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herbicidal drift control:

aerial spray equipment, formulations, and supervision

PROTECT
Use Pesticides Safely
FOLLOW THE LABEL
U.S. DEPARTMENT OF AGRICULTURE

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ABSTRACT

Public concern over environmental pollution requires increasingly sophisticated procedures when herbicides are used in silviculture. Many specialized aerial application systems and spray additives have been developed to reduce drift of herbicidal sprays. This publication provides forest-land managers with a brief description of these aerial spray systems and additives. Personnel and supervision to insure proper use of equipment and additives are also discussed.

Keywords: Herbicides, brush control, environment, silviculture.

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

During the past 20 years, aerial application of herbicides has developed into an effective silvicultural tool in the Pacific Northwest. During the same period, however, the world's rapidly increasing population and the industrial expansion required to satisfy its needs have seriously damaged the biosphere. Everywhere, people are becoming concerned about deterioration of the environment. They are now quickly antagonized by any public or industrial activity that may add to pollution. Herbicides, with their startling, eye-catching effects on vegetation, have attracted more than their share of this antagonism.

Although foresters have an impressive record in safe use of herbicides, we must become even more selective in deciding on treatment and more precise in applying herbicides. If a site requires treatment, we must restrict our sprays to that area and prevent drift onto adjacent areas.

FACTORS AFFECTING SPRAY DRIFT

Drift refers to the airborne movement of herbicidal spray from the site of application to untreated areas in the vicinity. This movement may be in the form of vapors, droplets, mists, aerosols, dusts, or other fine spray particles.

To a great extent, spray drift depends upon droplet size--large droplets fall more quickly and drift less than smaller ones. Theoretically, with no evaporation and a nonturbulent 5-mile-per-hour breeze, droplets 300 microns in diameter would drift only 42 feet while falling 50 feet (table 1). Under similar conditions, smaller 100-micron droplets could drift 375 feet (Hansen 1965).

Smaller droplets not only drift farther; they are also more likely to evaporate and be lost before reaching the vegetation. Seymour (1969) calculated that droplets 100 microns in diameter will evaporate

Table 1.--Predictable drift of different sized droplets when sprayed at 50 feet[1/]

Diameter of droplets	Cross wind		
	1 mile/hour	5 miles/hour	10 miles/hour
--microns--			
10	1.5 miles	7.5 miles	14.5 miles
100	75 feet	375 feet	750 feet
300	8 ft. 4 in.	42 feet	83 feet
590	2 ft. 2 in.	10 ft. 8 in.	21 ft. 5 in.
800	1 ft. 3 in.	5 ft. 9 in.	12 feet

[1/] Reproduced with permission of Hercules, Inc. (Hansen 1965).

after falling only 3 feet (fig. 1). Under the same conditions, larger droplets 200 microns in diameter could fall more than 20 feet without evaporating.

When spraying cuttings on rough, mountainous terrain, flying height must often be 50 feet or more above the vegetation; it may exceed 100 feet where flight lines are obstructed by snags or tall trees. In such areas, drift and evaporation may result in loss of more than half the active ingredients when applying phenoxy herbicides. Approximately 60 to 75 percent of low volatile esters of 2,4,5-T in diesel oil were lost from an early spring aerial application in the Oregon Coast Ranges (Norris 1967). To reduce drift and evaporation and to insure pilot safety, all dead trees and weed trees more than 10 feet tall should be felled during logging.

Flying speed is another critical factor; shearing and fragmentation of droplets by the airstream can produce large numbers of tiny, drift-susceptible droplets. As speed increases, the number of mistlike droplets also increases. Even at minimum safe speeds, shattering of spray in the airstream can almost obscure differences in droplet size and spray pattern produced by most commonly used aerial spray nozzles.

