Chapter 6

HARVEST-AID APPLICATION TECHNOLOGY

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INTRODUCTION

Cotton maturity, senescence, and injury are key components of leaf abscission (Cathey, 1986). Although leaf abscission often occurs naturally, it may not lead to a timely harvest. Therefore, defoliants are used by producers to promote leaf abscission and leaf drop.

Harvest aids often are classified as either herbicidal or hormonal. Although they differ in activity, both types of harvest aids enter the plant through the stomates (minor route) and by crossing the cuticle (major route) (Currier and Dybing, 1959). The ability of a harvest aid to pass into a leaf primarily is a function of the chemical and physical nature of the cuticle, as well as of the properties of the harvest aid and accompanying formulation ingredients, and the environment in which the leaf has developed. At present, the actual process of pesticide – including harvest aid – movement into the plant primarily is limited by a lack of knowledge of the physical and chemical properties of the cuticle (Devine *et al.*, 1993).

Once herbicidal and hormonal harvest aids enter the plant, they act quite differently. Herbicidal defoliants slowly injure or stress the leaf, causing epidermal cell wall disruption, thus stimulating ethylene synthesis. In contrast, hormonal defoliants and boll openers release or promote the production of ethylene without relying on contact injury. Regardless, both herbicidal and hormonal defoliants have a common mode of action by altering hormone balance in the plant, thereby initiating the abscission process (Cathey, 1986).

A successful defoliation encourages or forces cotton leaves to drop from the plant, improving picker efficiency, grade, and the quantity of lint harvested. Defoliation also may retard boll rot and stimulate boll opening, which, in turn, may promote earlier harvest and increased yield and profit.

Although it is quite apparent that a proper defoliation is beneficial, many factors must be considered prior to applying harvest-aid chemicals. Harvest-aid application decisions largely are based on crop maturity, crop condition, weather conditions, desired harvest schedule, and harvest-aid choices and rates. However, adjuvant usage, spray volume and pressure, defoliant drift, and application equipment also are critical aspects that must be considered prior to cotton defoliation.

ADJUVANTS

Adjuvants are chemicals added to agricultural chemical formulations or tank mixes to improve mixing and application or to enhance performance (Bohmont, 1990; Devine *et al.*, 1993; Foy, 1989). Most agricultural chemicals are not applied alone or in pure solutions but, instead, are used in combination with a variety of ingredients to improve efficacy. This variety of ingredients often includes surfactants and oil-surfactant concentrates used to enhance leaf-surface wetting and penetration; these formulations also include a number of biologically inert materials that improve the stability and rainfastness of the pesticide formulation (Bohmont, 1990; Devine *et al.*, 1993; Foy, 1989). Inorganic salts, phosphate esters, and chelating agents also have been used to enhance pesticide activity (Devine *et al.*, 1993).

In addition to inclusion as inert ingredients in pesticide formulations, adjuvants are added with pesticides in the spray tank to further increase efficacy. These adjuvants often decrease droplet surface tension and enhance leaf wetting and leaf contact angle. Surfactants, widely used as an adjuvant, have been shown to enhance pesticide activity by facilitating contact between pesticide spray droplets and leaf surfaces (Bohmont, 1990; Devine *et al.*, 1993; Foy, 1989). Surfactant structures and physical properties vary widely; however, surfactants share the common property of having hydrophilic and lipophilic portions. Having both hydrophilic and lipophilic properties causes surfactants to orient themselves along the droplet-cuticle interface, thus potentially enhancing diffusion through the cuticle (Devine *et al.*, 1993).

Although the functions of many adjuvants still are poorly understood, their use is increasing. Research has shown that pesticide penetration, translocation, metabolic fate, phytotoxicity, selectivity, and persistence often are altered by chemical adjuvants (Devine *et al.*, 1993; Foy, 1989). Used correctly, adjuvants often increase agricultural chemical effectiveness as much as five- or tenfold (Valkenburg, 1982). However, some pesticides require avoiding adjuvants altogether.

Similar to other agricultural chemicals, harvest-aid formulations include adjuvants as inert ingredients. Harvest aids often require additional adjuvants tank-mixed to improve efficacy. Adjuvants most often recommended with herbicidal and hormonal harvest aids include surfactants, petroleum- or vegetable-based oils, and crop oil concentrates. These adjuvants must be matched to particular harvest aids, crop maturity, and environmental conditions to ensure that they enhance – and do not detract from – the effectiveness of the harvest aid.

When adjuvants and harvest aids are properly matched, adjuvants may perform one or more of the following functions, enhancing harvest-aid defoliation:

Enhance wetting of foliage – Adjuvants often increase foliage wetting, thereby providing good retention and plant coverage by the harvest aid. Greater plant coverage and retention often allow for more harvest-aid absorption into the plant.

Improve uptake and translocation – Harvest aids perform most effectively when they have been absorbed by the plant. Typically, the level of activity is directly related to the quantity of the harvest aid absorbed into the leaves or bolls.

Enhance uniformity of deposit – Leaf penetration, rather than surface deposition, most often is the goal when using harvest aids. Adjuvants may enhance foliage coverage and uniformity of harvest-aid deposit, thereby increasing foliar uptake and harvest-aid efficiency.

