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Herbicide Spray Drift

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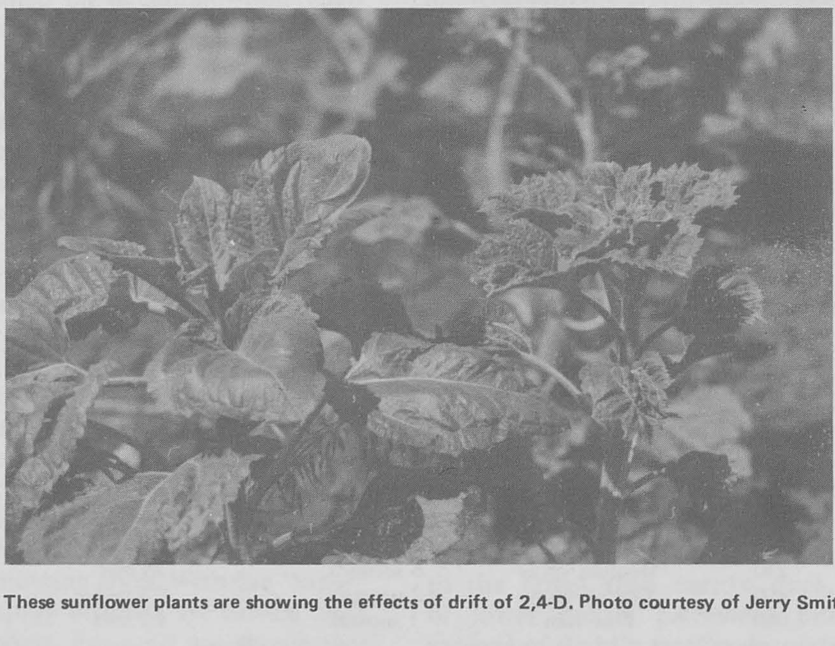
Herbicide spray drift is the movement of herbicide spray mixture or herbicide vapors from the target area to areas where herbicide application was not intended. While the number of acres damaged and the economic loss from spray drift annually in Minnesota is not large, individuals who are affected can suffer substantial losses.

Herbicide spray drift in high concentrations may injure susceptible crops and could cause prohibited residues in the harvested crops. Spray drift can also damage shelterbelts, gardens and ornamentals, cause water pollution and damage non-susceptible crops in a vulnerable growth stage (2,4-D drift on wheat in the flowering or seedling stage, for example). Drift can also cause non-uniform application in a field, risking crop damage and/or poor weed control.

Even though only a small portion of the applied herbicide drifts, some non-target areas can receive rather high doses. Herbicide drift can accumulate on the downwind side of a field, in a shelterbelt at the edge of a field, or in a portion of an adjacent field. In some cases, herbicide accumulated in downwind areas can exceed the rate applied to the field, with a small portion of each pass of the sprayer drifting to the non-target area. Shelterbelts are particularly susceptible to this problem because the trees intercept the drift.



These sunflower plants are showing the effects of drift of 2,4-D. Photo courtesy of Jerry Smith.

FACTORS AFFECTING SPRAY DRIFT

Spray particle size: Smaller spray droplets fall slower than larger droplets, so they drift farther and more easily (Table 1). Very small droplets—called "fines"—drift quite easily. One common objective of most drift control techniques is to eliminate these "fine" spray particles.

Methods of application: Herbicides are applied by airplane, helicopter, ground sprayer or mist blower applicators. Low pressure ground sprayers are commonly used for herbicide application and are normally operated at 30 to 50 pounds per square inch with 5 to 20 gallons of water per acre.

Herbicide spray drift is greater from mist blower and aerial application than from ground application when applied under similar environmental conditions (4). Ground sprayers generally produce larger spray droplets which are released from the nozzle closer to the target.

Nozzle height controls the distance a droplet must fall before reaching the crop. Less distance means less travel time and less drift. Wind velocity is often greater as height above the ground increases (2), so droplets from nozzles close to the ground would be exposed to lower wind speeds.

