Use of 2,4-D and Other Phenoxy Herbicides in Rights-of-Way in the United States

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- 2,4-D is the second most widely used herbicide for integrated vegetation management on rights-of-way across the United States, with 6.3 million lbs sold for such uses in 2013.
- It is estimated that there are 11.9 million acres of roadway right-of-way alone across the United States, with 77% of them being treated with herbicides.
- 2,4-D is effective and inexpensive; it controls problem broadleaf weeds while leaving desirable grasses unaffected.

Introduction

Rights-of-way have an important role to play in the US economy. These corridors allow travel to and from work, school, vacation, shopping, or the hospital. Highway, rail and levee rights-of-way facilitate transportation of exported products from the site of production to the port for export and imported goods from ports to retail outlets to home or business. An extensive network of safe, reliable transportation ensures items can be delivered to retail outlets quickly and efficiently, which means fresh produce, whether grown locally or in another country, is available at the grocery store; the newest electronic gadgets can be purchased locally or delivered if ordered; gasoline is available at the nearest convenience store. These transportation corridor systems are vital to deliver raw materials to manufacturing sites, then move the manufactured goods to distribution outlets and sales sites or ports for export. Right-of-way maintenance is the key to ensure ground transportation system, whether road or rail, is safe and reliable.

Other utility rights-of-way that rely on 2,4-D play key economic roles as well. Electricity and gas are the primary utilities used to maintain comfortable temperatures in homes or places of employment and prepare the foods people consume. Buyers can purchase food that is safe to eat and store it for relatively long periods of time because utility rights-of-way exist to facilitate the movement of electricity from generation plants to homes and businesses. Most Americans depend on the reliable flow of electricity from generation sites to home, work, school, and health care facilities.

Vegetation management on these rights-of-way is the key to its sustainability. Once the right- of-way is opened for the transportation corridor to be built, plant succession starts again. The repetitive cycle of annual plants is gradually replaced by biennial, then herbaceous perennial followed by woody perennial plants and starts all over again after removal of the existing vegetation from the initial construction. If plant succession is

allowed to continue to the stage at which woody perennials dominate the right-of-way, roots will destroy the road surface by breaking asphalt, penetrate levees, short electric power lines or damage pipelines and other buried utilities. Grass seed or sod has been recommended for establishment on road sideslopes for over a century due to the soil binding nature of grass roots (Gillespie 1850).

Hottenstein (1969) gives a list of preferred grasses to establish on rights-of-way in various regions of the US. Routine, selective vegetation management to maintain the right-of-way by removing the undesirable broadleaf vegetation while leaving the established grasses is imperative to ensure road surfaces are safe for travel or utility or that rail rights-of-way can be quickly and easily accessed for repair. Millions of dollars are invested in the construction of new highways, rail, and other utility line rights-of-way. After the investment of capital to build the right-of-way, vegetation must be managed to control plant succession and protect these investments that are vital to the economy of the US.

For more than two centuries, weeds along roadside rights-of-way have been viewed as a source of contamination to adjacent agricultural land (Beatson 1796; Sinclair 1826; Anonymous 1896; Upham 1910). Vegetation management should be approached from an integrated perspective – that is, all methods of vegetation management, including cultural, prevention, mechanical, biological, and chemical, should be incorporated as part of the total management system. Robbins et al. (1942) listed mowing, burning, disking, blading, hand pulling, hoeing, and chemical application as viable tactics to control vegetation on rights-of-way. However, mechanical combined with chemical control methods are the most effective to achieve this goal while minimizing soil erosion without the costs of more expensive, labor intensive management methods.

Use of Phenoxy Herbicides for Vegetation Management

The tolerance of most grasses and susceptibility of a wide spectrum of broadleaf weeds to 2,4-D and other phenoxy herbicides made them ideal candidates to manage vegetation on rights-of-way with the objective of controlling the undesirable woody broadleaf plants and not harming the desirable grassy plants.

