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Effect of Major Variables on Drift Distances of Spray Droplets

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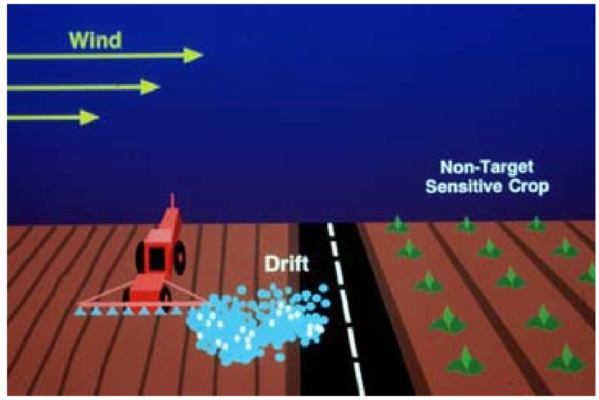
Pesticide applications are required to ensure an adequate and high quality supply of many agricultural crops. Due to concerns for production costs, safety, and the environment, it is important to maximize the pesticide deposit on the target. One of the major problems challenging pesticide applicators is spray drift, which is defined as movement of pesticides by wind from the application site to an off-target site.

Spray drift occurs wherever liquid sprays are applied. Although complete elimination of spray drift is impossible, problems can be reduced significantly if the pesticide applicator is aware of major factors which influence drift, and takes precautions to minimize their influence on off-target movement of droplets.

Drift is influenced by many factors that usually may be grouped into one of the following categories: 1) Spray characteristics, 2) Equipment and application techniques used, 3) Weather, and 4) Operator care and skill. A general discussion of these factors can be found in another publication by Ozkan (1991). In this publication, you will find specific information on how much influence some of these major factors have on the drift distances of spray droplets.

The factors that significantly influence off-target movement of droplets are wind velocity and direction, droplet size and density, and distance from the atomizer to the target. Other factors that influence drift include droplet velocity and direction of discharge from the atomizer, volatility of the spray fluid, relative humidity, ambient temperature, and atmospheric turbulence intensity. Many scientists have conducted field tests to study influence of these variables on spray drift. Unfortunately, field tests have the limitation that weather conditions cannot be controlled and the variables that influence spray drift may interact and vary during a test. Computer simulations can allow determination of the effects of different values of variables such as droplet size and velocity, relative humidity, and wind velocity on spray drift. One such computer model was developed by Reichard et al. (1992a) in Ohio for modeling the effects of several variables on spray drift. Using the computer program, individual or mean droplet trajectories were determined for different values of several variables listed above. Experiments were also conducted to verify the accuracy of the computer model in predicting drift distances of water droplets in a wind tunnel. These tests revealed that the computer model can be used to accurately calculate spray drift distances for a wide range of spray droplet sizes and wind velocities (Reichard et. al., 1992b).

The major drift factors included in this publication are droplet size, wind velocity, relative humidity, ambient temperature, droplet discharge height, and initial droplet velocity. Although turbulence intensity is a major factor which influence drift, data related to this variable was not included in this publication because it is not something pesticide applicators can assess easily, and its magnitude can vary rapidly unlike the changes in other atmospheric conditions such as relative humidity and temperature. The affect of turbulence intensity on drift distances of droplets is discussed in the publication by Reichard et. al. (1992a). A turbulence intensity of 20% was assumed for all the computer simulation results reported in this publication,.



Spray drift is the reason for the discoloration of part of the wheat crop shown in this photograph. The size of the area affected by drift and its severity depend on how adverse the weather conditions are and poor decisions made by the operator of the sprayer.

Although the accuracy of the drift data produced by computer simulation has been validated, one has to be cautious when drawing conclusions from the data presented in this publication. Due to the many variables that influence spray drift, it is extremely difficult to precisely predict drift distances of droplets for field conditions. Some of the variables that affect drift distances, such as wind turbulence, velocity and direction can vary considerably while a droplet is drifting. It is common for terrain and vegetation (size and density) to vary over the path of a drifting droplet and these influence local wind velocity and direction. The drift distance data presented in this publication are only valid for the constant conditions specified. The data presented are useful in comparing the relative effects of several factors on drift distances, but are not intended to precisely model variable field conditions.

Droplet Size, Wind Velocity and Relative Humidity

Droplet size and wind velocity are the two most influential factors affecting drift. Relative humidity influences the evaporation rate of a droplet and hence its size, flight time, velocity and drift distance. Table 1 and Figure 1 show the simulated mean drift distances for various sizes of water droplets (50-200 micron diameter), wind velocities (2-8 mph), relative humidities (20-80%), and 75 degrees F ambient temperature. (Additional data are included in Tables in the publication by Zhu et al., 1994). Unless otherwise indicated, all simulated drift distances discussed in this publication are for droplets discharged downward with 65 ft/second (45 mph) velocity toward a target 18 inches below the point of discharge.