Herbicide volatility: All herbicides can drift in spray droplets, but some herbicides, depending on formulation and relative volatility, can also drift as a vapor (gas). For example, 2,4-D or MCPA esters are volatile and can drift as droplets or vapors, while 2,4-D or MCPA amines are essentially non-volatile and can drift only as droplets.

Vapor drift occurs when a volatile herbicide changes from solid or liquid into the gaseous state and moves from the target area. Herbicide vapor drifts farther and over a longer time than spray droplets. A wind blowing away from a susceptible crop during application will prevent damage from droplet drift, but a later wind shift could move damaging vapors into the field. Research has shown that 3 to 4 percent of both 2,4-D amine and ester drifted as an aerial cloud, but an additional 25 to 30 percent of the ester drifted as vapor in the first 30 minutes after spraying (5).

Relative humidity and temperature: Low relative humidity and/or high temperature will cause more rapid evaporation of spray droplets between the sprayer and the target than will high relative humidity and/or low temperature. Evaporation reduces droplet size, which in turn increases the potential drift of spray droplets (illustrated in Table 1). The influence of temperature and relative humidity on drift of small spray droplets is probably minor.

Temperature also influences the volatility of herbicides. Research information (6) shows the vapor formation from a high volatile ester of 2,4-D would approximately triple with a temperature increase of from 60 to 80 degrees F. At 80 degrees, the vapor formation from the high volatile ester would be about 24 times greater than the vapor formation from a low volatile ester of 2,4-D.

An experiment (4) to test the vapor damage to tomato plants from various formulations of 2,4-D at different temperatures showed vapors from high volatile esters caused injury to plants at all temperatures. The low volatile esters did not damage plants at 70 to 75 degrees but did at temperatures of 90 and 120 degrees. Even though low volatile esters of 2,4-D are much less volatile, vapor drift from low volatile esters could still cause damage to susceptible plants. The amine formulation was essentially non-volatile, as no damage-causing vapor was produced even at high temperatures (Table 2).

These results indicate that a low volatile ester would begin to release damaging vapors at a temperature between 75 and 90 degrees. However, soil surface temperatures are often much warmer than air temperatures, especially on a sunny day, so vapor drift from low volatile esters may still occur at air temperatures lower than 75 degrees.

Table 1. Influence of Droplet Size on Potential Distance of Drift

Droplet diameter (microns)	Type of droplet	Time required to fall 10 feet	Lateral distance droplets travel in falling 10 feet in a 3 mph wind
5	Fog	66 minutes	3 miles
20	Very fine spray	4.2 minutes	1,100 feet
100	Fine spray	10 seconds	44 feet
240	Medium spray	6 seconds	28 feet
400	Coarse spray	2 seconds	8.5 feet
1,000	Fine rain	1 second	4.7 feet

Source: Klingman (7), Potts (9) and Akesson and Yates (1)

Table 2. Relative Damage to Tomatoes from Vapors Released from 2,4-D Formulations Held at Three Temperatures

(Ratings taken 24 hours after exposure, with 1 = no effect and 6 = severe damage.)

	Temperature of 2,4-D formulation					
	70-75 F		90 F		120 F	
	Hours of exposure					
2,4-D formulation	**2**	**16**	**2**	**16**	**2**	**16**
Butyl ester (high volatile)	3.5	6.0	5.8	6.0	6.0	6.0
Butoxyethanol ester (low volatile)	1.0	1.0	2.3	5.7	5.5	6.0
Dimethylamine (non-volatile)	1.0	1.0	1.0	1.0	1.1	1.2

Source: Baskin and Walker (3)

Wind direction: Herbicide should not be applied when the wind is blowing toward an adjoining susceptible crop or a crop in a vulnerable stage of growth. Wait until the wind blows away from the susceptible crop or, if weed problems are minor, don't spray at all. If herbicide must be applied while the wind is blowing toward a susceptible crop, use all possible drift control techniques, including, perhaps, using a ground sprayer rather than an airplane.

