117 Quigley Blvd., New Castle, DE 19720-4103
   Ph: 302-322-1840.

   Hydraulic spool valves, flow control valves, and cylinders

4. Benz Hydraulic Inc., 157 S. Dupont Blvd., New Castle, DE 19720
   Ph: 302-328-6648

   Custom hydraulic hoses, fittings and valves

5. Spraying Systems Co., 124 A. West Harrisburg St., Dillsburg, PA 17019
   Ph: 717-432-7222

   Sprayer filters, screens, orifice plates, nozzle bodies, control systems & fittings

6. Pleasure Products MFG., Co., Inc. 2421 – 16 Ave. So.
   Moorhead, MN 56560-3894
   Ph: 218-236-1818

   Poly tanks and stands

7. Ag Chem Equipment – East Petersburg, PA 17520
   Ph: 717-569-2610

   Sprayer tubing, strainers, nozzle bodies and fittings

8. Central Tractor Farm & Family, Dover, DE
   Ph: 302-697-9561

   12 volt spray pump, fittings and hardware

Table 8. continued

9.	Omega Engineering, Inc., One Omega Dr., Box 4047 Stanford, CT 06907-0047 Flow meters and metering valves
10.	McDonald's Safety Equipment, 581 Copper Dr., Wilmington, DE 19804 Ph: 302-999-0151 Tyvek coverall, Nitrile gloves and safety items
11.	Shopworks – The Ag – Parts Connection, 207 N. Rehoboth Bldg, Milford, DE 19963. Ph: 302-422-2915 or 1-888-713-8383. Poly tanks, couplers, valves, nozzles, tubing, spray guns, pumps, spray controls, strainers, fittings and sprayer accessories

This list of venders is not an endorsement of their products, but is offered as a convenience.

Table 9. Chemical Costs

Chemical	Concentration	Container Size	Unit Price	Price/Gallon
Roundup Pro	4 lb. - 41%	2.5 gallon	$161.00	$64.00
Arsenal	4 lb. - 53.1%	2.5 gallon	$1,481.00	$592.40
Roundup Ultra	4 lb. - 41%	bulk	$30.99	$30.99
Rodeo	5.4 lb. - 53.8%	bulk	$102.00	$102.00
Touchdown	5 lb. - 48.6%	bulk	$39.95	$39.95
40:1 Mix				
Roundup Pro Arsenal	4 lb. - 41% 4 lb. - 53.1%			$77.28
Roundup Ultra Arsenal	4 lb. - 41% 4 lb - 53.1%			$44.68
Touchdown Arsenal	5 lb. - 48.6% 4 lb. - 53.1%			$53.41
20:1 Mix				
Roundup Ultra Arsenal	4 lb. - 41% 4 lb. - 53.1%			$57.72

Table 10. Roundup Pro and Arsenal Costs

Ratio	Application Rate	Cost
Roundup Pro : Arsenal	Gallon / acre	$ / acre
40 : 1 mix	0.5	38.64
	0.45	34.78
	0.4	30.91
	0.35	27.05
	0.3	23.18
	0.25	19.32
	0.2	15.46
	0.15	11.6
	0.1	7.73

Roundup Pro (41%) @ $.503 per ounce
Arsenal (53.1%) @ $4.628 per ounce
40:1 ratio treats 1.025 acres - cost adjusted to 1 acre

Table 11. Roundup Ultra and Arsenal Costs

Ratio	Application Rate	Cost
Roundup Ultra : Arsenal	Gallon / acre	$ / acre
40 : 1 mix	0.5	22.34
	0.45	20.106
	0.4	17.872
	0.35	15.638
	0.3	13.404
	0.25	11.17
	0.2	8.936
	0.15	6.702
	0.1	4.468

Roundup Ultra (41%) @ $.242 per ounce
Arsenal (53.1%) @ $4.628 per ounce
40:1 ratio treats 1.025 acres - cost adjusted to 1 acre

Table 12. Touchdown and Arsenal Costs

Ratio	Application Rate	Cost
Touchdown : Arsenal	Gallon / acre	$ / acre
40 : 1 mix	0.5	26.705
	0.45	24.035
	0.4	21.364
	0.35	18.694
	0.3	16.023
	0.25	13.353
	0.2	10.682
	0.15	8.012
	0.1	5.341

Touchdown (48.6%) @ $.312 per ounce
Arsenal (53.1%) @ $4.628 per ounce
40:1 ratio treats 1.025 acres - cost adjusted to 1 acre