For adequate drift control, median diameter of herbicidal spray droplets should be approximately 400 to 600 microns. But as droplet size is increased, we get a smaller number of droplets per gallon and the number of hits on foliage decreases proportionately. We must, however, have a sufficient number of droplets per square foot to insure adequate coverage

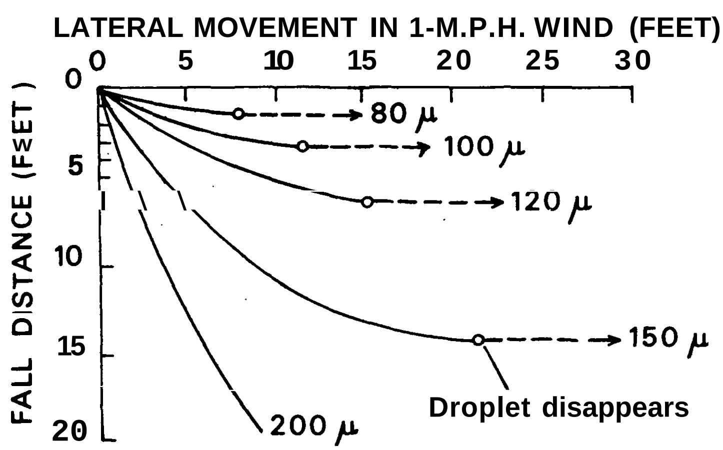

Figure 1.--Relation of vertical fall through air to lateral movement for water droplets falling at terminal velocity in a 1-mph wind. Calculated for 25° C., 50 percent RH, 760 mm Hg, and lateral air movement. (Adapted from "Pesticidal Formulations Research," with permission of The American Chemical Society (Seymour 1969).)

for brush control; incomplete coverage allows many species to survive herbicidal sprays. Therefore, as we increase droplet size, we may also need to increase spray volume and perhaps amount of herbicide applied per acre as well.

With conventional booms, we are somewhat limited in efforts to increase droplet size. We can vary formulations or change nozzle type and nozzle orientation on the spray boom. We can alsochange orifice diameter, whirl plates, and pump pressure. Droplet size increases as we change from flat fan to narrow angled hollow cone to jet nozzles without whirl plates. Larger droplets are also produced as orientation of nozzles is changed from straight down to back along the airstream (fig. 2). And finally, lower pump pressures will produce larger droplets.

At best, however, conventional booms on helicopters produce a large number of fine droplets and mist that are drawn up in whorls off each end of the spray boom. The whorls carry the fine droplets high above the helicopter, where they are most likely to drift with the wind or evaporate and drift away as vapor. Although the swirling vortices increase plant coverage and swath overlap, they also increase spray loss by drift and evaporation.

Foresters have already imposed many restrictions to reduce drift and other spray losses. Evaporation is reduced by using only low volatile esters and by spraying only when air temperature is below 75° F. and relative humidity above 50 percent. To minimize drift, aerial spraying is stopped when windspeed exceeds 6 miles per hour, In addition, aerial sprays are applied from minimum safe flying heights above vegetation, and flying speed must not exceed 50 miles per hour.