The discovery of the phenoxy herbicide family revolutionized weed control (Peterson 1967; Troyer 2001), not only in agricultural commodities, such as grain and turf, but in forestry and rights-of-way as well. Only 10 years after the discovery of the phenoxy herbicides, Robbins et al. (1952) stated that 2,4-D, was being used to treat many miles of utility, roadside and firebreak rights-of-way. Bovey (2001) provides approximate response levels of more than 400 woody plants to basal, foliar, and injection/cut stump applications of 2,4-D as well as other herbicides currently used for woody plant management. He also provides a

detailed history of phenoxy use for woody vegetation management. In an attempt to broaden the spectrum of vegetation management on rights-of-way and in forestry, mixtures of various phenoxy molecules as well as herbicides from other families were often manufactured by the agrichemical industry. Registration cancellations of 2,4,5-T and 2,4,5-TP by the Environmental Protection Agency in the 1980's reduced the utility of phenoxy herbicide family for woody plant and brush control in forestry and rights-of-way, and forced applicators to rely on alternative herbicides for satisfactory control of woody vegetation.

Management of wildfires in the West especially has been highlighted these past few years due to severe drought. One tried-and-true protection plan has been to develop and maintain firebreaks between the potential source and the fuel. Herbicides have played a major role over the years in managing bare ground around and in substations and transmission line poles. Managing fuel sources along transmission lines is a critical effort in preventing tree branches from damaging lines and initiating a fire. The enormous expense of fighting wildfires and rebuilding after they have passed – not to mention the potential for human harm and loss of life – illustrates the importance of maintaining fire breaks and rights-of-way. 2,4-D remains an effective and low-cost option for controlling woody plant and brush control in these spaces.

Off target movement of spray droplets and volatility of phenoxy herbicides has been a concern of applicators using the phenoxy herbicides, particularly in rights-of-way applications near sensitive crops. However, despite the potential for off-target damage, when applied with favorable environmental conditions, the phenoxy herbicides are environmentally safe, due to their low toxicity and rapid environmental dissipation. Bovey (2001) rightly stated that phenoxy herbicides have been proven safe longer than any other group of herbicides.

Kline and Company reports sales data of herbicides sold for industrial vegetation management (IVM) markets on road, rail, pipeline, and electric utility rights-of-way, in addition to forestry and aquatic applications (Table 9.1). However, currently there are more than 45 herbicides from 23 herbicide families that can be used for integrated vegetation management on rights-of-way (Table 9.2).

Table 9.1. Consumption of Herbicide Active Ingredients by the Industrial Vegetation Management Market in the United States by Brand, 2013.

Active ingredient	Brand name	Thousand lb a.i.	% of total
Glyphosate	Roundup®, Accord®, Rodeo®, Razor®, Aquamaster®, Aquaneat®, Aquapro®, Buccaneer®, Campaign®, Glyfos®, Honcho®, others	15847	47.2
2,4-D	Weedmaster®, Grazon P+D®, Escalade®, Cimarron®, Curtail®, Pathway®, Navigate®, Weedar 64®, others	6292	18.8
Triclopyr	Garlon®, Remedy®, Redeem®, Crossbow®, Renovate®, PastureGard, Pathfinder®, Renovate®, others	3188	9.5
Imazapyr	Arsenal®, Chopper®, Stalker®, Sahara®, Habitat®, Polaris®, Topsite®, Viewpoint®, others	1762	5.3
Picloram	Tordon®, Grazon®, Outpost®, Pathway®, Gunslinger®, Surmount®, others	1320	3.9
Dicamba	Vanquish®, Banvel®, Escalade®, Vison®, Weedmaster®, Overdrive®, others	630	1.9
Copper sulfate	Various	530	1.6
Aminopyralid	Milestone®, Forefront®, Opensight®, others	499	1.5
Diuron	Karmex®, Krovar®, Sahara®, SpraKil®, Topsite®, others	463	1.4
Endothall	Aquathol®, Hydrothol®	444	1.3
Clopyralid	CleanSlate®, Confront®, Curtail®, Momentum®, Reclaim®, others	441	1.3
Bromacil	Bromacil®, Hyvar®, Krovar®, others	225	0.7
Diquat	Diquat®, Knockout®, Solera®, Tribune®, others	216	0.6
Fosamine	Krenite®	200	0.6
Imazapic	Habitat®, Journey®, Panaromic®, Plateau®	192	0.6
Sulfometuron methyl	Landmark®, Oust XP®, Oustar®, Oust Extra®, SFM 75®, Spyder®, others	172	0.5
Metsulfuron methyl	Accurate®, Escort®, Opensight®, Oust Extra®, Spyder®	160	0.5
Hexazinone	Velpar®, Oustar®, Westar®	107	0.3
Copper chelate	Cutrine Plus®, Komeen®, others	105	0.3
Fluroxypyr	Vista®, Pasturegard®, Surmount®, Escalade®, others	85	0.3
Sodium carbonate peroxyhydrate	Green Clean®, Phycomycin	74	0.2
Tebuthiuron	Spike®, SpraKil®, others	68	0.2
Atrazine	Generic atrazine products	55	0.2
Chlorsulfuron	Landmark®, Perspective®, Telar®	43	0.1