Wind velocity: The amount of herbicide lost from the target area and the distance it moves both increase as wind velocity picks up, so increased wind velocity will generally cause more drift. However, severe drift injury can occur with low wind velocities, especially under temperature inversion situations.

Air stability: Air movement largely determines the distribution of spray droplets. Lateral air movement (wind) is generally recognized as an important factor, but vertical air movement is often overlooked. In the normal "lapse" situation, air temperature decreases 3.2 degrees F. for each 1,000 feet of altitude. Cool air tends to sink, displacing lower warm air and causing vertical mixing. If the "lapse" condition is greater than normal–greater than a 3.2-degree decrease per 1,000 feet–vertical mixing will be greater.

Another possibility is temperature inversion, where cool air is near the surface under a layer of warm air. Under inversion conditions, little vertical mixing of air occurs, even with a wind. Spray drift is most severe under inversion conditions since small spray droplets will fall slowly and will also move with any wind into adjoining areas. With the "lapse" condition the small spray droplets are carried aloft where they are dispersed. Research has shown that three times more spray drifted 100-200 feet and 10 times more drifted 1,000-2,000 feet under inversion conditions as compared to "lapse" conditions with a given weed speed.

Spray drift may occur even with relatively calm conditions under an inversion, especially with small droplets. Some of the most severe drift problems have occurred with low wind velocities, inversion conditions and small spray droplets. Spray drift under inversion conditions could be reduced by increasing droplet size by using large orifice nozzles and/or lower spray pressures.

Avoid applying herbicides near susceptible crops during temperature inversion conditions. Inversions can often be identified by observing smoke from a smoke bomb or fire. Smoke moving horizontally close to the ground would indicate a temperature inversion.

Spray pressure: Spray pressure influences the formation of droplets from the spray solution. The spray solution emerges from the nozzle in a thin sheet, and droplets form at the edge of the sheet. Higher nozzle pressure causes the sheet to be thinner, and this thinner sheet breaks up into smaller droplets. Larger orifice nozzles with higher delivery rates produce larger droplets than smaller nozzles.

Nozzle spray angle: Spray angle is the angle formed between the edges of the spray pattern from a single nozzle. Nozzles with wider spray angles will produce a thinner sheet of spray solution–and smaller spray droplets–than a nozzle with the same delivery rate but narrower spray angle. However, wide angle nozzles are placed closer to the target than narrow ones, and the benefits of lower nozzle placement outweigh the disadvantage of slightly smaller droplets.

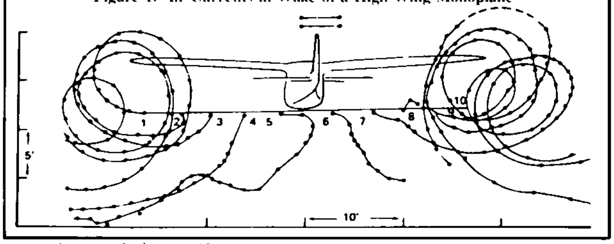
Spray angle relative to direction of travel can also influence drift—especially with aerial applications. Because of greater wind sheering when the nozzles are pointed into the wind, nozzles pointed toward the direction of travel will produce smaller droplets than nozzles pointed back. The smallest droplets are produced from nozzles 45 degrees forward of vertical, with the largest produced by a straight-back (90 degree) orientation.

Nozzle type: Nozzle types vary in droplet sizes produced at various spray pressures and gallons per minute output (Table 3). "Flat fan," "flood" and "hollow cone" nozzles produce similar-sized droplets and a similar volume of small droplets. The flood nozzle tends to produce slightly larger droplets than the flat fan, while the flat fan produces slightly larger droplets than the hollow cone.

Two types of Raindrop nozzles have been developed for drift control. The type "RA" is a whirl chamber nozzle with a secondary swirl chamber attached. The type "RD" is a disc-core nozzle with a secondary swirl chamber attached. Compared with the other nozzle types listed in Table 3, the Raindrop nozzles produce the largest droplets and also the lowest volume of small droplets.