Table 13. Roundup Ultra and Arsenal Costs

Ratio	Application Rate	Cost
Roundup Ultra : Arsenal	Gallon / acre	$ / acre
20 : 1 mix	0.5	28.66
	0.45	25.974
	0.4	23.088
	0.35	20.202
	0.3	17.316
	0.25	14.43
	0.2	11.544
	0.15	8.658
	0.1	5.772

Roundup Ultra (41%) @ $.242 per ounce
Arsenal (53.1%) @ $4.628 per ounce
20:1 ratio treats 1.05 acres - cost adjusted to 1 acre

Table 14. Roundup - Rodeo – Touchdown Costs

Rate			Cost	
Gallon / acre			$ / acre	
	Roundup			
	Pro	Ultra	Rodeo	Touchdown
1.00	64.40	30.990	102.00	39.950
0.90	57.96	27.891	91.80	35.955
0.80	51.52	24.792	81.60	31.960
0.70	45.08	21.693	71.40	27.965
0.60	38.64	18.594	61.20	23.970
0.50	32.20	15.495	51.00	19.975
0.45	28.98	13.945	45.90	17.977
0.40	25.76	12.396	40.80	15.980
0.35	22.54	10.846	35.70	13.982
0.30	19.32	9.297	30.60	11.985
0.25	16.10	7.747	25.50	9.987
0.20	12.88	6.198	20.40	7.990
0.15	9.66	4.648	15.30	5.992
0.10	6.44	3.099	10.20	3.992

Table 15. Spray Application Costs

Chemical	Concentration	Rate	Dry Area	Road Side*	Tax Ditch**
		gallon / acre	$ / acre	$ / mile	$/mile
Roundup Ultra	4 lb. - 41%	0.75	23.25	61.85	168.97
Arsenal	4 lb. - 53.1%	0.3125	185.12	492.42	1345.82
Roundup Ultra	4 lb. - 41%	0.625	19.36		
Arsenal	4 lb. - 53.1%	0.125	74.05		
			93.41	196.97	697.09
Roundup Ultra	4 lb. - 41%	0.75	23.25		
Arsenal	4 lb. - 53.1%	0.0218	11.11		
			34.36	91.39	249.8
		Costs for Wet Areas			
Rodeo	5.4 lb. - 53.8%	0.375	38.25	101.75	278.08

*Roadside treatment equals 2.66 acres per mile
** Tax ditch treatment equals 7.27 acres per mile