Reduce spray evaporation – Evaporation of spray or vapor drift during and just after application often can be reduced by using a suitable adjuvant; this benefit is most apparent when applications are made in ultra-low volumes.

Although adjuvants may enhance the activity of some harvest aids, they also may hamper the goal of producing cotton that is free of trash. For example, when some mixtures of adjuvants and defoliants are applied, desiccation of the crop may occur too rapidly. With rapid leaf kill, the cotton leaves may become stuck on the plant, creating unnecessary trash. The potential for creating unnecessary trash at harvest exemplifies the need to match harvest aids, adjuvants, crop maturity, and the environment for a successful defoliation.

APPLICATION

The purpose of defoliation is to maintain lint quality, to facilitate harvesting, and, in some cases, to preserve yield. Thorough spray coverage is essential for good defoliation, because harvest aids are not translocated from one leaf to the other. Each leaf must be covered to cause the abscission process. A second application may be needed on rank cotton with dense foliage, because initial coverage may not be sufficient on the lower leaves of plants. Complete coverage also is the reason for high gallonage rates on labels. Coverage is even more important in a non-ideal environment.

Nozzle selection also affects defoliation applications. The type of nozzle affects the amount of spray applied to a particular area, uniformity of the applied spray, coverage obtained on the sprayed surfaces, and amount of drift. Each nozzle type has characteristics and capabilities designed for use under specific application conditions.

Much previous chemical application research has focused on improving the deposition and reducing the quantity of chemicals applied. Studies have concentrated on producing and delivering spray droplets hydraulically or mechanically, or on using air-assisted methods. These efforts have resulted in the development of several different types of chemical application equipment and techniques of delivering spray droplets, including air-assisted and electrostatically charged delivery. More recent research has focused on reducing the amount of off-target pesticide drift. The research has resulted in development of spray nozzles that produce more large, uniform droplets.

The effectiveness of new spray devices has been the subject of several research projects. Most of the studies focused on weed control, insect control, and canopy deposition. Some of the earliest attempts to improve spray coverage and reduce pesticide usage employed spray atomizers that mechanically generated a narrow range of droplets. Several spray atomizers were evaluated for foliar-applied weed control in soybeans. None of the atomizers performed better than flat-fan nozzles, and it was concluded that the non-conventional devices could not be justified for weed control (Walker *et al.*, 1989). These types of units no longer are in production for use in ground application.

Womac *et al.* (1993) evaluated the spray deposition obtained by air-assisted sprayers. He found that higher spray rates and greater levels of air assistance increased canopy penetration. Air-assisted sprayers force the spray particles down into the canopy with turbulent air flow. Air-assisted hydraulic sprayers presently are superior in placing spray material into dense cotton canopy. These sprayers are more suited to higher-valued crops; their feasibility is questionable in normal cotton production.

Coverage can be significantly affected by spray volume. The higher the spray volume, the better the canopy penetration. Another important factor is droplet size: Smaller drops will give better coverage, but they are more susceptible to drift.

DRIFT

Particle drift is the actual movement of spray particles away from the target area. Drift occurs by two methods: vapor drift and particle drift. Drift of defoliants away from the target area is an important, potentially costly problem facing both commercial and private applicators. Drift causes many problems, including damage to susceptible off-target sites; a lower application rate than intended, which can reduce the effectiveness of the defoliant, wasting harvest aid and money; and increased environmental contamination, such as water pollution and illegal pesticide residues.

DRIFT DYNAMICS

A solution dispersed through a hydraulic spray nozzle is broken into droplets that are spherical or nearly spherical in shape. Droplets smaller than 100 microns in diameter are considered highly "driftable." They are so small that they cannot readily be seen unless in high concentrations, such as fog. For comparison, a human hair is about 100 microns thick. As a result of the small size, drift is more dependent on the irregular movement of turbulent air than on gravity.

Many factors affect drift, but the most important is the initial size of the droplet. Small droplets fall through the air slowly and are carried farther by air movement. Table 1 shows the effect of droplet size on the rate of fall. The longer the droplet is airborne, the greater the potential for drift.

Table 1. Effect of droplet size on drift potential.

Diameter (microns)	**Spray Type**	**Time to Fall 10 Feet in Still Air (seconds)**
1	Fog	100,800
10	Fog	1,020
100	Mist	11
200	Fine	4
400	Coarse	2
1,000	Coarse	1

Source: Ross and Lembi, 1985.

Volume Median Diameter (VMD) is a term used to describe the droplet size produced from a nozzle tip. VMD is the droplet size at which one-half the spray volume consists of large droplets and one-half consists of smaller droplets. Since it takes many more small droplets to make up one-half the spray volume, there always will be more small droplets present in a typical spray pattern. A general droplet size guide is given in Table 2.

Table 2. Basic droplet size guide.

Application	**Droplet Size Based on Volume Median Diameter (VMD) (microns)**
Fungicide	150-250
Insecticide	150-300
Contact Herbicide	250-400
Phenoxy and Incorporated Herbicide	400+

When leaving the nozzle, the solution may have a velocity of 60 feet per second (41 mph) or more. Unless the spray particles are electrostatically charged, two forces act on the emerging droplets: gravity and air resistance. These forces greatly influence the speed and movement of spray droplets.