Air movement around aircraft: "Vortices" are irregular drafts of air around the fixed wing of airplanes or the rotary blades of helicopters. Updrafts are produced by the fixed wing or rotor tip, while downdrafts are produced by the body of the aircraft. The vortices move spray particles aloft with updrafts and down into the target area with downdrafts (Figure 1). Strength of the vortices is related to the weight and airspeed of a given aircraft. Increased airspeed and increased weight boost the strength of the vortices, raising the chances of potential drift.

Figure 1. Air Currents in Wake of a High Wing Monoplane



Source: Yates and Akesson 12

A spray boom which covers no more than three-fourths of the distance from the center of the aircraft to the end of the wing or rotor tip will limit the spray released into the updrafts and reduce potential drift (11). Lowering the spray boom

Table 3. Influence of Nozzle Type and Spray Pressure on Droplet Size

Nozzle type	Delivery rates (gal./min.)	Spray pressure (lbs./sq. in.)	Spray angle (degrees)	Volume median diameter (microns)	Volume with less than 100 micron dia. (per cent)
Flat fan	0.12	15	65	239	
(LF-2)	0.17	30	76	194	
	0.20	40	80	178	17.5
Flood	0.12	15	90	289	
(D-1)	0.17	30	115	210	
	0.20	40	125	185	15.5
Hollow cone	0.12	15		228	
(HC-12)	0.17	30		185	
	0.20	40	70	170	19.0
Whirl chamber	0.12	15		195	
(WRW-2)	0.17	30		158	
	0.20	40	120	145	23.0
Raindrop	0.12	15		539	
(RA-2)	0.17	30		381	
	0.20	40	120	330	1.0
Raindrop	0.11	15		506	
(RD-1)	0.16	30		358	
	0.18	40	90	310	0.8

Source: Delavan Manufacturing Company

a foot or more below the wing of fixed-wing aircraft or moving the boom as far forward as possible on helicopters also reduces the exposure of spray droplets to vortices.

Proper spacing of nozzles to reduce drift and achieve uniform application varies with the type of airplane. Nozzles should generally be closer together near the end of the boom, with three- and four-foot gaps on the left of center and three or four nozzles grouped to the right of center. Air drawn by the propeller will spread the spray from the clustered nozzles into the area lacking nozzles, forming a uniform pattern. Spray distribution should be regularly tested, with the nozzle spacing adjusted to produce a uniform spray pattern if necessary.

A summary of the influences of various factors on spray drift is given in Table 4.

REDUCING DRIFT POTENTIAL

Ways of reducing potential drift from aerial application include: (1) flying as low as possible; (2) locating nozzles away from wing or rotor tips; (3) placing the spray boom well below the wing of airplanes or as far forward as possible on helicopters; (4) orienting nozzles backward; and (5) spacing nozzles to produce a uniform pattern.

Spray drift in general can be reduced by: (1) avoiding spraying when drift-promoting environmental conditions exist; (2) using herbicides which do not produce damaging vapors; and (3) using spray techniques and equipment which produce large droplets that are released close to the target.

Large spray droplets can be produced in several ways. Increasing nozzle orifice size and lowering spray pressure will each increase average droplet size. Change nozzles to increase volume per acre rather than raising spray pressure or reducing travel speed. Increasing pressure boosts the percentage of small droplets, or fines, that are more likely to drift.

The Raindrop nozzle and the LP (low pressure) nozzle were developed to increase droplet size and reduce fines. These nozzles can be used on conventional spray equipment and will reduce drift potential.

Spray drift can also be reduced by modifying the spray solution. An invert emulsion spray system applies the herbicide in a "mayonnaise-like" material. The equipment required to produce an invert emulsion is of special design and not easily adapted to many agricultural uses.

"Nalco-Trol" is an additive which causes the spray solution to become more viscous, causing larger spray droplets. Nalco-Trol is for use in conventional spray equipment. The amount to add to the spray tank is critical. Too little will not control drift and too much will cause the spray pattern to collapse. Follow directions on the container.

There are several mechanical methods of producing uniform droplets but none has been widely adapted for agricultural uses. Future developments may produce a practical and adaptable method of applying herbicides without drift.