Figure 1. Weed Wiper with Bars Lowered

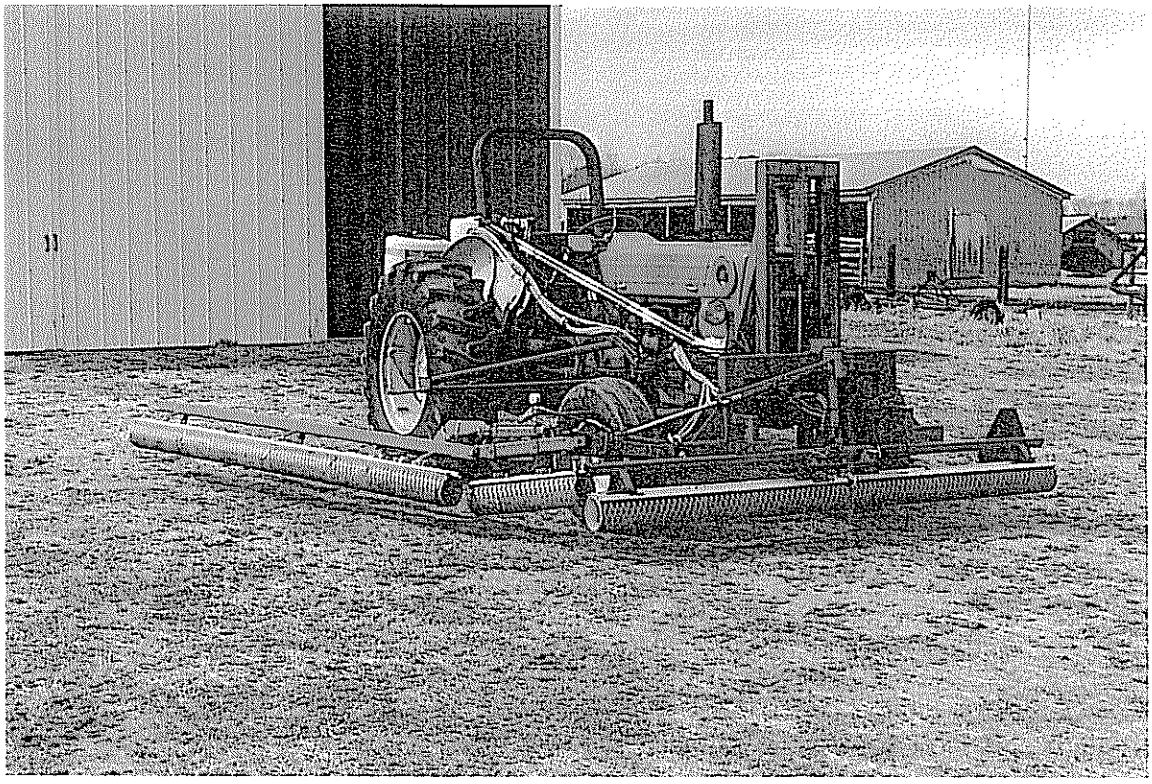

Figure 2. Weed Wiper Front and Side-Bars

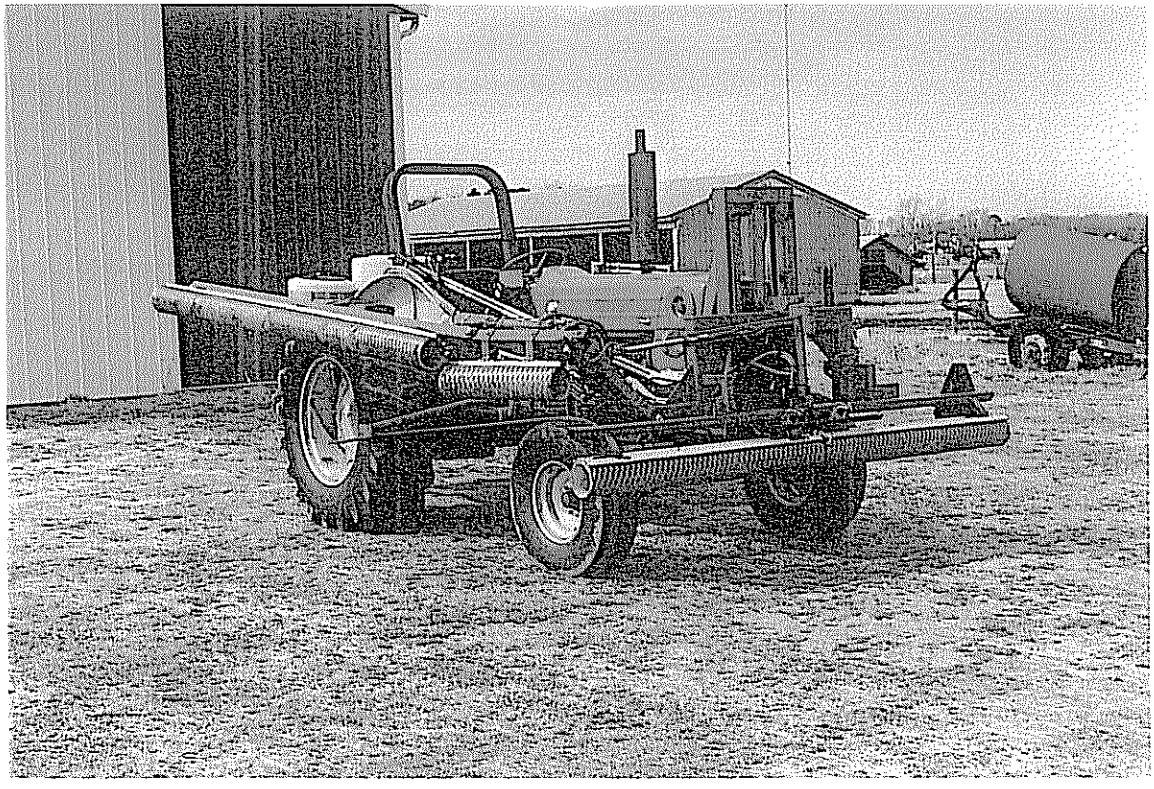