Droplet speed is reduced by air resistance, which breaks up the droplets. After their initial speed slows, droplets continue to fall under gravitational pull. With low boom heights, the initial speed may be great enough that the droplet reaches the target before drift occurs. Large droplets maintain a downward velocity longer than smaller ones. Small droplets also evaporate quickly and move farther in wind (Figure 1).

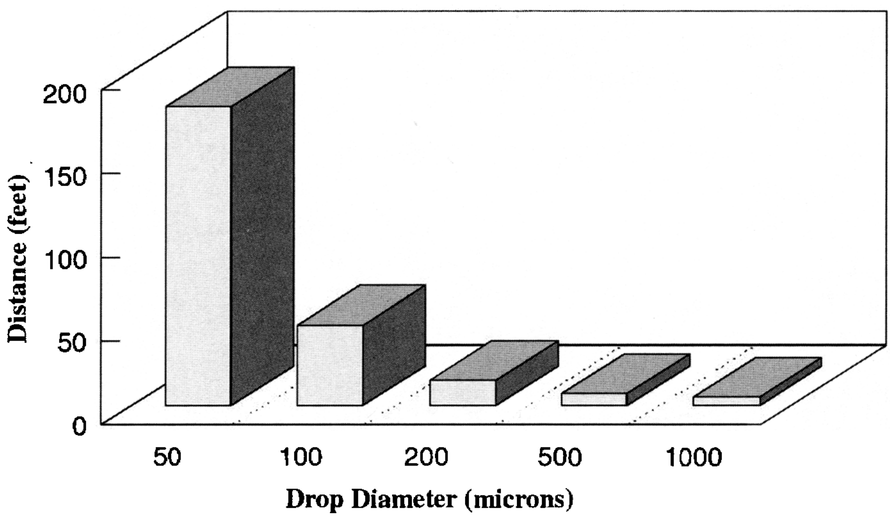

Figure 1. Effect of wind and droplet size on drift in a 10-foot fall at 3 mph wind speed. (Hoffman *et al.*, 1986)

Ideally, most of the volume should be contained in larger droplets. When the pressure is increased, a higher percentage of the droplets are smaller in size. With a greater proportion of the total spray volume in smaller droplets, the potential for drift to off-target sites increases.

ALTERING DROPLET SIZE

Many components of a sprayer can be adjusted to alter droplet size. Of these, nozzle selection is one of the most critical.

Nozzle Type – Droplet sizes are influenced by various nozzle types and different spray pressures. Spray droplets are produced from nozzles in different ways. A *fan nozzle* forces the liquid under pressure through an elliptical orifice; the liquid spreads out into a thin sheet that breaks up into different-sized droplets. A *flood nozzle* deflects a liquid stream off a plate that causes droplets to form. A *whirl chamber nozzle* swirls the liquid out an orifice with a circular motion and aids droplet formation with a spinning force. A *rotary nozzle* meters liquid through an orifice and releases it into a rotating wire basket to atomize the spray.

Spray Pressure – Spray pressure influences droplet formation. The spray solution emerges from the nozzle in a thin sheet; droplets form at the edge of the sheet. Higher pressures cause the sheet to be thinner, and the sheet breaks up into smaller droplets.

Small droplets are carried farther downwind than larger drops formed at lower pressures (Figure 1). The relationship between flow rate (gpm) and pressure (psi) is not linear: Pressure would have to be increased by four times to double the flow rate. Higher pressures decrease the droplet size, greatly contributing to drift potential. Table 3 shows the mean droplet size for a nozzle when spraying at three different pressures.

Table 3. Effect of spray angle and various pressures on fan nozzle droplet sizes.

	Pressure (psi)		
Spray Angle (degrees)	15	40	60
	Volume Median Diameter (microns)		
65	600	550	530
80	540	470	450
110	410	380	360

Source: Spraying Systems Co., 1998.

Spray Volume – The size or capacity of the nozzle also influences droplet size. A larger orifice will increase droplet size at a common pressure. It also will increase the volume applied, but the increased application rate improves coverage and, in some cases, increases pesticide effectiveness.

Spray Thickeners – Some spray adjuvants act as thickeners when added to a spray tank. These materials increase the number of larger droplets and decrease the number of fine droplets. They tend to give water-based sprays a "stringy" quality and reduce drift potential.

Oil Carriers – Droplets formed from an oil carrier tend to drift farther than those formed from a water carrier. Oil droplets usually are smaller and lighter, and they remain airborne for longer periods, but don't evaporate quickly.

ENVIRONMENTAL FACTORS

The effectiveness of pesticide application varies with environmental conditions. Several pesticide labels now contain information on the environmental conditions needed during application.

Wind Speed – Both the amount of pesticide lost from the target area and the distance it moves increase as wind velocity increases (Figure 2). However, severe drift injury also can occur with low wind velocities, especially under temperature inversion. Most recommendations are to stop spraying if wind speeds exceed 10 mph. Wind influences can be minimized by using shielded booms and lowering boom height.