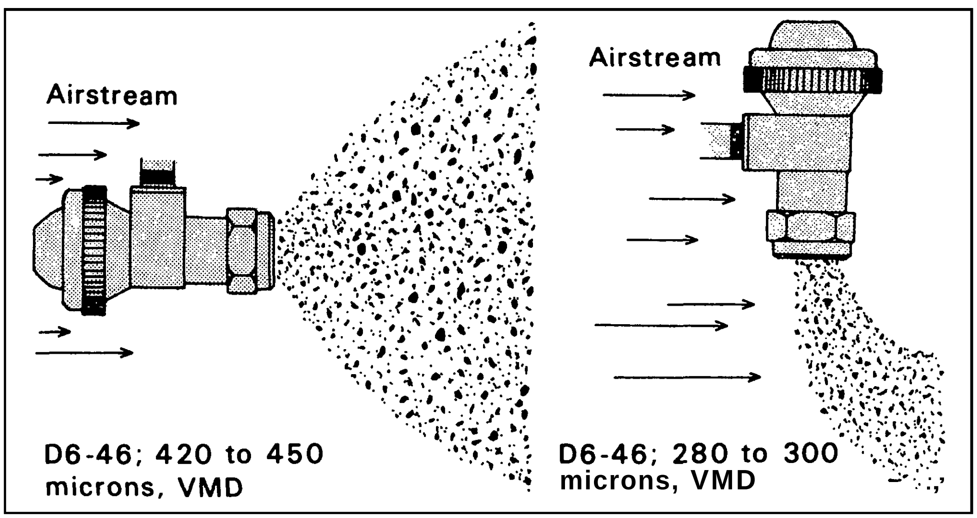

Figure 2.--Variation in droplet size resulting from change in nozzle orientation on the spray boom. VMD = volume median diameter--half of spray volume is in droplets of this diameter or larger; half is in droplets of this diameter or smaller. 06-46 refers to spraying system's D6 disk backed up by a 46 whirlplate (any nozzle that produces droplets in the same range can be substituted). (Adapted from Brazelton (1971), with permission of University of California Cooperative Extension Service .)

DRIFT REDUCTION

Three items must be considered if we are to reduce drift in an aerial spray operation: (1) aerial spray equipment, (2) formulations and spray adjuvants, and (3) project personnel. A good understanding of 1 and 2 are necessary to obtain large droplets for drift reduction and still get adequate spray coverage for acceptable effects on vegetation. But even the best formulations and equipment will not prevent damage on adjacent areas unless the spray is applied by a well-trained and responsible pilot with proper help and project supervision.

There are two ways to increase droplet size. First, by using special spray equipment that will produce droplets of the desired size. Or second, by using special formulations and spray additives to get the same result.

Aerial Spray Equipment

Helicopters are more expensive to operate but have proved far more useful and adaptable than fixed-wing aircraft for spraying forest land in the steep, mountainous terrain of the Pacific Northwest. Helicopters are highly maneuverable and allow more accurate spraying along edges of cuttings, buffer strips, and ecologically sensitive areas. They can fly at low height and slow speed over the steepest terrain, where fixed-wing aircraft must fly at greater height and higher speed to insure safety of the pilot.

In addition, helicopters can operate from heliports on roads and landings in the immediate vicinity of the spray areas. This minimizes ferry time in reloading and eliminates possible contamination of streams and farmlands in flying cross country from airports or landing strips needed for fixed-wing aircraft.

Many specialized types of aerial spray systems to reduce drift have been developed during the past 15 years. Most are designed or adaptable for use on helicopters. For herbicides in conventional carriers, the Microfoil Boom is most useful. Others, such as Amchem's Spra-Disk, the Rhodia Visko-Rhap, and Stull Bi-fluid spray systems were developed to apply invert emulsions. The Dow R-511 helicopter spray system was designed to apply particulated sprays, but a modified form of the R-511 has also proved effective in applying thickened sprays and tank-mixed invert emulsions. Most recently, foam spray systems were developed. These only require substitution of special nozzles on conventional booms to produce foamed sprays of herbicides in water or oil-in-water emulsions.

MICROFOIL BOOM

The Microfoil Boom developed by Amchem Products, Inc. is the only aerial spray system specifically designed to reduce drift using conventional carriers of water, oil, or oil-in-water emulsions. Thickening agents, invert emulsions, or particulating agents are not needed.

In aerial spraying, shearing and production of fine spray droplets can be greatly reduced by releasing spray through an open tube directed back along the airstream. The Microfoil uses this principle to produce nearly uniform large droplets with a minimum number of fine droplets.

The Microfoil is specifically designed for helicopters; it is not adaptable for fixed-wing aircraft. Boom length can be varied from 10 to 26 feet by bolting 3- or 5-foot sections of the boom together. Swath width varies with boom length, pump pressure, flying height, and--to some extent--with size of orifice selected.

The Microfoil boom consists of a

double tubing to equalize pressure with a series of airfoil-shaped nozzles mounted behind the trailing tube. Each Microfoil nozzle is 6 inches long with 60 needlelike tubes projecting from the trailing edge. Streams of spray solution are released through the needlelike tubes into the non-turbulent airstream behind the airfoil-shaped nozzles; a 26-foot boom has 3,120 orifices on 52 nozzles (fig. 3). Two orifice sizes are available--0.013- and 0.028-inch inside diameter. These produce droplets with mean diameters of 800 microns and 1,700 microns, respectively (Kirch 1968).

