Regional Off-Target Movement of Auxin-Type Herbicides

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Abstract

Grape vineyards, especially in regions of mixed cereal and field crop production have historically been exposed to auxin-type herbicides, presumably from a combination of local spray drift and regional off-target movement. The combined efforts among affected grape and cereal grain commodity groups, regulatory agencies, and land grant university research has significantly reduced the severity and number of reported auxin-type herbicide injuries over the past fifty years. These efforts have lead to the banning of dust and volatile ester formulations, restricting the timing of low volatile ester formulations, and prohibiting applications when physical drift is likely. Unfortunately, episodic vine injuries from off-target herbicide movement remain severe and occasionally cause economic losses to the grape industry. Recent WSU air and vine injury monitoring programs further underscore the chronic nature of regional off-target movement of this class of herbicides to vineyards throughout the Columbia River and Walla Walla valleys. The auxin-type herbicides will remain important agrochemical tools for economically managing broadleaf weeds cereal grains and field crops. To minimize future injury to non-target sensitive crops, all stakeholders must continue to work together. Cooperation among commodity grower groups and policy harmonization among state agricultural departments in the Pacific Northwest should be encouraged. Meanwhile, applied field research should also continue to assist stakeholders in characterizing potential sources of local, regional, and long-range transport of chlorophenoxy herbicides and taking necessary steps to more effectively mitigate non-crop injury of these highly active herbicides.

Introduction

The National Coalition on Drift Minimization (NCDM) has defined "*Spray Drift*" as "the physical movement of pesticide droplets or particles through the air at the time of pesticide application or soon thereafter from the target site to any non- or off-target site." Also implicit in the NCDM definition is what spray drift is not (i.e., "drift shall not include movement of pesticides to non- or off-target sites caused by erosion, migration, volatility, or windblown soil particles that occurs after application."). The movement of these substances from the target site as aerosols, on/in soil wind-blown particulates, or in the gas-phase are unfortunately difficult to predict and therefore more difficult to apply consistent label language. For the remainder of this proceeding, I shall discuss the implications of regional *off-target movement* (i.e., *all transport processes other than physical drift)* of certain highly active broad-spectrum herbicides on non-target cropping systems in the U.S. Pacific Northwest (PNW).

Of particular interest in the PNW is the inadvertent off-target movement of the highly active hormone (auxin)-type chlorophenoxy, benzoic, and carboxylic acid herbicides. The auxin-type herbicides are among the most thoroughly investigated families of chemical compounds in the world with 2,4-D (2,4-dichlorophenoxybenzoic acid) receiving most of the investigative attention (Mullison, W. R. 1987). This group of acid herbicides act as potent plant auxins, rejuvenating old cells, overstimulating young cells, attenuating growth in girth, retarding apical development, and disrupting nutrient transport. Simply put, this herbicide class kills broadleaf plants by drastically interfering with their normal physiology and growth at extremely low exposure concentrations. Juice and wine grape vines are one of the more sensitive broadleaf plants for expressing auxin-type herbicide injury. There are approximately 28,000 acres and 11,000 acres in Washington State and Oregon, respectively, of juice and wine grape vineyards (OASS, 2002; WASS, 2001). In Washington State, Concord and wine grape vineyards have sustained severe auxin-type damage over the years. Yet use of these herbicides is carefully regulated, and the vineyard injury doesn't seem to correlate with local (adjacent field) use of these products. The remainder of this proceeding will focus on the history and impact of regional movement of auxin-type herbicides in the PNW to juice and wine grapes. In addition, I will discuss recent WSU air monitoring programs for aiding cereal grain and wine grape growers to better identify, understand, and help minimize regional off-target movement of these highly active herbicides to wine grape vineyards and susceptible native plant communities.