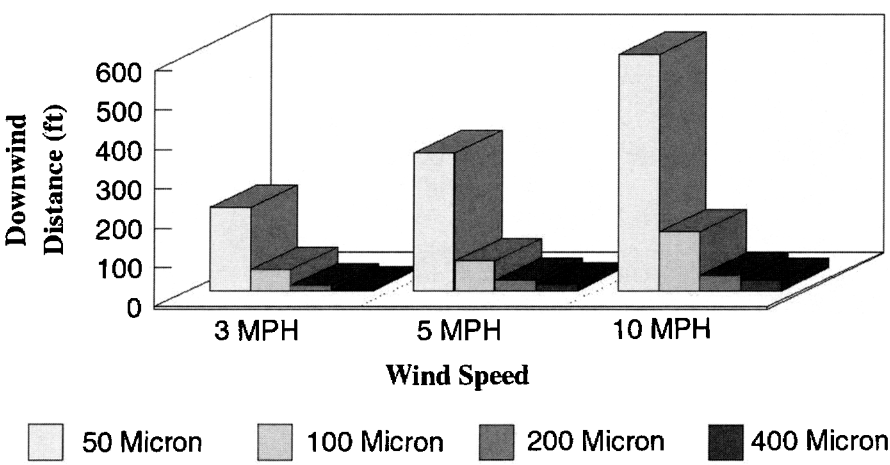

Figure 2. Effect of wind speed on drift in a 10-foot fall. (Hoffman *et al.*, 1986)

Wind Direction – Pesticides should not be applied when the wind is blowing toward a nearby susceptible crop or a crop in a vulnerable stage of growth. Select a time when there is little wind or when the wind blows gently away from susceptible crops. If these conditions do not exist, consider another method of control or time of application.

Air Stability – Air movement largely determines the distribution of spray droplets. Wind generally is recognized as an important factor, but vertical air movement often is overlooked. Temperature inversion is a condition where cool air near the soil surface is trapped under a layer of warmer air. A strong inversion potential occurs when ground air is 2 F to 5 F cooler than the air above. Under inversion conditions, little vertical mixing of air occurs, even with a breeze. Spray drift can be severe under inversion conditions. Small spray droplets may fall slowly or may be suspended by a gentle breeze and move several miles to susceptible areas.

Avoid applying harvest aids near susceptible crops during temperature inversion conditions. Inversions can be identified by observing smoke from a smoke bomb or fire (Figure 3). Smoke moving horizontally, close to the ground, would indicate a temperature inversion.

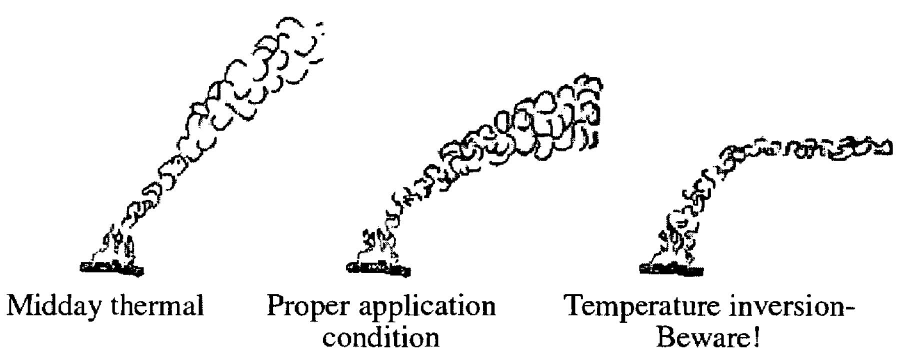

Figure 3. Smoke rising with wind velocity of less than 5 mph. (Samples and Seigler, 1982)

Relative Humidity and Temperature – Low relative humidity or high temperature conditions cause faster evaporation of spray droplets, posing higher potential for drift. During evaporation, the droplets become smaller. Evaporation is greater from the same deposit in small droplets than in larger drops, because the small droplets have greater surface area relative to their volume. Thus, the smaller the droplet, the less harvest-aid material that gets to the target.

Evaporation increases the drift potential, so crops should be sprayed during lower temperature and higher humidity conditions. Harvest aids evaporate at different rates. Use formulations and adjuvants that reduce evaporation.

As a rule of thumb, if the relative humidity is above 70 percent, conditions are ideal for spraying. However, a relative humidity below 50 percent should warrant special attention.

Water Contamination – The most critical problem posed by chemical drift, by far, is contamination of surface water. Water contamination causes fish kills in lakes, streams, and farm ponds, both on the lands being treated and on other lands in the vicinity. Contamination can be minimized by leaving an untreated buffer zone of 100 to 300 feet along the water line. Aerial application patterns parallel to a stream or pond should never be used unless the wind direction is directly away from the water.

GROUND APPLICATION

Nozzle selection is one of the most important decisions to be made related to pesticide applications. The types commonly used for ground application of agricultural chemicals are flat-fan, even flat-fan, and cone nozzles.

Flat-fan – Regular flat-fan nozzles are used for most broadcast spraying of herbicides and for certain insecticides when foliar penetration and coverage are not required. These nozzles produce a flat, oval spray pattern with tapered edges. This pattern is illustrated in Figure 4, where nozzles are offset five degrees to reduce distortion of spray from adjacent nozzles. They are available in spray-fan angles of 65, 80, and 110 degrees. The 65- and 80-degree nozzles usually are spaced 20 inches apart; 110-degree nozzles usually are spaced at 30 inches. At these respective spacings, the nozzles are operated at boom heights of 15 to 24 inches. The wide-angle (110-degree) nozzles frequently are operated at more narrow (20-inch) spacing and lower boom height to minimize drift caused by windy conditions at application.