The Microfoil lays down a sheetlike pattern of spray that falls cleanly behind the helicopter and allows close, accurate placement of spray along boundaries. Drift control was excellent on the Siuslaw National Forest, where little drift was observed with windspeeds up to 12 miles per hour.

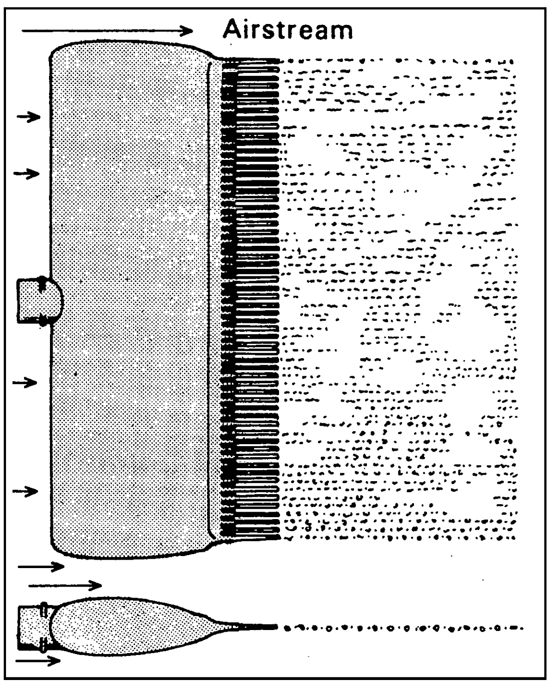

Figure 3.--Top and cross sections of a Microfoil nozzle. (Adapted from Brazelton (1971), with permission of University of California Cooperative Extension Service.)

The Microfoil appears better adapted for foliage spraying than for stem treatments in dormant or bud-break spraying. Average defoliation from bud-break sprays on red alder and tanoak in the Siskiyou National Forest was nearly comparable to that obtained with a conventional boom and D8 nozzles. In a bud-break spray on alder on the Siuslaw National Forest, however, more of the large Microfoil droplets passed through the leafless branches to be lost on the forest floor.

There are several disadvantages in the Microfoil: (1) the needlelike jets are easily clogged or broken, (2) excessive pump pressure can split the plastic bodies of nozzles, (3) some helicopters are not readily adapted to use the Microfoil, and (4) the sheetlike pattern falls behind the pilot where spray coverage is difficult to observe and skips (unsprayed strips) are common.

SPRA-DISK

This apparatus was developed by Amchem Products for helicopter application of invert emulsions, since conventional spray systems had proved unsuitable for use with thick inverts (Gratkowski and Stewart 1973). The Spra-Disk has been useful in spraying utility rights-of-way but has not been used much in spraying forests.

Briefly, the Spra-Disk operates on gravity flow and centrifugal force. The thick invert emulsion flows from the saddle tanks through large-diameter feedlines into a hollow disk mounted beneath the helicopter bubble. An electric motor spins the disk, and centrifugal force carries the invert emulsion out through 12 nozzles mounted on the perimeter of the disk. Centrifugal force is controlled by the pilot through a rheostat that varies speed of revolution of the disk. By changing height above vegetation and varying speed of revolution of the disk, spray swath can be varied from 20 to 50 feet.

VISKO-RHAP AND STULL BI-FLUID

These spray systems are similar in operation. Both are designed to apply invert emulsions. The Stull system was developed by the Stull Chemical Company; the Visko-Rhap system by Hercules, Incorporated. The Visko-Rhap system is now marketed through the Simplex Manufacturing Company of Portland, Oregon, by Rhodia, Incorporated.