Table 1. Effect of wind velocity and relative humidity on drift distances of droplets directed downward with initial velocity of 65 ft/second toward target 18 inches below discharge point.
(Temperature = 75 degrees F; turbulence intensity = 20%)

Initial droplet size (microns)	Wind velocity (mph)	20	40	60	80
20	2	3.03*	3.72*	6.41*	15.29*
20	4	6.00*	6.47*	10.24*	21.45*
20	6	6.57*	7.66*	11.87*	23.23*
20	8	7.96*	8.97*	13.29*	26.42*
20	10	8.99*	10.58*	15.06*	30.10*
50	2	10.70*	12.10	17.20*	25.30*
50	4	18.70*	21.00*	28.80*	41.70*
50	6	26.50*	30.00*	40.00*	55.60*
50	8	34.30*	38.20*	50.90*	69.00*
50	10	37.60*	42.00*	55.32*	87.24*
100	2	3.44	3.41	3.37	3.30
100	4	6.87	6.81	6.71	6.58
100	6	10.30	10.20	10.05	9.85
100	8	13.72	13.61	13.39	13.14
100	10	17.94	17.77	17.48	17.05

150	2	0.92	0.92	0.92	0.91
150	4	1.83	1.82	1.82	1.82
150	6	2.74	2.74	2.73	2.71
150	8	3.67	3.66	3.62	3.60
150	10	4.78	4.78	4.75	4.77
200	2	0.20	0.20	0.20	0.20
200	4	0.38	0.38	0.38	0.38
200	6	0.55	0.55	0.55	0.55
200	8	0.75	0.75	0.75	0.75
200	10	0.96	0.96	0.96	0.96
300	2	0.05	0.05	0.05	0.05
300	4	0.10	0.10	0.10	0.10
300	6	0.15	0.15	0.15	0.15
300	8	0.21	0.21	0.21	0.21
300	10	0.26	0.26	0.26	0.26
* Droplet completely evaporated before deposition.					

Water droplets with 50 micron diameter and smaller are highly susceptible to drift. All droplets 50 micron diameter and smaller completely evaporated before they reached 18 inches below point of discharge for wind velocities between 2.0 and 10.0 mph and relative humidities (RH) between 20 and 80% (Table 1). The mean drift distances of small droplets increased rapidly with increased wind velocity. For example, with 60% RH, 50 micron diameter droplets were displaced 17.2, 28.8, 40.0, 50.9, and 55.3 ft before they completely evaporated when wind velocities were 2, 4, 6, 8, and 10 mph, respectively.

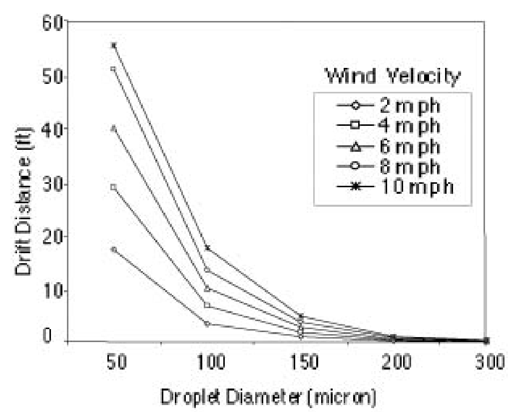


Figure 1. Effect of droplet diameter and wind velocity on drift distances of water droplets directed downward at 65 ft/second toward a target 18 inches below disharge point (Temperature = 75 degrees F; Relative Humidity = 60%).

The mean drift distances of 50 micron diameter water droplets and smaller increased with increased relative humidity because high relative humidity increased the lifetimes of the volatile droplets. Although both evaporated completely before deposition, the mean drift distances of 50 micron diameter droplets were greater than for 20 micron diameter droplets with the same relative humidity and wind velocity. This occurs because 50 micron diameter droplets have 15.6 times more volume and hence longer life than 20 micron diameter droplets. With 10 mph wind velocity and 60% RH, 20 and 50 micron diameter droplets drifted 15.1 and 55.3 ft downwind from the discharge point, respectively.

Most nozzles used for applying pesticides produce a large portion of the spray volume in 100 micron diameter droplets and larger. For example, our measurements of spray droplets from an XR 8002 VS nozzle (Spraying Systems Co., Wheaton, IL 60189) with 0.2 gpm flow rate when operated at 40 psi indicated that about 75% of the total spray volume was in droplets 100 micron diameter and larger. Computer simulation results indicate that all 100 micron and larger diameter water droplets reached 18 in below point of discharge at wind velocities up to 10 mph regardless of the relative humidity. However, due to affecting the evaporation rate, and hence droplet size, relative humidity significantly influenced the drift distances of 50 micron diameter droplets before they evaporated. With wind velocity of 10 mph, the mean drift distances of 50 micron diameter water droplets increased from 37.6 to 87.2 ft as relative humidity increased from 20% to 80%.

Data in Table 1 indicate that drift distances of droplets 200 micron diameter and larger are much less than for 100 micron diameter. For example, with 10 mph wind velocity and 60% RH, the mean drift distance of 100 micron diameter droplets was about 18 times that of 200 micron diameter droplets (0.96 ft versus 17.48 ft). The mean drift distances of 200 micron diameter droplets were 0.20, 0.38, 0.55, 0.75, and 0.96 ft for wind velocities of 2, 4, 6, 8, and 10 mph, respectively. Relative humidity over a range of 20-80% had very little influence on the drift distances of 200 micron diameter droplets. The mean drift distances of all droplets 200 micron diameter and larger did not exceed 0.96 ft with wind velocities up to 10.0 mph.