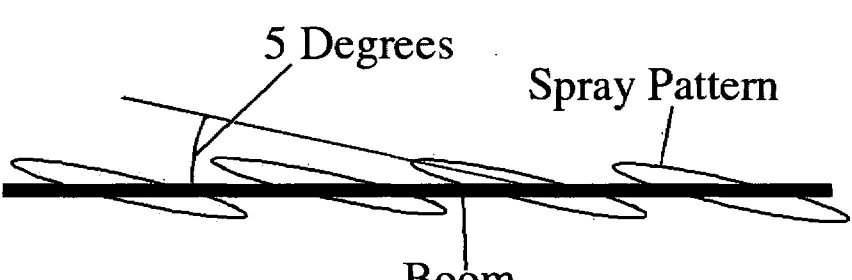

Figure 4. Overhead view of flat-fan nozzles angled 5 degrees from the boom, to illustrate spray patterns. Patterns overlap, but do not intersect.

Overlap of flat-fan nozzles is required, because spray volume at the outer edges of the spray patterns is tapered or reduced. The most uniform pattern is achieved when this overlap is 40 to 50 percent of the nozzle spacing (Figure 5). Check spray overlap by spraying clean water onto a hard, flat surface (concrete) and observing drying patterns. Because of their ability to produce a very uniform pattern when correctly overlapped, the flat-fan type of nozzle generally is the best choice for broadcast application of harvest aids.

Normal recommended operating pressure for regular flat-fan nozzles is 20 to 30 psi. At these pressures, this type of nozzle will produce medium to coarse drops that are not as susceptible to drift as the finer drops produced at pressures of 40 psi or greater. At these higher pressures, the possibility of drift increases significantly, so appropriate precautions must be taken.

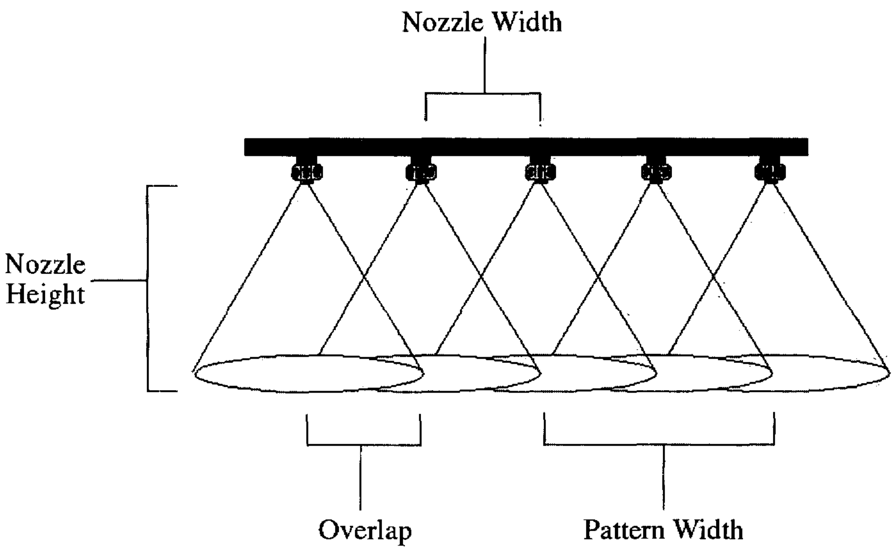

Figure 5. Spray pattern overlaps 40 to 50 percent for flat-fan nozzles.

Extended-Range flat-fan nozzles vary droplet size and flow rate by alternating pressures. These flat-fan nozzles hold their pattern at lower pressure than standard flat-fan nozzles (15 psi), ensuring uniform coverage along the boom. Extended-range flat-fan nozzles are available in both 80- and 110-degree fan angles. Smaller drops are produced at pressures from 30 to 60 psi, increasing the likelihood of drift. High pressures should be used only to apply foliar pesticides that must penetrate into the plant canopy or that require maximum coverage. Spray drift is a major concern at pressures higher than 40 psi.

Drift-Reduction pre-orifice nozzles produce a standard flat-fan pattern while effectively lowering the exit pressure at the nozzle. The lowered exit pressure creates a larger droplet spectrum with less driftable fines, minimizing off-target movement of the spray pattern.

Two styles of drift-reduction flat-spray nozzles currently are available. The RF Raindrop® flat spray nozzle is available with fan angles of 105 to 115 degrees, and the DG TeeJet® flat spray nozzle is available in both 80- and 110-degree fan angles. With a larger droplet size, drift-reduction pre-orifice nozzles can replace conventional flat-fan 80- and 110-degree tips in broadcast applications where spray drift is a problem. The recommended pressure for this nozzle is 30 to 60 psi. An alternative to the pre-orifice nozzle is use of a larger extended-range flat-fan nozzle operated at a lower pressure.

Turbo flat-fan nozzles are designed to produce less turbulence within the nozzle body, thus reducing wear and increasing the nozzle's life. These nozzles produce large droplets that will not drift. This nozzle is available in 110-degree fan angle. A cutaway view is shown in Figure 6.