Both systems require special invert formulations containing "flash" emulsifiers. As bifluid systems, they depend upon an instantaneous or "flash" formation of the invert emulsion in flight just before discharge through the nozzles. In flight, the oil and the water phases of the spray are carried in separate tanks and pass through separate lines to the mixing chamber. In the Stull system, the invert is formed in a special mixing and metering chamber just before it reaches the pump. In the Visko-Rhap system, the two phases are metered into a pump inverter, which forms the invert and pumps the spray through the system. In both systems, the invert emulsion is then discharged through nozzles spaced along a standard length spray boom.

Both the Stull and Visko-Rhap systems are suitable for use on forest lands. The Stull system has provided acceptable brush control on southwestern forest and range land for about 10 years.

DOW R-511

The Dow Chemical Company's R-511 spray system was specially designed for helicopter application of thick, granular sprays of Tordon 101 Mixture thickened with Norbak particulating agent. The R-511 is more suitable for spraying utility rights-of-way than forest lands.

Basically, the R-511 system consists of a powerful positive displacement pump, extra-large hoses and supply lines, and a cluster of five nozzles centered between the skids ahead of and below the cockpit bubble. The center nozzle has a flat-fan spray tip with an orifice diameter of 0.04 inch or larger. The other nozzles are offcenter nozzles that spray outward; their angle of discharge can be changed in flight to control swath width. In flight, the pilot can vary swath width from 25 to 50 feet while maintaining a constant per-acre application rate with a flow control valve.

MODIFIED R-511

The modified form of the Dow R-511 is better suited for application of thickened sprays on forest land. This version has the five nozzles spaced across a short boom about 8 feet long, with the outer nozzles spraying outward to increase swath width. This modification produces a wider swath than that obtained with the R-511.

This unit seems very adaptable and useful for forest spraying. A modified R-511 has already been used in applying Vistik-thickened, Norbak-thickened, and tank-mixed invert emulsion sprays on the Siuslaw National Forest. With some variation in pump pressure and number and types of nozzles, it should be possible to apply herbicides in conventional carriers as well as thickened sprays.

FOAM SPRAY SYSTEMS

Foam spray application only requires substitution of specially designed foam nozzles on conventional aerial spray booms. Foam nozzles consist of an adapter nut, a special flow control disk and strainer, a foam generator body, and a special nozzle tip. These replace the normal orifice tips and cores of standard aerial diaphragm nozzles. The flow control disk and strainer replace the standard strainer. Boom pressures of at least 40 p. s. i. (pounds per square inch) are generally recommended for applying foam sprays.

Formulations and Spray Adjuvants[1/]

Aerial spray drift can also be reduced by use of invert emulsions or spray adjuvants. Those now available may be classified as: (1) invert emulsions, (2) spray thickeners, (3) particulating agents, or (4) foaming agents. All are designed to reduce drift by increasing droplet size. This is accomplished by increasing viscosity of the spray solution or by producing a larger particle or globule that contains the herbicide. No formulation will completely eliminate drift; all produce some **small, driftable droplets.**

INVERT EMULSIONS

Invert emulsions are thick, creamy or mayonnaiselike mixtures of low volatile esters with oil and water that have been available for more than 10 years. Generally, invert emulsions have not been as effective as equal amounts of herbicides in normal oil-in-water emulsions or oil carriers (Phillips 1963).

1/ More detailed information on formulations, mixing, and use of spray additives is provided in General Technical Report PNW-3 (Gratkowski and Stewart 1973).

In invert emulsions, small water droplets are dispersed within oil. In contrast, the more commonly used oil-in-water emulsions have oil droplets dispersed throughout a much larger volume of water. Invert emulsions contain far more oil (15 to 25 percent by volume) than normal oil-in-water emulsions (5 to 10 percent by volume).

Many special commercial formulations of herbicides that will produce invert emulsions are available. Those containing low volatile esters of 2,4-D and 2,4,5-T are most widely used for woody plant control.

Invert emulsions reduce spray drift by increasing the number of large droplets. Drift is not entirely eliminated, however. Inverts, like all formulations, produce some small droplets during application. As with conventional carriers, the number of small droplets produced depends upon such factors as viscosity of the invert emulsion, nozzle tips, orifice size, boom pressure, flying speed, and nozzle orientation on the spray boom.