Figure 1 illustrates the effect of water droplet size (50-300 micron diameter) on mean drift distance for wind velocities of 2.0, 4.0, 6.0, 8.0, and 10.0 mph, and 60% RH at 75 degrees F. All droplets 100 micron diameter or larger reached 18 in below point of discharge and deposited. The mean drift distances of the droplets increased with increased wind velocity but decreased as initial droplet size increased. The amount of droplet displacement that can be tolerated depends on several factors including the crop and surrounding area, and the pest control agent. If the target is a row crop that is sprayed from a nozzle centered over each row, then small amounts of droplet displacement by wind can result in large portions of the spray missing the target. It is also common for gusts with velocities two or more times the mean wind velocity to occur while spraying. Figure 1 indicates that drift is far less likely to be a problem when spraying with 200 micron diameter and larger droplets.

Figure 2 illustrates the simulated effect of wind velocities up to 10.0 mph on the mean drift distances for

100, 150, 200, and 300 micron diameter water droplets at 60% RH. Figure 2 and Table 1 both indicate that the influence of wind velocity on drift distance increases as droplet size decreases. Figure 2 shows that there is a nearly linear relationship between mean drift distance and wind velocity for each droplet size. The rate of change in drift distance with change in wind velocity was much greater for 100 than 200 micron diameter droplets. For example, over a range of 2 to 10 mph wind velocity the drift distances of 100 and 200 micron diameter droplets increased 1.8 and 0.01 ft per mph increase in wind velocity respectively.

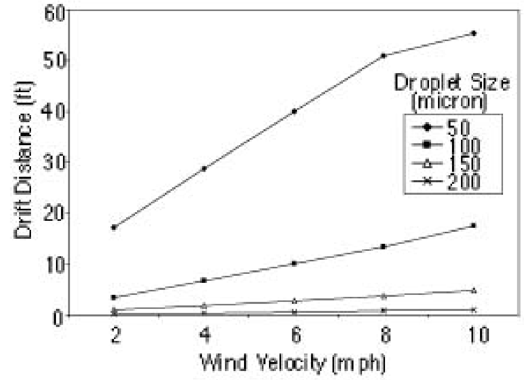


Figure 2. Effect of wind velocity and droplet diameter on drift distances of water droplets directed downward at 65ft/second toward a target 18 inches below discharge point (temperature = 75 degrees F; Relative Humidity = 60%).

Some spray carriers are oil or nonvolatile liquids. If the nonvolatile droplet density is close to the density of water, drift distances would be similar to drift distances in Table 1 for water droplets with 80% RH. Droplets 50 micron diameter or smaller can have very long drift distances with 100% RH. For example, the mean drift distances of 10 micron diameter droplets are beyond 650 ft with wind velocities of 5.5 mph and higher. For many pesticide applications, a small portion of the mixture is nonvolatile. For small droplets that are still airborne when all of the water evaporates, there is potential for the small nonvolatile portion remaining to drift very long distances.

Temperature and Relative Humidity

Pesticides are applied over wide ranges of temperatures and relative humidities which influence the evaporation rates of droplets. Since evaporation of liquid from a droplet decreases its mass, it also influences the drift distance of the droplet. Table 2 shows the effects of temperatures (50, 68, and 86 degrees F) on droplet diameters at the end of droplet flights, and mean drift distances for water droplets with initial diameters ranging from 50 to 300 micron, wind velocities of 1 to 22 mph and 50% RH.

Table 2 indicates that ambient temperature had more influence on droplet sizes at end of flights for smaller droplets than larger droplets. For 70 micron diameter droplets, 5.6 mph wind velocity, and 50% RH, the mean droplet sizes at end of flights were 59.2, 42.7, and zero micron for ambient temperatures of 50, 68, and 86 degrees F, respectively. For 200 micron diameter droplets and the same conditions, the mean droplet sizes at times of deposition were 200, 199, and 199 micron. Over a temperature range of 50-86 degrees F, the volumes of 100 and 200 micron diameter water droplets changed about 20.9 and 1.5% respectively during flights when wind velocity was 1.1 m/s.

Table 2. Effect of temperature and wind velocity on droplet size at the end of flight of various size water droplets discharged downward at 65 ft/second toward a target 18 inches below point of discharge. (Relative humidity = 50%)