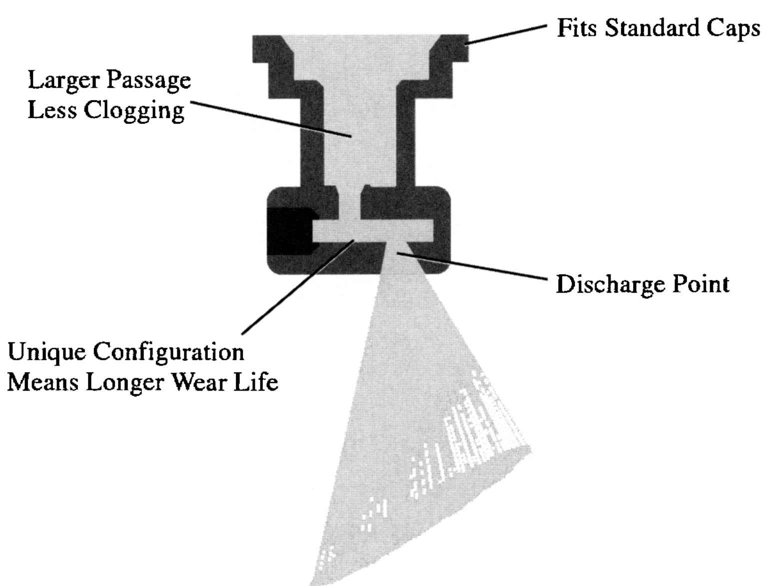

Figure 6. Turbo TeeJet® flat-fan nozzle.

Air-Assist nozzles are designed to produce large droplets and reduce the percentage of fine droplets. As with other low-drift nozzles, air-assisted nozzles contain a pressure reduction chamber with a narrow port. The liquid passing through the orifice plate causes a pressure drop. This venturi effect draws air into the nozzle body, blending air and spray solutions in the mixing chamber, much like a water aspirator. As the liquid is discharged from the nozzle tip, air-filled droplets are produced. Upon leaving the nozzle orifice, the air included in the droplet expands, increasing the size of droplets; this expansion causes the droplet velocity to increase. The higher velocity improves the chances of the droplet reaching the target. The large droplets shatter and splatter on contact, causing the small air-filled drops to spread out on the target for better coverage.

These nozzles produce an average droplet size of 400 to 600 microns. Spray volumes for this type of nozzle should be above 15 gpa at a spray pressure of 70 psi or greater. A cutaway view of this nozzle is shown in Figure 7.

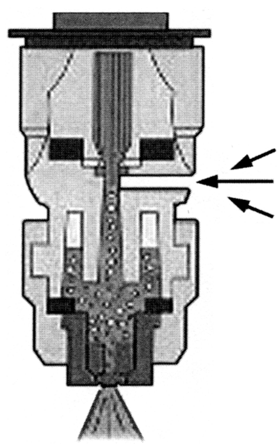

Figure 7. Air-assist nozzle. (Greenleaf Technologies, 1999)

Cone nozzles primarily are used when plant foliage penetration is essential for effective insect or disease control and when drift is not a major concern. At pressures of 40 to 80 psi, these nozzles produce small droplets that readily penetrate plant canopies and cover the underside of the leaves more effectively than any other nozzle type.

Cone nozzles are available in two configurations, nozzle body and disc-core (Figure 8). The spray angle for the nozzle body is fixed by the manufacturer. Spray angles and volume can be changed in disc-core nozzles by using different pressure, disc, and core combinations. The narrower the spray angle, the better the penetration into the canopy.

However, because of the small droplets and high operating pressures, these nozzles produce patterns very susceptible to drift. Therefore, they never should be used with any chemical for which drift can cause a problem. They also are very difficult to arrange along a boom for uniform distribution and are not recommended for broadcasting harvest aids.

The two common styles of cone nozzles are solid-cone and hollow-cone. Solid-cone nozzles produce a cone-shaped pattern with a uniform distribution of chemical throughout the pattern. Hollow-cone nozzles produce a cone-shaped pattern with the spray concentrated in a ring around the outer edge of the pattern (Figure 8).

Table 4 gives the effect of nozzle type and pressure on droplet size for several nozzles.

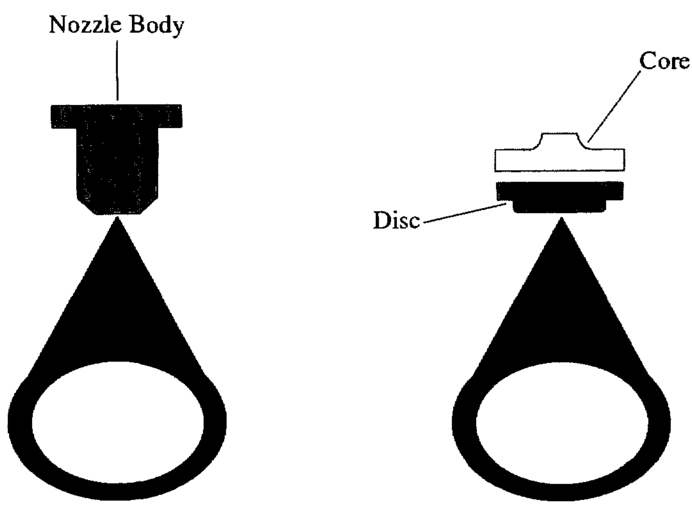

Figure 8. Hollow-cone nozzles: nozzle body and disc-core.