Figure 3. Weed Wiper Unit Design Used in 1998

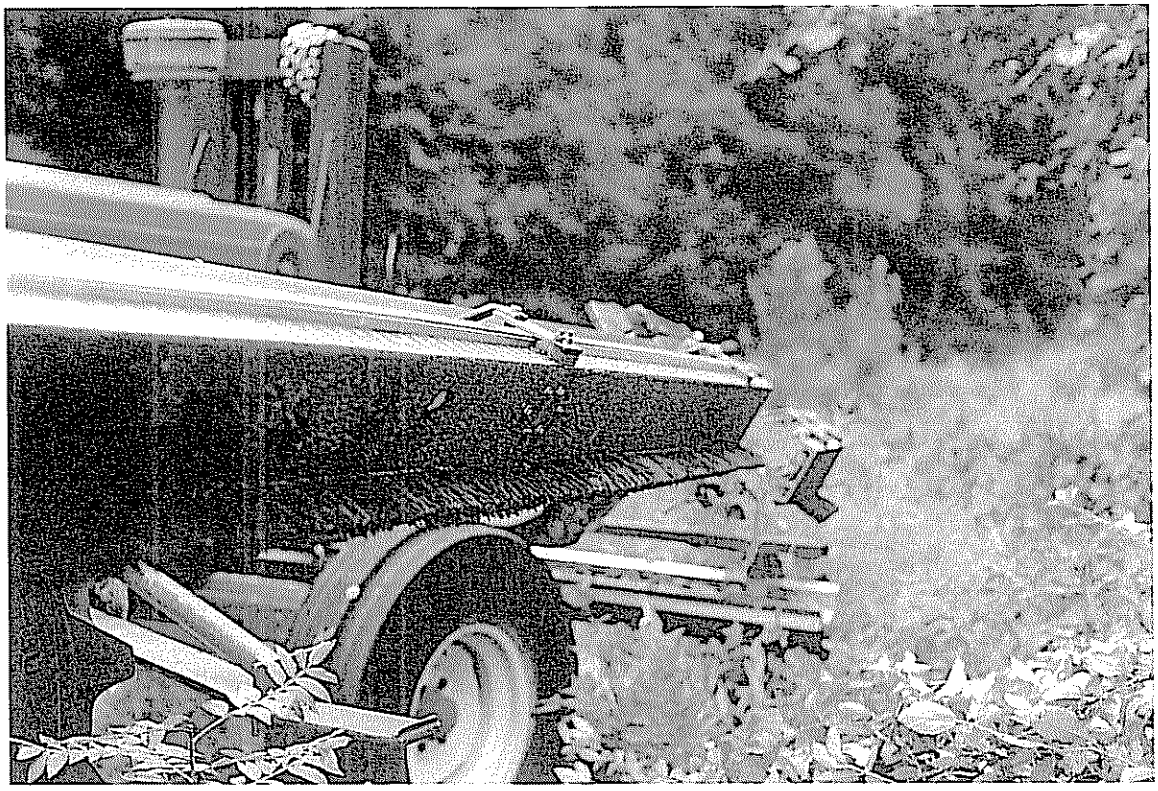

Figure 4. New Weed Wiper Design Used in 1999

Figure 5. Weed Wiper Control Panel

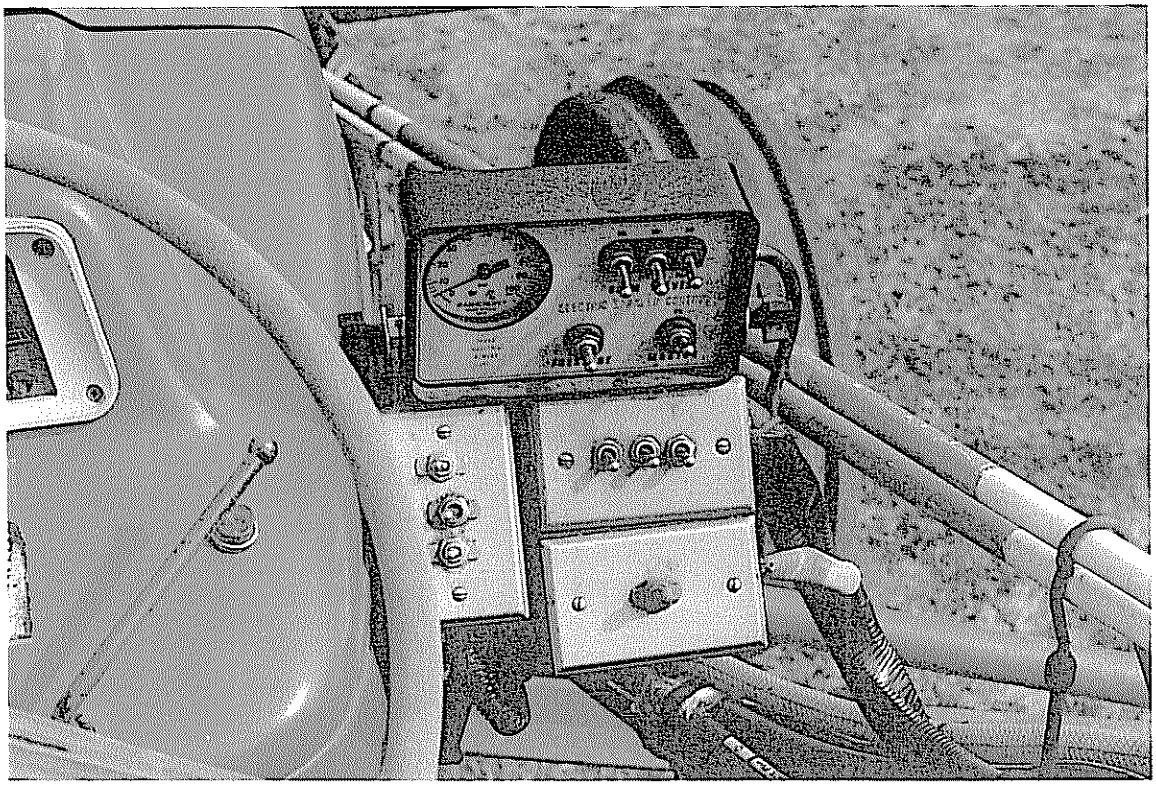