Initial Droplet size (micron)	Wind Velocity (mph)	Final Droplet Size (micron) and Drift Distance (ft)					
		Temperature (degrees F)					
		50		68		86	
		DS#	DD##	DS#	DD##	DS#	DD##
50	1.1	0.0	11.58*	0.0	9.84*	0.0	9.74*
50	5.6	0.0	53.14*	0.0	32.8*	0.0	23.52*
50	11.1	0.0	105.94*	0.0	61.34*	0.0	41.32*
50	22.4	0.0	208.61*	0.0	117.75*	0.0	75.76*
70	1.1	59.4	5.18	43.6	6.30	0.0	12.50*
70	5.6	59.2	26.14	42.7	32.14	0.0	38.70*
70	11.1	59.0	52.48	41.9	64.61	0.0	70.19*
70	22.4	58.8	105.94	40.4	132.18	0.0	132.51*
100	1.1	96.7	2.13	93.7	2.13	88.7	2.36
100	5.6	96.7	10.53	93.7	10.73	88.7	11.64
100	11.1	96.7	19.48	93.7	21.48	88.6	23.39
100	22.4	96.6	42.97	93.5	43.62	88.3	47.56
150	1.1	149	0.59	148	0.59	147	0.59
150	5.6	149	2.72	148	2.85	147	2.98
150	11.1	149	5.58	148	5.74	147	6.04
150	22.4	149	11.97	148	12.27	147	12.82
200	1.1	200	0.13	199	0.13	199	0.13
200	5.6	200	0.56	199	0.56	199	0.56
200	11.1	200	1.18	199	1.18	199	1.18
200	22.4	200	2.69	199	2.69	199	2.69
300	1.1	300	0.03	300	0.03	299	0.03
300	11.1	300	0.33	300	0.33	299	0.33
300	22.4	300	0.69	300	0.69	299	0.69

* Droplet completely evaporated before deposition. # DS - Droplet diameter (micron) at end of flight. ## DD - drift distance (ft).

Table 2 also shows that wind velocities up to 22.4 mph had greater influence on droplet size change during flight on smaller than on larger droplets. For 70 micron diameter droplets at 68 degrees F and 50% RH, the droplet diameters at deposition were 43.6 and 40.4 micron with wind velocities of 1.1 and 22.4 mph, respectively. The 70 micron diameter water droplets lost 76 and 81% of their volume during flights with wind velocities of 1.1 and 22.4 mph, respectively. For 200 micron diameter droplets with the same conditions, the final droplet sizes at time of deposition were 199 micron for all wind velocities over a range of 1.1 to 22.4 mph.

Temperature can affect evaporation rate during flight and hence droplet size and drift distance. Because smaller droplets have greater surface area to volume ratios and longer flight times than larger droplets, temperature has greater influence on the drift distances of smaller droplets. With wind velocity of 5.6 mph and relative humidity of 50%, 50 micron diameter water droplets drifted 53.1 and 23.5 ft before completely evaporating at temperatures of 50 and 86 degrees F, respectively. With the same conditions, 100 micron diameter droplets drifted 10.5 and 11.6 ft before deposition at temperatures of 50 and 86 degrees F, respectively. Ambient temperatures within the range of 50 and 86 degrees F had very little influence on drift distances of 200 micron diameter and larger water droplets when wind velocity varied from 1.1 to 22.4 mph.

Figure 4 illustrates the simulated mean drift distances for 50, 100 and 200 micron diameter water droplets with 10 mph wind velocity, 50% RH and ambient temperatures of 55, 65, 75 , and 85 degrees F. The curve for 50 micron droplets shows that drift distance decreased as temperature increased. The 50 micron diameter droplets completely evaporated before deposition. Small droplets tend to travel at speed close to wind velocity. When temperature, and hence evaporation rate increases, their travel distance over their lifetime tends to decrease. The curve for 100 micron diameter droplets shows that drift distance before deposition increased with increased temperature. The drift distance tended to increase with increased temperature because increased temperature resulted in faster evaporation rate, smaller droplet size and increased travel distance before deposition. Temperature over the range of 50 to 86 degrees F had little influence on drift distances of 200 micron diameter droplets. The data used to produce the curves on Figure 3 are presented in Table 3.

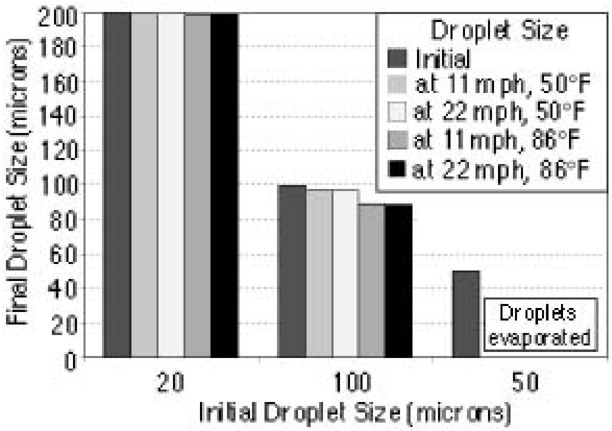


Figure 3. Effect of temperature and wind velocity on droplet sizes at the end of flight of 50, 100 and 200 micron diameter water droplets discharged down at 65 ft/second toward a target 18 inches below nozzle RH=50%).

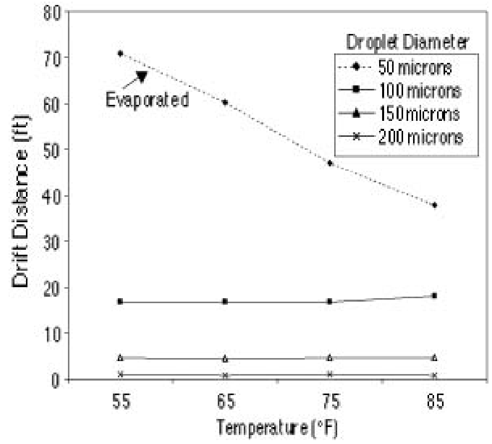


Figure 4. Mean drift distances for 50, 100 and 200 micron diameter water droplets with 10 mph wind velocity, 50% RH and ambient temperatures of 55, 65, 75 , and 85 degrees F.