Background: Beginning in the early 1950's, purported off-target movement from 2,4-D aerial dust applications caused injury to various susceptible cropping systems and was severe enough to cause substantial production losses to juice grapes in Southeastern Washington (Appleby, A. P. 2000). Although subsequent use restrictions on aerial 2,4-D dust applications reduced the frequency of localized damage, drift problems continued to persist in the Pacific Northwest. Altered formulations (volatile isopropyl, butyl and lower-volatile butoxyethyl and isooctyl ester formulations and non-volatile 2,4-D salts) reduced local spray drift problems, but may have contributed to a different injury pattern. Where local spray drift tended to result in intense damage at the field edge that lessened along the wind gradient, more uniform vineyard injury was becoming more evident, thus suggesting regional or general air mass contamination (Robinson, E. and L. L. Fox. 1978). From the early 1970s through 1980, a team of atmospheric scientists from the Air Pollution Research Section of Washington State University (WSU) tried to find an explanation for this generalized air mass auxin-like injury pattern (Pack, M. R. and E. Robinson. 1981; Reisinger and Robinson 1976; Robinson and Fox 1978; Farwell et al., 1976). This team gathered data on pesticide use, meteorological conditions, vineyard injury, and airborne 2,4-D concentrations across a principal wind trajectory in wheat- and grape-growing districts of central Washington. This extensive field and laboratory research effort did not show correlation between local pesticide use and grape injury. Instead, a relationship seemed to exist between plant injury, increased airborne 2,4-D concentrations, and weak prefrontal activity (i.e., a meteorological condition characterized in this region by mid-level cloudiness and light southerly surface winds) from regional nonpoint sources estimated to be as far as 10 to 50 miles away.

Based on the above combined WSU air monitoring results, it was hypothesized that trans-state movement of high volatility 2,4-D esters were emanating from Northeastern Oregon directionally towards Southeastern Washington State (Reisinger and Robinson 1976; Robinson and Fox 1978). These WSU researchers observed that vine injury in the Columbia River Valley coincided when registered applications of 2,4-D volatile esters were conducted in central eastern Oregon. Although claims of directional transport from Oregon to Washington State have been contested, Oregon regulatory authorities have eliminated the use of volatile 2,4-D ester formulations in favor of the lesser volatile ester and salt formulations.

From the early to late 1980s, auxin-like injury problems attracted little investigative attention although it might be incorrect to conclude that injury to grape vineyards was not occurring. Banning the use of volatile 2,4-D esters and placing restrictions on the timing of low volatility ester formulations in Washington State were no doubt effective in minimizing off-target herbicide movement. Aerial applications of lower volatility phenoxy-acid esters, however, could still be used in Oregon well after the imposed springtime ester cutoff date in Washington State. Reports of auxin-type herbicide damage to grapes began resurfacing in 1988, with a greater number of WSDA investigative reports appearing from 1997 to the present. Much of the notable 2,4-D grape damage symptoms were reported along the Columbia River corridor in the area of newly established vineyards from the Alder Canyon area eastward into the Walla Walla Valley in central Washington. In their 1992 to 1994 sentinel plant research, Felsot et al. (1996) observed that the Columbia River Valley grape-growing region remained a major "hot-spot" for phenoxy-type plant injury to both grape vineyards and native vegetation. Washington State Department of Agriculture case studies also chronicled the recent and sporadic occurrences of auxin-like symptoms in areas of the Columbia and Walla Walla Valley grape growing regions. During the 2000 and 2001 growing seasons in south central Washington, wine grape injury was extensive and severe enough to adversely affect production in vineyards in this region. From just one vineyard in this area in May and June of 2000, reduction in yield allegedly from phenoxy-like symptoms was estimated to have reduced revenues by $290,000 (WSDA, 2000). Other vineyards in the Columbia River Valley have also expressed strong auxin-type herbicide symptoms from Lyle up river to the Wallula Gap and eastward into the Walla Walla Valley (WSDA, 2000).

Thus far, state agencies in Washington State and Oregon have not been able to pinpoint the source(s) contributing to auxin-type injury in specific vineyards. Many wine grape growers are of the opinion that sources remain regional in nature and may be emanating southerly from cereal and grain crops grown along the Oregon-Washington Columbia River and Walla Walla Valley border northward.