Table 9.1 continued. Consumption of Herbicide Active Ingredients by the Industrial Vegetation Management Market in the United States by Brand, 2013.

Active ingredient	Brand name	Thousand lb a.i.	% of total
Flumioxazin	Clipper®, Payload®	37	0.1
All other-[a]	-	391	1.2
Total	–	33547	100

[a]- Includes aminocyclopyrachlor, prodiamine, fluridone, and sulfosulfuron, among others.
Source = Kline and Company 2014 Global Industrial Vegetation Management Analysis and Opportunities

Highway rights-of-way represent a sizeable land mass in the US. The Federal Highway Administration reported 4,092,730 lane miles of roadways across the US (Table 9.3). These road systems are maintained by federal and state agencies or counties. In Mississippi, there are 75,181 centerline road lane miles, of which 29,640 miles with 139,290 acres of right-of-way are maintained by the Mississippi Department of Transportation (MDOT) (Dave Thompson, personal communication). The remaining 45,541 lane miles are maintained by other state or federal agencies or counties. Rights-of-way width varies among states, geographies, number of road lanes, and road size. Kline and Company (2014) reports that on interstate roads in Montana, there are 21.8 acres per center line mile, compared to 15.5 acres for primary roads, and only 11.2 acres for secondary and frontage road per center line mile. Using an average of 9.7 acres of right-of-way per centerline mile of road, Kline and Company (2014) estimate there are nearly 11.9 million acres of roadway right-of-way across the US. They also estimate that 77%, or 9.1 million acres, of the right-of-way acres are regularly treated with herbicides.

Table 9.3. Right-of-way miles by state and function.

State	Roadway[a]	Railroad[b]	Transmission[c]	Pipeline[d]
Alabama	101811	3194	17404	39612
Alaska	16301	506	2505	5247
Arizona	65262	1643	16846	31416
Arkansas	100123	2698	8579	29708
California	175499	5295	49144	123947
Colorado	88524	2662	17716	47779
Connecticut	21431	364	1982	8433
Delaware	6377	250	1169	3239
District of Columbia	1502	20	283	1214
Florida	121829	2900	18292	32447
Georgia	125523	4653	17237	50288
Hawaii	4416	0	1313	725
Idaho	48492	1623	9023	10189
Illinois	144337	6986	16235	78029
Indiana	97288	4075	15860	49533
Iowa	114438	3869	17878	30244
Kansas	140614	4855	17092	47338
Kentucky	79321	2608	12736	25631
Louisiana	61326	2927	8983	67668
Maine	22871	1116	4131	1513
Maryland	32372	758	3513	15780
Massachusetts	36330	973	4202	22515
Michigan	122051	3542	11339	68789
Minnesota	138832	4450	24841	40499
Mississippi	75181	2452	9443	30278
Missouri	131978	3957	15303	36399
Montana	74905	3200	13396	14131
Nebraska	93797	3375	13307	21222
Nevada	38568	1192	3767	12074
New Hampshire	16105	344	1158	2197
New Jersey	39272	981	5982	35997

Table 9.3 continued. Right-of-way miles by state and function.