Table 3. Effect of wind velocity and temperature on drift distances of droplets directed downward with initial velocity of 65 ft/second toward target 18 inches below discharge point. (Relative humidity = 50%; Turbulence intensity = 20%)					
Initial Droplet size (micron)	**Wind velocity (mph)**	**Drift Distance (ft)**			
		Temperature (degrees F)			
		55	**65**	**75**	**85**
20	2	4.24*	4.47	4.64	4.79*
20	4	7.23*	7.33*	7.71*	7.79*
20	6	10.07*	9.20*	9.22*	9.07
20	8	12.82*	11.33*	10.42*	10.38*
20	10	15.55*	13.27*	11.92*	11.44
50	2	15.73*	14.97*	13.51*	12.60*
50	4	29.55*	26.39*	22.00*	18.82*
50	6	43.28*	37.87*	30.19*	25.18*
50	8	56.91*	49.21*	38.73*	31.79*
50	10	70.92*	60.31*	46.97*	37.90*
100	2	3.35	3.34	3.53	3.63
100	4	6.69	6.71	7.03	7.23
100	6	10.03	10.05	10.58	10.82
100	8	13.37	13.40	14.08	14.44
100	10	16.74	16.76	16.73	18.10
150	2	0.94	0.92	0.96	0.94
150	4	1.85	1.82	1.91	1.88
150	6	2.77	2.73	2.85	2.81
150	8	3.69	3.64	3.78	3.76
150	10	4.64	4.56	4.75	4.70
200	2	0.21	0.20	0.21	0.20
200	4	0.39	0.39	0.39	0.38
200	6	0.57	0.54	0.58	0.54
200	8	0.74	0.76	0.78	0.74
200	10	0.98	0.95	0.96	0.93

* Droplet completely evaporated before deposition.

Table 4 shows the mean drift distances for water droplets with initial diameters (25-300 micron), ambient temperatures (55-85 degrees F), relative humidities (20-100%), and 10 mph wind velocity. At low temperature (55 degrees F) and high relative humidity (80%), 50 micron diameter droplets were able to reach 18 in below their discharge point but traveled about 120 ft downwind before depositing. Table 4 indicates that relative humidity has little influence on drift distances of 150 micron diameter and larger droplets. This is because the flight times of these droplets are short. With wind velocity of 10 mph, 200 micron diameter droplets were only displaced over a range of less than 1 foot (0.93 to 0.98 ft) for the ranges of relative humidity and ambient temperature.

Table 4. Effect of relative humidity and ambient temperature on mean drift distances of various size water droplets directed downward at 65 ft/second toward a target 18 inches below point of discharge. (Wind velocity = 10 mph)

Droplet size (micron)	Ambient temp. (degrees F)	Drift distances (ft)				
		Relative humidity (%)				
		20	40	60	80	100
25	55	17.93*	20.37*	29.76*	56.43*	381.60
25	65	14.67*	16.63*	23.53*	43.18*	377.97
25	75	12.58*	14.41*	19.94*	37.95*	391.31
25	85	11.41*	12.77*	17.81*	33.25*	400.12
50	55	63.32*	60.87*	60.87*	119.73	76.78
50	65	48.21*	53.93*	63.82*	93.51*	76.05
50	75	37.58*	42.00*	55.32*	87.24*	78.82
50	85	30.81*	34.40*	44.81*	73.93*	80.34
100	55	16.90	16.82	16.63	16.43	16.20
100	65	16.97	16.88	16.64	16.36	15.99
100	75	17.94	17.77	17.48	17.05	16.46
100	85	18.55	18.28	17.88	17.34	16.55
150	55	4.65	4.64	4.62	4.62	4.59
150	65	4.58	4.57	4.56	4.54	4.50
150	75	4.78	4.78	4.72	4.72	4.66
150	85	4.76	4.73	4.70	4.64	4.58
200	55	0.98	0.98	0.95	0.95	0.95
200	65	0.95	0.95	0.94	0.94	0.94

200	75	0.96	0.96	0.96	0.96	0.96
200	85	0.93	0.93	0.93	0.93	0.93
300	55	0.98	0.98	0.95	0.95	0.95
300	65	0.95	0.95	0.94	0.94	0.94
300	75	0.96	0.96	0.96	0.96	0.96
300	85	0.93	0.93	0.93	0.93	0.93
* Droplet completely evaporated before deposition.						

Figure 5 illustrates the effect of relative humidity on mean drift distances of 25, 50, 100 and 200 micron size water droplets for 10 mph wind velocity. The ambient temperature was 65 degrees F for the simulations. The mean drift distances of 25 and 50 micron diameter water droplets, before complete evaporation, increased with increased relative humidity over the range of 20 to 80%. For the same conditions, but with 100% RH, 50 micron diameter droplets deposited 18 in below and 76 ft downwind from the point of discharge while 25 micron diameter droplets drifted beyond 378 ft. There was no change in drift distance of 200 micron diameter water droplets over the 10 to 80% range of relative humidity.