Figure 6. Weed Wiper Flow Meters

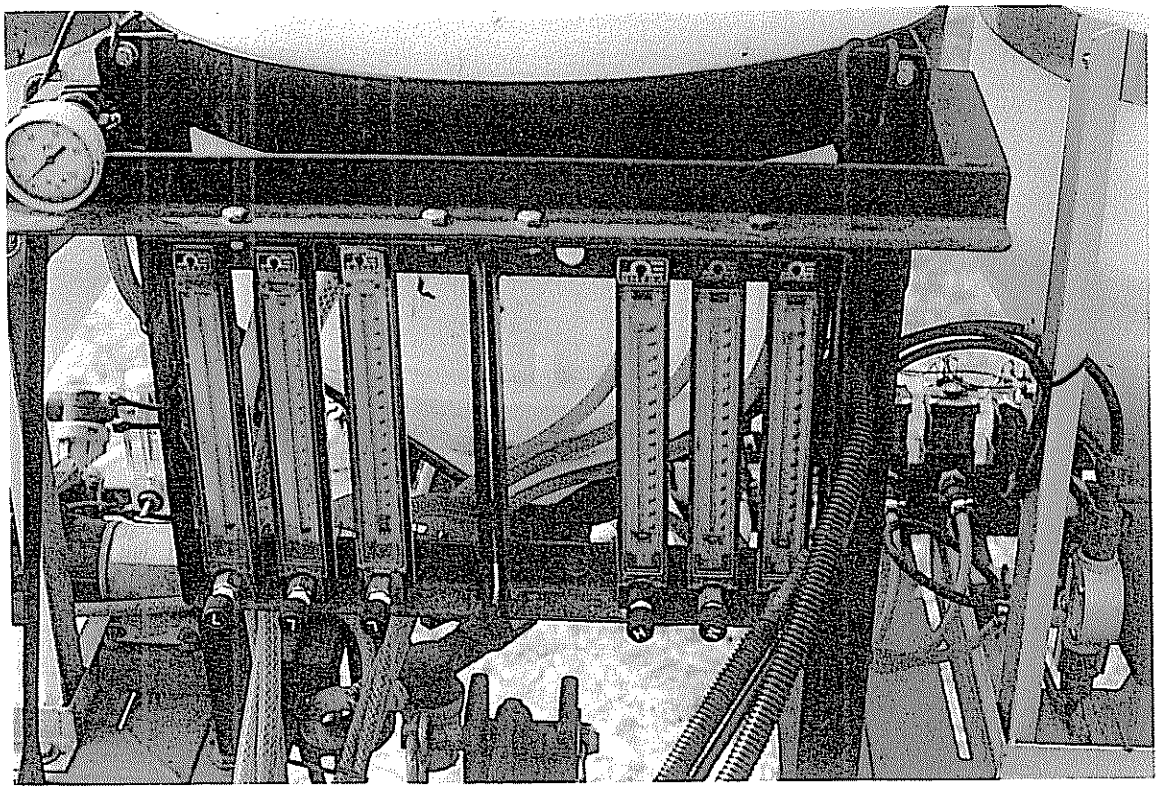

Figure 7. Weed Wiper Herbicide Tanks

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