State	Roadway[a]	Railroad[b]	Transmission[c]	Pipeline[d]
New Mexico	68384	1837	10183	26180
New York	114709	3447	20637	53863
North Carolina	106063	3258	15326	34351
North Dakota	86851	3330	15059	8891
Ohio	123281	5288	23103	71659
Oklahoma	112821	3273	17022	49582
Oregon	59262	2396	12386	18239
Pennsylvania	119846	5151	15065	60606
Rhode Island	6480	19	431	3282
South Carolina	66244	2311	12274	24313
South Dakota	82536	1753	10267	6935
Tennessee	95523	2649	14637	44354
Texas	313210	10469	53560	207925
Utah	45891	1343	11095	21724
Vermont	14291	590	2936	890
Virginia	74591	3215	8941	25096
Washington	83878	3192	18337	24480
West Virginia	38684	2226	6347	15250
Wisconsin	115095	3449	7923	44620
Wyoming	28416	1860	4670	18606
Totals	4092730	138524	641011	1744927

[a]Source http://www.fhwa.dot.gov/policyinformation/statistics/2012/hm10.cfm

[b]Source 2011 STB Waybill Sample, American Association of Railroads

[c]Source EEI Statistical Handbook, 2012 Data, Edison Electric institute

[d]Source US Department of Transportation, Pipeline and Hazardous Materials Safety Administration http://primis.phmsa.dot.gov/comm/States.htm?nocache=6839 accessed online 09/22/2014

Table 9.4. Consumption of Herbicide Active Ingredients by Roadways in the United States by Brand, 2013.

Active ingredient	Brand name	Thousand lb a.i.	% of total
Glyphosate	Roundup Pro®, Rodeo®, Glystar Plus®, Mad Dog®, Ranger Pro®, Glypro®, Campaign®, Accord®, Honcho®, and others	5239	76.4
2,4-D	Weedar 64®, Pathway®, Forefront R&P®, Crossbow®, Triplet®, Grazon P+D®, Tordon®, and others	652	9.5
Triclopyr	Garlon 3A®, Garlon 4®, Capstone®, Outrider®, Pathfinder®, Crossbow®, and others	301	4.4
Aminopyralid	Milestone VM®, Forefront®, Chaparral®, Capstone®, Opensight®	173	2.5
Fosamine	Krenite S®	75	1.1
Imazapic	Plateau®	60	0.9
Picloram	Tordon®, Picloram®, Pathway®, Grazon P+D®	55	0.8
Metsulfuron methyl	Opensight®, Escort®, Oust®, Streamline®, Viewpoint®	45	0.7
Diuron	Diuron®, Sahara DG®, Bromacil®, Krovar®	43	0.6
Bromacil	Bromacil®, Krovar®	37	0.5
Sulfometuron methyl	Oustar®, Oust®	32	0.5
MCPA	MCPA®	27	0.4
Clopyralid	Transline®, Confront, Millennium®	24	0.3
Imazapyr	Habitat®, Sahara DG®	17	0.2
Aminocyclopyrachlor	Viewpoint®, Streamline®, Perspective®	15	0.2
Fluazifop	Fusilade II®	13	0.2
Chlorsulfuron	Telar®, Perspective®, Landmark®	11	0.2
Pendimethalin	Pendulum®	10	0.1
MCPP	Triplet®	10	0.1
Dicamba	Overdrive®, Vanquish®, Clarity®, Triplet®, Banvel®, Millennium®, and others	9	0.1
All other[a]	-	11	0.2
Total		6859	100

[a] Includes oryzalin, prodiamine, fenoxaprop, atrazine, hexazinone, and diquat, among others

Source = Kline and Company 2014 Global Industrial Vegetation Management Analysis and Opportunities

In their 2011 STB Waybill Sample, the American Association of Railroads (2012) reported 138,524 miles of railroad across the US in 2011 (Table 9.2). Kline and Company (2014) estimate 1.7 million acres of railroad rights-of-way with approximately 54% or 912,000 acres treated with herbicides in 2013.

Table 9.5. Consumption of Herbicide Active Ingredient by Railroads in the United States by Brand, 2013.