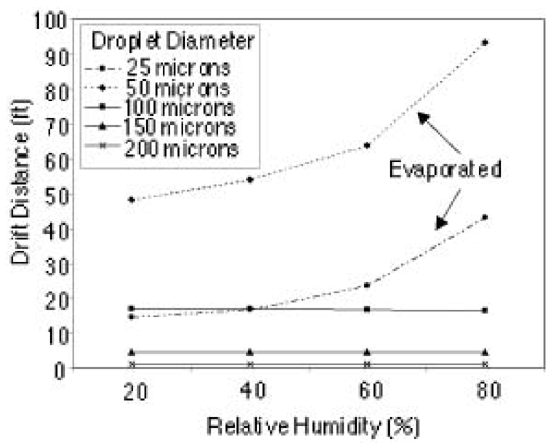


Figure 5. The effect of relative humidity on mean drift distances of 25, 50, 100 and 200 micron size water droplets for 10 mph wind velocity. (The ambient temperature= 65 degrees F).

Droplet Discharge Height

Agricultural pesticides are applied with a very wide range of nozzle heights above targets. Nozzle height depends on several factors including the sprayer setup, target and operating conditions. Table 5 shows the effects of discharge height (0.5-3.0 ft), droplet diameter (50-300 micron) and wind velocity (2.0-10.0 mph) on mean drift distances of water droplets directed downward with initial velocity of 65 ft/seconds. Relative humidity and ambient temperature were 50% and 70 degrees F, for all simulations. The mean drift distances of 50 micron diameter and smaller droplets were nearly constant with each wind velocity for the discharge height range of 0.5 to 3.0 ft. This occurs because these droplets have short life times and do not travel downward far enough to deposit before completely evaporating.

Table 5. Effect of droplet discharge height and wind velocity on drift distances of various size droplets discharged downward at 65 ft/second toward a target. (Temperature: 70 degrees F; Relative Humidity = 50%)

Initial Droplet size (micron)	Wind velocity (mph)	Drift distances (ft)					
		Nozzle height (ft)					
		0.5	1	1.5	2	2.5	3.0
50	2	0.43*	13.87*	14.02*	14.14*	14.22*	13.97*
50	4	14.28*	23.51*	23.72*	23.80*	23.83*	23.98*
50	6	19.96*	32.92*	33.41*	33.65*	33.78*	33.76*
50	8	25.61*	42.32*	43.18*	43.40*	43.39*	43.73*
50	10	31.20*	51.48*	52.29*	52.89*	53.37*	53.43*
100	2	0.50	1.50	3.37	5.40	7.51	9.85
100	4	0.99	2.99	6.76	10.82	15.02	19.72
100	6	1.48	4.47	10.15	16.23	22.54	29.62
100	8	1.98	5.97	13.51	21.63	30.05	39.51
100	10	2.49	7.47	16.91	27.06	37.59	49.40
150	2	0.04	0.29	0.92	1.80	2.77	3.76
150	4	0.07	0.57	1.82	3.57	5.50	7.49
150	6	0.11	0.86	2.73	5.34	8.25	11.23
150	8	0.16	1.15	3.63	7.12	11.01	14.99
150	10	0.19	1.43	4.55	8.92	13.78	18.75
200	2	0.02	0.07	0.20	0.61	1.13	1.76
200	4	0.03	0.14	0.38	1.19	2.24	3.51
200	6	0.05	0.20	0.55	1.76	3.34	5.23
200	8	0.06	0.27	0.75	2.37	4.48	7.01
200	10	0.08	0.34	0.93	2.98	5.63	8.79
300	2	0.00	0.01	0.05	0.11	0.20	0.38
300	4	0.02	0.05	0.10	0.24	0.41	0.79
300	6	0.02	0.07	0.15	0.35	0.62	1.17
300	8	0.02	0.08	0.21	0.46	0.80	1.56
300	10	0.04	0.12	0.26	1.04	1.04	1.97

* Droplet completely evaporated before deposition.

Increased discharge height resulted in increased drift distances for 100 micron diameter and larger water droplets (Table 5). For example, with 10 mph wind velocity and 65 ft/second initial droplet velocity, when discharge height increased from 0.5 to 3.0 ft, the mean drift distance of 200 and 300 micron diameter droplets increased from 2.49 to 49.40 ft and 0.08 to 8.79 ft, respectively. When the discharge height increased from 0.5 to 3.0 ft, the mean drift distance of 100 micron diameter droplets increased from 1.98 to 39.51 ft and kept increasing until the discharge height of 10 ft is reached. When the discharge height is increased beyond 10 ft, the drift distance remained constant (217 ft) because the 100 micron diameter water droplets completely evaporated before deposition.

When simulations for large size droplets were performed, results indicated that if the discharge height becomes too large, even the large droplets have tendency to drift under high wind velocity conditions. For example, the mean drift distance of 1000 micron diameter droplets was 5 ft for wind velocity and discharge height of 22 mph and 10 ft, respectively. Computer simulation also indicated that the mean drift distances of 1000 and 2000 micron diameter droplets were 57 and 19 ft, respectively, before impaction 13 ft below the point of discharge for 22 mph wind velocity, 50% relative humidity, and zero mph initial droplet velocity.