Viscosity (thickness) of invert emulsions depends upon the ratio of oil to water and upon the size of water droplets produced by agitation. In the field, viscosity can be changed by changing the amount of oil. As more oil is added, an invert emulsion becomes thinner and more fluid. Very thin inverts can be applied through conventional aerial spray systems.

Special aerial spray equipment is needed to apply thick invert emulsions. Type of equipment required depends upon the commercial product used.

Amchem's Spra-Disk or Dow's R-511 can be used to apply thick invert emulsions. For these, the invert emulsion is premixed in a nurse tank and then pumped into the saddle tanks of the helicopter.

The Visko-Rhap and Stull Bi-fluid spray systems require special commercial formulations. These bifluid systems depend upon an instantaneous or "flash" formation of the emulsion in flight; therefore, the commercial product must contain a flash emulsifier. Label instructions specify whether the herbicide should be added to the oil tank or to the water tank on the helicopter. **Invert emulsions for Bi-fluid systems are never premixed in a separate nurse tank.**

THICKENING AGENTS

Three commercial thickening agents are available at present. These are Vistik, Dacagin, and Lo-Drift. **All** are water soluble and increase droplet size and reduce drift by increasing the viscosity (thickness and flowability) of the water in herbicidal spray mixtures. **None of these can be used to thicken oil carriers.**

Vistik.--Vistik is a chemically inert cellulose product that looks and feels like flour. When applied during the proper season, Vistik did not reduce effectiveness of 2,4,5-T **or** 2,4,5-T/TCA mixtures on woody plants in the east (Suggitt 1965) nor that of paraquat on crop plants in Oregon (Ekins et al. 1970). However, it did reduce defoliation of salmonberry treated in late August--a season generally too late for good control of salmonberry.

Vistik can be used to thicken herbicides in water carriers or in oil-in-water emulsions. Such sprays may be in the form of solutions, emulsions, or suspensions of wettable powders. It has been used with amitrole-?', phenoxy esters and amines, picloram, and silvex. Vistik will thicken only the water phase of such spray mixtures. Four to **6** pounds are normally added per 100 gallons of spray. During the past 2 years, **4** pounds of Vistik per 100 gallons of spray mixture has provided acceptable drift control with phenoxy herbicides and with amitrole-T.

Vistik-thickened sprays are fluid and can be applied through conventional aerial spray booms. For aerial spraying, D8 **or** D10 hollow cone tips without whirl plates are used on standard diaphragm tee-jet nozzles. Pump pressure should be 25 to 35 p. s. i., depending upon viscosity, nozzle tips, and desired rate of discharge. Vistik-thickened sprays can also be applied with the modified R-511 spray system.

A Vistik viscosity cup should be used periodically to check viscosity of Vistik-thickened spray in the mixing tank. For aerial spraying from approximately 80 feet above vegetation, the mixture should take 75 to 80 seconds to drain from a filled cup. If a tank of Vistik-thickened spray is'left standing in the sun, viscosity will decrease as the solution warms. More Vistik may be added (with agitation) to maintain the desired viscosity.

Dacagin. -- Dacagin is a dry, granular material that forms a gel when mixed with water or oil-in-water emulsion carriers. As with Vistik, Dacagin thickens only the water phase of the carrier. The gel can be used as a carrier for water soluble herbicides, emulsifiable chemicals, and wettable powders. Examples are amine salts and ester formulations of 2,4-D and'. 2,4,5-T and wettable powders such as atrazine or dalapon. Dacagin does not seem to affect herbicidal activity. On shrubs and weed trees in northwestern California, Dacagin-thickened sprays appeared as effective as the same herbicides and carriers without Dacagin.

Unlike Vistik sprays, Dacagin gels do not become more fluid while standing. However, the gels have the unusual property of decreasing in viscosity while being agitated or pumped but regaining their initial viscosity after agitation stops. In practical terms, this allows herbicides in Dacagin gels to be applied with ordinary aerial spray equipment. The gel thins while moving through the spray lines and boom but thickens again to produce large droplets after discharge from the nozzles. Therefore, special application equipment is not required.