Active ingredient	Brand name	Thousand lb a.i.	% of total
Glyphosate	Roundup®, Accord XRT II®, generic glyphosate products	615	33.0
Diuron	Karmex®, Krovar®, generic diuron products	420	22.5
2,4-D	2,4-D®, Escalade®	263	14.1
Bromacil	Krovar®, generic bromacil products	188	10.1
Sulfometuron methyl	Oust XP®, Oust Extra®, Throttle®, generic products	60	3.2
Picloram	Tordon®, generic picloram products	54	2.9
Dicamba	Overdrive®, Escalade®, generic dicamba products	46	2.5
Triclopyr	Garlon®, generic triclopyr products	44	2.4
Imazapyr	Arsenal®, generic imazapyr products	39	2.1
Flumioxazin	Payload®	34	1.8
Fluroxpyr	Escalade®, Vista®	30	1.6
Aminopyralid	Milestone®, Opensight®	27	1.4
Metsulfuron methyl	Escort, Opensight®, Oust Extra®, Spyder®	10	0.5
Prodiamine	Generic prodiamine	10	0.5
Sulfentrazone	Crossing®, Throttle®	7	0.4
All other-[a]	-	18	1.0
Total		1,865	100.0

[a]- Includes clopyralid, chlorsulfuron, and other.

Source: Kline and Company 2014 Global Industrial Vegetation Management Analysis and Opportunities.

Sales of 2,4-D for application to the electric and pipeline right-of-way vegetation management was 9,000 lbs ai or 0.2% of the total sales mass in 2013

Electricity moves from generation plants to substations along transmission lines and from substations to consumers along distribution lines. The Edison Electric Institute (2012) reported 641,011 pole miles of electric transmission in the US in 2012 (Table 9.2). This data does not include the miles of distribution that facilitates the movement of electricity from substations to consumers. Like highway rights-of-way, electric utility rights-of-way width varies depending on the number of lines, kilowatts transmitted, tower height, and adjacent vegetation. Similarly, the US Department of Transportation, Pipeline and Hazardous Materials Safety Administration (2014) reported 1.7 million miles of pipeline across the US (Table 9.2). Kline and Company (2014) combined herbicide sales data for electric utility and pipeline applications (Table 9.6).

Table 9.6. Consumption of Herbicide Active Ingredient by Electric Utilities and Pipelines in the United States by Brand, 2013.

Active ingredient	Brand name	Thousand lb a.i.	% of total
Glyphosate	Accord®, Roundup®, Rodeo®, generic glyphosate products	2251	51.4
Triclopyr	Garlon 3A®, Garlon 4®, Pathfinder®, generic triclopyr products	1289	29.4
Imazapyr	Arsenal®, Sahara®, Habitat®, Stalker®, Topsite®, generic imazapyr products	497	11.3
Fosamine	Krenite®	114	2.6
Aminopyralid	Milestone®	63	1.4
Picloram	Tordon®, Pathway®	38	0.9
Diuron	Krovar®, Topsite®, other diuron products	27	0.6
Sulfometuron methyl	Oust®, Landmark®, Oust Extra®	18	0.4
Imazapic	Panoramic®	17	0.4
Aminocyclopyrachlor	Streamline®	15	0.3
Clopyralid	Transline®, Cleanslate®	12	0.3
Norflurazon	Predict®	11	0.3
2,4-D	2,4-D products	9	0.2
Pendimethalin	Pendulum®	2	[a]
All other[-b]	-	16	0.4
Total		4379	100

[a]- Minor

[b]-Includes metsulfuron methyl, fluoxypyr, dicamba, bromacil, tebuthiuron, and others

Source = Kline and Company 2014 Global Industrial Vegetation Management Analysis and Opportunities

The primary advantage of 2,4-D applications as a component of integrated vegetation management on rights-of-way is selective control of broadleaf weeds combined with tolerance by a wide variety of annual and perennial grasses.

The primary advantage of 2,4-D applications as a component of integrated vegetation management on rights-of-way is selective control of broadleaf weeds combined with tolerance by a wide variety of annual and perennial grasses. For control of a broader spectrum of broadleaf weeds and improved control of woody vegetation, 2,4-D can be combined with a number of other herbicides. Tank mixtures and premixed blends of 2,4-D with various other herbicides have been used by land managers for half a century. While an outstanding and economical herbicide for vegetation management in these sites, 2,4-D is not a perfect herbicide. The primary disadvantage of 2,4-D – which good management practices have been required to mitigate – has been off-target movement. Symptoms of damage are often visible. The sensitivity of plants like tomato or grape, plus a host of agronomic crops, vegetables and landscape ornamentals, limits the utility of this

herbicide in many areas. The potential for off-target movement of 2,4-D from drift or volatility has resulted in some litigations. In Mississippi, the MDOT estimated the cost of mowing highway rights-of-way in 2012 was $44.58 per acre with agency equipment and labor compared to $33.21 per acre with contracted mowers[1]. While a few other herbicides also regulate the growth of turfgrass to reduce mowing, these can cause undesirable weed population shifts, increased prevalence of unwanted grasses such as broomsedge (Andropogon virginicus) (McCullough et al. 2015) or severely injure the preferred turfgrass (Johnson 1990; Grichar et al. 2008; Shinn and Thill 2004).