Figure 6 illustrates the effect of discharge height of droplets on the mean drift distances of 50, 100, 200, and 300 micron diameter water droplets for 10 mph wind velocity, 50% RH and 65 degrees F. The graph shows that increasing discharge height above 0.5 ft had no affect on the mean drift distance of 50 micron diameter droplets because they completely evaporated before depositing. However, increasing discharge height of 100 micron diameter and larger droplets affects their mean drift distances. Changes in discharge heights have less effect on mean drift distances as droplet size increases above 200 micron diameter.

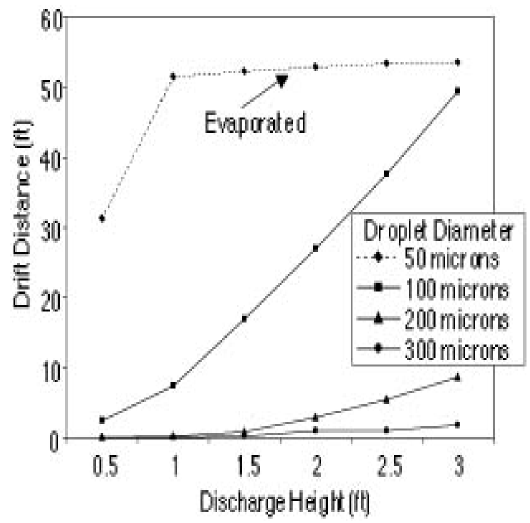


Figure 6. The effect of discharge height of droplets on drift distances of 50, 100, 200, and 300 micron diameter water droplets at 10 mph wind velocity (RH= 50%, T= 65 degrees F.)

Initial Droplet Velocity

Pesticides are applied with many different types of nozzles. The velocity of droplets delivered by nozzles depends on the configuration of the nozzle, and operating pressure. Table 6 shows the effects of initial droplet velocity (0-120 ft/second) and wind velocity (2.5-10.0 mph) on the mean drift distances of various size water droplets directed downward toward a target 1.5 ft below the point of discharge. Relative humidity and ambient temperature were 50% and 70 degrees F, for all simulations. The data indicate that increasing the initial downward droplet velocity can decrease the mean drift distances before deposition of 75 micron diameter and larger droplets. When spray is directed downward from a nozzle centered over a row of plants, for example, it is important to maximize spray deposition on the target. Even for 30 ft/second initial droplet velocities, the drift distances of 100 micron diameter and smaller water droplets would be excessive when spraying row crops if the droplets were exposed to crosswinds with velocities of only 1 mph. Also, for many applications where the spray is exposed to crosswinds, the drift distances of 200 micron diameter droplets would be excessive for droplets directed downward with slow velocities. For example, the mean drift distances of 200 micron diameter droplets in 2.5 mph crosswinds are 2.4 and 0.9 ft for droplets directed downward with 0 and 30 ft/sec velocities, respectively. When wind velocity was 10 mph, the mean drift distance of 200 micron diameter droplets decreased from 9.88 to 0.28 ft as the initial downward droplet velocity increased from 0 to 120 ft/s. Some applicators use large droplets to reduce spray drift potential. With no initial downward droplet velocity (zero ft/second) and 18 in discharge height, the mean drift distances of 1000 micron diameter droplets were 0.24, 0.63, 1.08, and 1.62 ft when wind velocities were 2.5, 5.0, 7.5, and 10.0 mph, respectively. With 60 ft/sec instead of 0 m/s initial velocity, the mean drift distance of the 1000 micron diameter drops was only 0.04 ft when wind velocity was 10 mph. Table 6 also illustrates that initial droplet velocities had no effect on drift distances of 50 micron diameter water droplets. None of the 50micron diameter and smaller droplets reached 18 in below the point of discharge before complete evaporation for a range of initial droplet velocities from zero to 120 ft/second and wind velocities from 2.5 to 10.0 mph.

Table 6. Effect of initial droplet velocity and wind velocity on drift distances of various size water droplets directed downward toward a target 18 inches below point of droplet discharge. (Temperature: 70 degrees F; Relative Humidity = 50%)

Droplet size (micron)	Wind velocity (mph)	Drift Distances (ft)				
		Initial Droplet Velocity (ft/second)				
		0	30	60	90	120
50	2.5	16.50*	16.42*	16.40*	16.53*	16.50*
50	5.0	28.80*	28.74*	28.62*	28.67*	28.67
50	7.5	40.76*	40.73	40.74	40.70	40.54*
50	10.0	52.98*	52.70*	52.43*	52.48*	52.67*
75	2.5	17.86	13.05	11.35	10.29	9.09
75	5.0	33.83	25.82	22.19	20.03	18.31
75	7.5	49.58	38.64	33.03	29.74	27.17
75	10.0	65.28	52.26	44.00	39.49	36.01
100	2.5	5.39	5.39	4.37	3.64	3.06
100	5.0	14.51	10.79	8.75	7.26	6.10
100	7.5	21.84	16.25	13.11	10.88	9.12
100	10.0	29.25	21.75	17.51	14.48	12.15
150	2.5	3.64	2.05	1.26	0.73	0.39
150	5.0	7.34	4.10	2.49	1.45	0.76
150	7.5	11.07	6.19	3.73	2.15	1.12
150	10.0	14.83	8.34	5.00	2.87	1.49
200	2.5	2.36	0.89	0.31	0.13	0.07
200	5.0	4.82	1.79	0.58	0.25	0.15
200	7.5	7.34	2.72	0.89	0.82	0.20
200	10.0	9.88	3.72	1.20	0.52	0.28
300	2.5	1.39	0.24	0.08	0.04	0.03
300	5.0	2.91	0.49	0.15	0.08	0.5
300	7.5	4.56	0.76	0.22	0.12	0.07
300	10.0	6.23	1.06	0.31	0.17	0.11
500	2.5	0.67	0.08	0.03	0.01	0.00