Methods

Over a 3-year 2001-2003 time span research/monitoring efforts presented herein were designed to assist in differentiating among possible local, regional or general nonpoint sources of auxin-type herbicide residues to wine grape vineyards in the Columbia River-Walla Walla Valley corridor. Field monitoring was conducted from April and continued until late June to coincide with grape vine susceptibility to possible 2,4-D off-target injury. Research conducted in 2001 intensively focused on characterizing sources of possible auxin-type herbicide movement into the Alder Ridge/Paterson wine grape producing areas in Benton-Klickitat Counties, southeastern WA. Cuttings from a local wine grape rootstock served as sentinel bioassays and were placed then removed at each vineyard on a weekly basis for observing auxin-like symptomology. Additionally, three vines from each of the Washington vineyard locations were visually inspected to assess auxin-like injury on a weekly basis. We also collected dry/wet deposition sample trays at weekly intervals. At the four air-monitoring locations, we also attempted to differentiate between ester versus free-acid aerial transport by collecting air in two-stage Thermo Anderson® high-volume air samplers (model PS-1) operated over a 24 hour air-sampling period two times per week.

Year 2003 monitoring efforts in the Walla-Walla-Milton Freewater grape-growing region similarly focused on air and depositional monitoring. However, due to constraints in acquiring sentinel root stock cuttings, only visual assessments from six vineyard locations were conducted. During this monitoring year, we also developed a plant severity index system to aid in determining if vine injury could be reasonably associated with measured air and deposition herbicide concentrations. The EPA 8151A analytical method for quantifying acid herbicide residues was modified by the WSU Food and Environmental Quality Laboratory to measure trace-level 2,4-D esters and acids from wet/dry deposition and air samplers using gas chromatography (GC) with electron capture detection (ECD) and/or mass selective (MS) detection.

Results

2001 Columbia River Valley Monitoring: During the months from April through late June, we generally observed slight auxin-type herbicide injury (i.e., bumpy features, slight shortening of lobes and sinus, and deformation of leaf margins) in seven of our eight test vineyards. Severe auxin-like symptomology (i.e., stunted, grossly deformed leaf showing vein clearing and veination) was observed at one vineyard starting in mid-May. This vineyard injury was severe enough to reduce grape production by over fifty percent. To the best of the grower's knowledge, there were no auxin-type herbicide applications being conducted near the vineyard in early to mid-May. However, over this two-week span in early May 2001, quantifiable residues were detected at two air-monitoring stations and at the wet/dry deposition tray positioned within the affected vineyard. Unfortunately, an air-sampling unit was not positioned at this affected vineyard. Overall, the 2001 residue data suggest a general air-mass contamination, but too few data points were generated to substantiate this observation. Results at sites with detectable 2,4-D residues corresponded to our general observations of mild broad-leaf injury. Trace 2,4-D residues ($< 0.001\ \mu g/m^3$) were detected on ca. 35% of air sample particulate filters. Trace 2,4-D residues were detected on 22% of deposition samples. 2,4-D was the only auxin-type herbicide identified.

2003 Walla Walla Valley Monitoring: Table 1 presents the 2003 2,4-D residue monitoring data. Again, there was generally minor auxin-type symptomology expressed in all test vineyards, with one notable vineyard exception. Overall, visual assessments from 5 of the 6 vineyards were in agreement with the general observation of chronic but very low ambient 2,4-D residues in air and deposition samples. A light rain event occurred in mid-May resulting in very high wet deposition 2,4-D concentrations (i.e., > 2 ppm, see Table 1) at one of the vineyard locations. After this rain event, severe auxin-type injury became evident in this vineyard affecting bloom and reducing grape production by approximately 50% (personal communication with the vineyard manager). This particular herbicide injury incident may more likely be due to local and not regional transport since the high wet deposition concentrations also coincided with a 2,4-D application in close proximity to the vineyard.