Based on the estimated retail price of $46.00 per 2.5 gallon container of 4 lb ai amine formulated product, the value of total rights-of-way sales in 2013 was $4,296,600

The market value of 2,4-D and other phenoxy herbicide sales for rights-of-way is an elusive figure to estimate. Sales of these herbicides for the roadside rights-of-way market is often direct to governmental agencies by sealed bid. Sales for applications to utility rights-of-way are often through contract applicators who supply and apply the herbicide mixture to control vegetation. Bid price quotes are often reflective of the volume of herbicide specified in the request for bids, product formulation (ester or amine), container size or miles of rights-of-way to treat. Prices are often reduced with larger total herbicide volume purchased. Larger containers, i.e., 30 gallon drums, are typically priced lower per unit active ingredient compared to small containers, such as 1 gallon or 2.5 gallon drums. Amine formulations are less costly compared to ester formulations. Contract applicators may discount the herbicide cost to secure treatment of a large right-of-way land area. Combined sales of 2,4-D on highway, railroad and utility rights-of-way, according to Kline and Company data for 2013 (Kline and Company 2014), totaled 924,000 lbs ai. Their data does not differentiate the percentage sold as ester compared to amine formulations. Based on the estimated retail price of $46.00 per 2.5 gallon container of 4 lb ai amine formulated product (Oktibbeha County Coop 2015), the value of total right-of-way sales in 2013 was $4,296,600. If half the total 2,4-D sold in 2013 was ester and half amine, based on a retail price of $59.00 per gallon 4 lb ai ester formulated product (Oktibbeha County Coop 2015), the market value would have been $4,874,100.

Despite the evidence that glyphosate is the most widely used herbicide for rights-of-way vegetation management, 2,4-D remains a vital active ingredient for these markets. In the US, only six weed species have been documented with resistance to 2,4-D, compared to 15 species with documented resistance to glyphosate (Heap 2015). The Weed Science Society

[1] Interview. Dave Thompson.

of America states the primary cause of herbicide resistance is repeated exposure of weed populations to herbicides with the same mode of action (WSSA 2015). While herbicide applications for integrated vegetation management on rights-of-way does not occur with the same frequency as applications in crop production systems, loss of this family of herbicides will remove active ingredients from this market that have been proven effective, economical, and safe longer than any other herbicide group. In addition, loss of the phenoxy herbicides will reduce the number of modes of action integrated vegetation managers can use, thus increasing the selection pressure that leads to herbicide resistance within other herbicide families. While the increased cost of herbicides other than 2,4-D for rights-of-way vegetation management can be calculated, the economic threshold for resistance development is more elusive as it is difficult to predict the frequency with which weed populations develop resistance.

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John D. Byrd, Jr. was raised on a small cotton and tobacco farm in South Carolina. He learned the importance of integrated weed control using a hoe as an adolescent and teen. He received a B.S. in Agronomy from Clemson University, M.S. and Ph.D. degrees in Weed Science from North Carolina State University. His real education began 25 years ago when he was hired as the Extension Weed Specialist for agronomic and horticultural crops and noncropland at Mississippi State University. His research efforts primarily focus on vegetation management on highway and utility rights-of-way, forage crops, and terrestrial exotic, invasive weeds of natural areas. He currently has 4 graduate students and has served on committees of 84 additional students.

He has more authored or co-authored 83 Extension publications, 186 abstracts, 29 refereed journal articles, right-of-way training modules for pesticide certification, WSSA's herbicide resistance training modules for noncrop and a book chapter. He has served as President of the National Roadside Vegetation Management Association and still serves on the Board of Directors. He has served on the Board of Directors for the Southern Weed Science Society. He is the Secretary of the Mississippi Vegetation Management Association. He is a member of the Weed Science Society of America and International Weed Science Society, National Association of County Agricultural Agents.