AERIAL APPLICATION

Aerial pesticide application offers several advantages: rapid coverage of large areas, accessibility to crops when ground equipment is not suitable, and, when properly managed, reasonable cost. The danger of contamination of adjacent nontarget areas from drift or misapplication should remain a constant concern.

Table 4. Effect of nozzle type on droplet size. Volume Median Diameter ($D_{V0.5}$, microns).

Nozzle Type, Pressure, Flow Rate	15 psi	20 psi	30 psi	40 psi	50 psi	60 psi	90 psi
XR TeeJet® Extended Range Fan XR-80° (Spraying Systems Co., 40 psi and 0.2 gpm)	239	214	177	159		141	
Lo-Drift® Flat-Fan LD-80° (Lurmark Ltd., 40 psi and 0.2 gpm)	367		264	223		189	157[1]
Raindrop® Fan RF-80° (Delavan Corp., 40 psi and 0.2 gpm)		339	290	248	215	200	
DG TeeJet® Fan DG-80° (Spraying Systems Co., 40 psi and 0.2 gpm)			350	292	260	234	
XR TeeJet® Extended Range Fan XR-110° (Spraying Sytems Co., 40 psi and 0.2 gpm)	199	185	166	153		142	
Lo-Drift® Flat Fan LD-110° (Lurmark Ltd., 40 psi and 0.2 gpm)	335		238	209		183	156[1]
DG TeeJet® Fan DG-110° (Spraying Systems Co., 40 psi and 0.2 gpm)			296	241	219	206	
Turbo TeeJet® Flat-Fan TT-110° (Spraying Systems Co., 40 psi and 0.2 gpm)	392		311	271		215	179
Flood CP® (CP Products Inc., 20 psi and 0.25 gpm)		418	341	300			
FloodJet® TK (Spraying Systems Co., 10 psi and 0.2 gpm)	236	224	213	207			
Turbo Floodjet® TFVS (Spaying Systems Co., 10 psi and 0.2 gpm)	598	552	492	427			
Raindrop® RA (Delavan Corp., 40 psi and 0.2 gpm)		549	468	422	394		
TurboDrop® TD 110° (Greenleaf Technologies, 40 psi and 0.25 gpm)				610		511	374[1]
ConeJet® Hollow Cone TXVS (Spraying Systems Co., 40 psi and 0.2 gpm)				178	173	169	

Source: Bouse, 1991, 1994.

[1] Droplet sizes at 100 psi.

Aerial application may be by either fixed- or rotary-wing aircraft. Metering and dispersal equipment must deliver adequate quantities of liquids or solids accurately and in a short period of time. An aircraft with a ground speed of 120 mph and a swath width of 70 feet covers 17 acres per minute.

Liquid application systems consist of pump, tank, hose, boom, filters, regulators, pressure gauge, and metering nozzles. Flow meters are valuable aids in monitoring system output and improving application performance. The hydraulic pumps either are wind driven or direct-powered from the aircraft engine. Fairly low-pressure, high-volume centrifugal pumps generally are used. Air shear across the nozzle pattern aids in breaking the liquid into spray; thus, high pressure is not required for atomization. Some pesticides may require pumps made of special materials or of specific designs. Special requirements and cautions usually are noted on pesticide labels. Nozzle screen sizes of 50 to 100 mesh, or an equivalent slotted strainer, should be used, depending on nozzle orifice size and materials being applied. Nothing finer than 50-mesh screens should be used with wettable powders.

Booms are required to support nozzles along the wingspan of fixed-wing craft. Booms are airfoil-shaped and are located behind and below the trailing edge of the wing to reduce drag and to place the nozzles in cleaner airflow. Location of outboard nozzles on booms is critical, because wingtip and main rotor vortices influence pattern width and drift. End nozzles must be sufficiently inboard to minimize entrapment of fine droplets by wingtip vortices. Such entrapment adversely affects both distribution and drift. Boom length should not exceed three-quarters of the wingspan.

NOZZLE SELECTION

Nozzles are a critical part of aircraft spray equipment. Usually, the same nozzle tips, discs and cores, caps, and strainers are used on both aerial- and ground-application equipment. Nozzle pattern is a major factor in distributing spray across the swath in ground application. In aerial application, spray distribution across the swath is affected considerably by aircraft wake. Thus, nozzle features affecting spray droplet size, droplet size distribution, flow rate, and tendency to clog are more critical than is nozzle spray pattern.

All nozzles used on aircraft produce a wide range of droplet sizes. The versatile disc and core-type hollow cone probably is the most popular. The range of droplet sizes may be changed by varying internal parts and components of these nozzles. Whirl chamber-type hollow-cone nozzles also are quite popular.

Droplet size is greatly affected by nozzle orientation and placement. Nozzles are mounted straight back to minimize small droplet formation caused by wind shear. Two- to four-inch drops on each nozzle place the nozzle in clean air (Figure 9).

Table 5. Droplet size distribution for various nozzles at 40 psi. Water in 115- to 120-mph airstream and parallel to airflow.