500	5.0	1.52	0.16	0.05	0.03	0.03
500	7.5	2.49	0.25	0.09	0.05	0.03
500	10.0	3.58	0.34	0.11	0.06	0.04
1000	2.5	0.24	0.03	0.00	0.00	0.00
1000	5.0	0.63	0.05	0.03	0.01	0.00
1000	7.5	1.08	0.08	0.03	0.03	0.01
1000	10.0	1.62	0.11	0.04	0.03	0.03
* Droplet completely evaporated before deposition.						

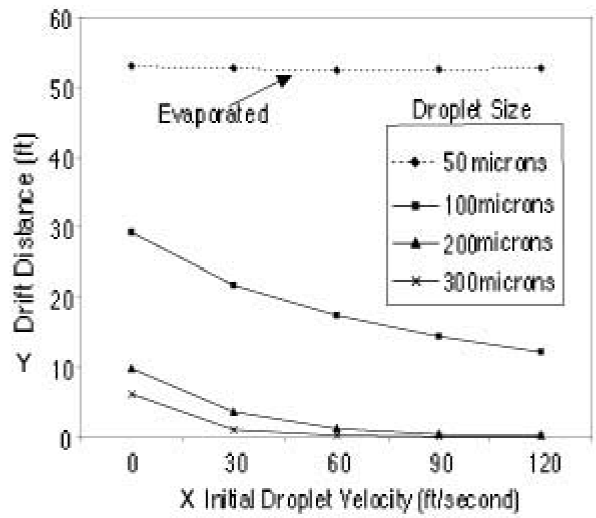


Figure 7. The influence of droplet size and initial downward velocity on drift distances of 50 to 300 micron diameter water droplets for 10 mph wind velocity (RH= 50%, T=70 degrees F).

Figure 7 illustrates the influence of droplet size and initial downward velocity on drift distances of 50 to 300 micron diameter water droplets for 10 mph wind velocity. The relative humidity and ambient temperature were 50% and 70 degrees F for all simulations. As evident from the data presented on Figure 7, for 10 mph wind velocity, drift distances are greatly influenced by both droplet size and the initial downward velocity of the droplet. The drift distances of 100 micron diameter and larger droplets decreased with increased initial droplet velocity. Figure 7 also illustrates the large difference in drift distances between 100 and 200 micron diameter water droplets.

Conclusions

The following conclusions are based on the computer simulations of mean drift distances of water droplets within the range of variables discussed in this publication.

1. Changes in wind velocity, discharge height, ambient temperature and relative humidity had much greater influence on the drift distances of droplets 100 micron diameter or less than on 200 micron diameter and larger droplets. For droplets that did not evaporate before deposition, there was a nearly linear relationship between wind velocity and drift distance.

2. With 100% RH, 10 micron diameter droplets drifted beyond 650 ft when wind velocity exceeded 5.5 mph.
3. Droplets 50 micron diameter and smaller completely evaporated before reaching 18 inches below the discharge point, regardless of initial velocity, for relative humidities 60% and lower and temperatures between 55 and 85 degrees F. Also, the mean drift distances of these droplets increased with increased droplet size.
4. Mean drift distances of 100 micron diameter and larger droplets increased with increased wind velocity and discharge height, but decreased with increased droplet size and discharge velocity.
5. Drift distances of water droplets as large as 200 micron diameter were influenced by initial droplet velocity and height of discharge.
6. For 10 mph wind velocity, 20% turbulence intensity, 50% RH, 70 degrees F ambient temperature, 60 ft/second initial downward droplet velocity and 18 inches discharge height, the mean drift distances of 100, 200, and 500 micron diameter droplets were 17.5, 1.2, and 0.11 ft, respectively.
7. The drift potential of 200 micron diameter droplets is considerably less than for 100 micron diameter droplets. Unless some means such as shields or air jets are used, drift reduction techniques should be directed toward reducing the portion of spray volume contained in droplets less than 200 micron diameter for applications where minimizing drift is important. For some applications, such as with high nozzles and slow initial downward velocity and high wind velocity, droplets larger than 200 micron diameter may be needed to satisfactorily reduce drift.

Acknowledgment

Most of the information presented in this publication was adapted from the following publication.

Zhu, H., D.L. Reichard, R.D. Fox, R.D. Brazee and H.E. Ozkan. 1994. Simulation of drift of discrete sizes of water droplets from field sprayers. Transactions of the ASAE 37(5):1401-1407.

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- Reichard, D.L., H. Zhu, R.D. Fox and R.D. Brazee. 1992a. Computer simulation of spray drift that influence spray drift. Transactions of the ASAE 35(5):1401-1407.
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