Conclusions and Impacts

Grape vineyards, especially in regions of mixed cereal and minor crop production, have historically been exposed to auxin-type herbicides, presumably from a combination of local and regional transport. Banning dust and volatile ester formulations, restricting the timing of low volatile ester formulations, and prohibiting applications when drift is likely have all helped to minimize the damage to grapes. Unfortunately, episodic injury remains severe enough to cause economic losses to the grape industry. Our recent two years of field monitoring of 2,4-D residues supports the above assertion The movement of these highly active substances from the target site as aerosols, on/in soil wind-blown particulates, or in the gas-phase are unfortunately difficult to predict and therefore more difficult to apply consistent label language. Moreover, post-application processes are beyond the direct control or influence of pesticide applicators. Because of the high potency, mitigating injury from the use of auxin-type herbicides to sensitive crops upwind will remain difficult.

The auxin-type herbicides will remain important agrochemical tools for managing broadleaf weeds in cereal grains and field crops. However, there seems to be no silver bullet for preventing off-target injury short of eliminating their use. To minimize future off-target injury to sensitive crops, all stakeholders must continue to work together. Recent efforts by Oregon State Extension in forming the Walla Walla Valley-based Drift Task Force have given all stakeholders (i.e., spray applicators, cereal grain/wine grape growers, state agency representatives) an opportunity to better understand regional herbicide transport. Continued cooperation among commodity grower groups and consistent policies for ester cut-off dates among state agricultural departments in the Pacific Northwest should be encouraged. Meanwhile, the land grant universities must continue and expand research to better characterize potential sources of local, regional, and long-range movement of these potent and economically valuable herbicides.

Table 1: 2003 Walla Walla Valley 2,4-D Air and Wet/Dry Deposition Residue Results

Method Percent Recoveries

	Dry Deposition	Wet Deposition	Particulate Filters	Polyurethane Foam
2,4-D	80.8 ± 20.5	80 ± 6.6	80.1 ± 13.9	70.1 ± 16.3
	n = 11	n = 2	n = 23	n = 22

n = total number of fortified samples evaluated

Air Monitoring
Number of Detections and Maximum Residues

	Particulate Filter		Polyurethane Foam	
	Detections	Maximum Residue	Detections	Maximum Residue
Site 1	20 of 22	0.0436 μg/m^3	13 of 22	0.0047 μg/m^3
Site 2	16 of 21	0.0085 μg/m^3	5 of 21	*Trace
Site 3	16 of 21	0.0087 μg/m^3	9 of 21	*Trace
Site 4	20 of 23	0.0029 μg/m^3	13 of 23	*Trace
Site 5	17 of 22	0.0072 μg/m^3	11 of 22	*Trace
Site 6	17 of 22	0.0076 μg/m^3	14 of 22	*Trace

*Trace is a non-quantifiable concentration greater than LOD (0.001 μg/m^3) but less than the LOQ (0.004 μg/m$^{3)}$

Deposition Monitoring
Number of Detections and Maximum Residues

	Dry Deposition Monitoring		Wet Deposition Monitoring	
	Detections	Maximum Residue	Detections	Maximum Residue
Site 1	8 of 11	4.51 ηg/cm^2	3 of 4	2.33 mg/L
Site 2	5 of 10	1.71 ηg/cm^2	1 of 4	*Trace
Site 3	6 of 10	2.87 ηg/cm^2	1 of 2	0.03 mg/L
Site 4	5 of 10	0.89 ηg/cm^2	None Detected	
Site 5	5 of 11	4.31 ηg/cm^2	None Detected	
Site 6	7 of 11	1.45 ηg/cm^2	None Detected	

*Trace is a non-quantifiable concentration greater than LOD (Dry - 0.12 ηg/cm^2, Wet - 0.25 μg/mL) but less than the LOQ (Dry - 0.48 ηg/cm^2, Wet - 1.0 ug/mL)

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