Nozzle	**GPM**	**VMD (microns)**	**% <100 microns**	**% <200 microns**
D6 Disc	1.05	697	0.05	0.60
Accu-Flo™; 32 Tubes (Bishop Equipment Mfg. Inc.)	1.90	409	0.14	1.95
M.L. Tips No. 6 Plastic (Lund Flying Service Inc.)	1.08	718	0.11	1.49
6510 Fan	0.93	397	0.08	2.58
D6-46 Cone	0.96	423	0.06	1.59
⅛ B5-5 WhirlJet® (Spraying Systems Co.)	0.84	325	0.29	5.30
TK5 FloodJet® (Spraying Systems Co.)	0.91	339	0.18	5.26
Nylon CP® 0.078 - 30° Deflection (CP Products Inc.)	0.97	403	0.09	2.07
Nylon CP® 0.078 - 60° Deflection (CP Products Inc.)	0.97	321	0.37	7.64
Nylon CP® 0.078 - 90° Deflection (CP Products Inc.)	0.97	273	1.11	13.15
REGLO JET® 0.078 - 45° (ICI Agrochemicals)	0.98	348	0.31	7.20
A&C Hi-Tek Rotary Mosquito Nozzle – 80 Mesh Screen (Davidon Inc.)	1.12	319	1.19	7.94

Source: Bouse, 1991, 1994.

ULTRA-LOW VOLUME

Ultra-Low Volume (ULV) application rates range from a few ounces to 2 gallons per acre. Special metering and atomizing attachments such as Micronair™, mini-spin, and airfoil frequently are used to achieve more uniform-sized droplets. Rotating nozzles may be wind driven or driven from the power unit. Wind-driven nozzles are dependent on aircraft speed and may fail to provide desired atomization when the craft is operating at reduced speeds. Ultra-Low Volume systems may be furnished with smaller diameter mainline hoses and fittings than normal for standard systems. Ultra-Low Volume nozzles may require individual supply lines for each nozzle. Concentrate sprays (no water added) may vary in density and other properties that alter flow characteristics and rate of fall. ULV droplets have unique drift characteristics; the technique is not suitable for all materials. Flying heights of 5 to 15 feet above ground contribute to uniformity and tend to minimize drift.

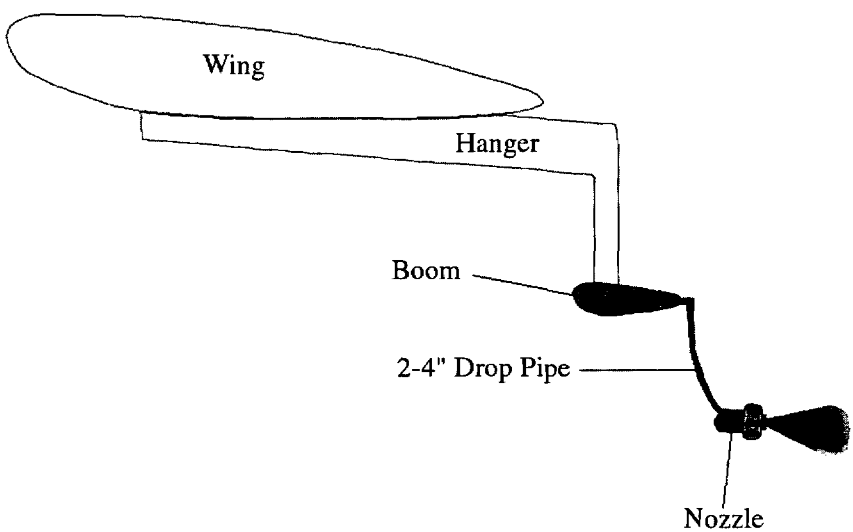

Figure 9. Uniform droplets can be attained by lowering the nozzle into cleaner air.

FUTURE NEEDS

The population shift into rural areas requires the development of new harvest-aid application technology. As more housing units are located around cotton fields, drift, odor and general application will be more in the public eye. More precise placement will be needed to avoid off-target harvest-aid drift. The costs of harvest aids will drive the development of more efficient methods of application.

Harvest-aid drift currently is being addressed by the development of new types of nozzles. Several nozzle manufactures are addressing drift by developing new, improved configurations. The development of techniques to enhance the canopy penetration of harvest aids would be of great benefit. This technology would allow for better defoliation in rank foliage and possibly the elimination of one or more spray applications.

Traditionally, combinations of harvest aids are applied across entire fields without regard to the variability of plant conditions in the field. New developments in site-specific crop management practices, such as variable-rate technology, may help lower the cost of applying harvest aids. This could be accomplished by two methods. Areas in fields that contain cotton plants that are fully cut out and plants that still have lush foliage could be treated with different rates of harvest aids.

In fields with nonuniform growth conditions – uneven distribution of unopened bolls, different regrowth potential, etc. – the mixture of harvest aids could be adjusted for each distinct location. Fields would have to be pre-mapped to facilitate applying different rates or combinations of harvest aids to different areas. This could be achieved by analyzing prior field history, by aerial mapping, or, perhaps, by satellite mapping.

These technologies currently are under development. As advancements occur in spray technology, they will become more practical and economically feasible.

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