Drift control techniques which produce large droplets can reduce the effectiveness of any herbicides that require good coverage and small droplets to be effective. Barban (Carbyne) is an example of a herbicide requiring small droplets and should not be applied using drift control nozzles or additives that produce large droplets. Herbicides most

Table 4. Summary of Influences of Various Factors on Spray Drift

Factor	More drift	Less drift
Spray particle size	smaller	larger
Release height	higher	lower
Wind speed	higher	lower
Spray pressure	higher	lower
Nozzle size	smaller	larger
Nozzle orientation (aircraft)	forward	backward
Nozzle location (aircraft)	beyond ¾ wing span	¾ or less wing span
Air temperature	higher	lower
Relative humidity	lower	higher
Nozzle type	produce smaller droplets	produce larger droplets
Air stability	inversion	lapse
Herbicide volatility	volatile	non-volatile

likely to cause drift injury to broadleaf crops are 2,4-D, MCPA, dicamba (Banvel or Mon-Dak) and picloram (Tordon). Weed control from these herbicides is not reduced by application in large droplets if an adequate volume of water is used.

INFLUENCE OF 2,4-D DRIFT

Sugarbeets and sunflower were treated at various growth stages with several rates of 2,4-D at North Dakota State University to simulate herbicide drift. The yield losses caused by the treatments and the relative level of injury are given in Tables 5 and 6.

Sugarbeets and sunflower generally became more susceptible to 2,4-D as they grew larger. Rates of 2,4-D which did not significantly reduce yield caused abnormal-appearing leaves and stunted plants, showing that the presence of 2,4-D injury symptoms did not necessarily indicate a yield loss. The level of yield loss increased as the percentage of injured sugarbeet leaves or the percent sunflower height reduction increased.

The data in Table 6 show that a slight but not significant yield increase occurred with application of low rates of 2,4-D to sunflower. Varying environmental conditions change sunflower response to 2,4-D, and 2,4-D should not be applied to sunflower to try to increase yields.

Crop yield loss from 2,4-D drift is very difficult to assess from visual observation. Generally, yields should be taken from the damaged portion of a field and compared to yields from an undamaged portion to determine yield loss from drift damage.

The fact that yields can vary within a field should always be kept in mind when making comparisons. Comparisons between fields or between years are usually unreliable and should only be used as a last resort.

Table 5. Extractable Sugar and Per Cent Injured Leaves Ten Days After Application of Sugarbeets Treated with 2,4-D at Three Growth Stages in 1974

	Growth stage at application					
	6- to 8-leaf		12- to 14-leaf		20- to 22-leaf	
2,4-D rate (oz/A)	Extractable sugar (lb/A)	Injured leaves (%)	Extractable sugar (lb/A)	Injured leaves (%)	Extractable sugar (lb/A)	Injured leaves (%)
0.0	4120	0	4120	0	4120	0
0.5	4040	11	3520	23	3080	47
1.0	4040	10	3220	41	3080	59
1.5	3960	23	3280	62	2600	77
2.0	2680	39	2400	66	2760	75
3.0	3100	51	2220	78	1900	90
4.0	2440	64	2100	91	1560	100
5.0	1720	81	1000	94	1680	99
LSD (.05)	640	12	640	12	640	12

Table 6. Yield and Per Cent Height Reduction of Sunflower Treated with 2,4-D at Two Growth Stages in 1973

	Growth stage at application			
	6- to 8-leaf		12- to 14-leaf	
2,4-D rate (oz/A)	Seed yield (lb/A)	Height reduction* (%)	Seed yield (lb/A)	Height reduction* (%)
0.0	1237	0*	1237	0*
0.125	1256	9	1359	12
0.25	1348	3	1198	3
0.5	1339	5	1179	3
1.0	1319	5	928	12
1.5	1551	10	682	20
2.0	974	19	426	30
4.0	556	41	136	65
LSD(.05)	363	11	363	11

**Heights were measured 30 and 20 days after treatment at the 6- to 8-leaf and 12- to 14-leaf growth stages, respectively.*

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