Although conventional aerial spray equipment can be used to apply Dacagin gels, the modified R-511 should also be suitable. All screens in supply lines and nozzles must be 50 mesh or larger. Pump pressures should be 25 to 35 p. s. i.

Lo-Drift. --Lo-Drift is a new product--a water soluble polyvinyl polymer designed for use with herbicides in water carriers. It differs from Vistik and Dacagin in that it: (1) is a liquid, (2) requires a wetting agent such as Multi-film X-77 to activate the polymer. Lo-Drift may be used with herbicides in either water carriers or oil-in-water emulsions. Like Dacagin gels, aerial sprays thickened with Lo-Drift can be applied with conventional aerial spray equipment. Limited data indicate that Lo-Drift did not change activity of six different herbicidal formulations on several agricultural crop plants.

Only very small amounts of Lo-Drift are required in herbicidal sprays. For aerial application of herbicides in water carriers, at least 32 fluid ounces of Lo-Drift must be added per 100 gallons of spray.[2/] The thickened spray has a viscosity like that of mineral oil and is easily pumped through conventional spray booms with a 30-p. s. i. boom pressure. D8 nozzles without whirl plates are used on conventional booms; the nozzles directed back along the airstream at an angle not greater than 30 degrees from horizontal. All screens in supply lines and nozzles should be 50 mesh or larger.

Lo-Drift O.S. --Early spring herbicidal sprays on red alder, vine maple, and other deciduous species in the Pacific Northwest are applied in oil carriers. Oil is needed to carry the chemical through the bark of the leafless branches. Since oil with its low surface tension produces even more fine droplets than water carriers, a thickening agent for oil carriers is urgently needed to control drift in early spring aerial spraying.

Lo-Drift O.S. (oil soluble) is the only spray thickener designed for use with oil carriers. Lo-Drift O.S. is still in the developmental stage. Project-scale trials to determine its effectiveness in reducing drift of herbicidal sprays and to measure its influence on herbicidal activity are in progress on several National Forests in western Oregon.

PARTICULATING AGENTS

Norbak (Dow Chemical Co.) is the only particulating agent available at present. It is a water swellable plastic polymer that looks and feels like granulated sugar.

Unlike thickening agents that increase the viscosity of water, each Norbak granule absorbs the water of spray solutions and swells to a fixed size. Any herbicide dissolved in the water will also be absorbed.

Norbak is especially useful for herbicides that are soluble in water. These

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[2/] Change from recommendation in General Technical Report PNW-3 (Gratkowski and Stewart 1973). This new recommendation is based upon aerial spray tests conducted on the Umpqua National Forest after General Technical Report PNW-3 was published.

include amines and metallic salts of 2,4-D or 2,4,5-T. Such formulations will be imbibed with the water. If used with esters of phenoxy herbicides or with wettable powders such as atrazine or dalapon, only the water phase of the spray will be absorbed.

Effects of Norbak on herbicidal activity are contradictory. Byrd and Reimer (1966) found no reduction in effect of picloram, but Ekins et al. (1970) state that Norbak reduced the activity of paraquat on field crops. Unfortunately, good comparisons are not available for woody plants. It seems possible, however, that clumping of Norbak particles and absorption of some herbicide into the particles could reduce absorption of herbicides from Norbak on plant surfaces. If true, this could reduce effects of herbicides in the low volume sprays used on forest-land shrubs and weed trees.

Because granular Norbak-particulated sprays are much thicker than viscous sprays thickened with Vistik, Dacagin, or Lo-Drift, agitation in the mixing tanks, pumps, and spray equipment must be more powerful. Mixing tanks should have the best mechanical agitation possible. The transfer pump must be a positive displacement pump. The tank must have a bottom outlet, and the pump should be mounted below that level. All hoses and supply lines must be 1-1/2 inches or larger in inside diameter and as short as possible.

Norbak sprays can be applied only with the Dow R-511 or possibly the modified R-511 with short boom. The R-511 is used only on utility rights-of-way; the modified R-511 can be used in forest spraying as well as on rights-of-way. In either case, nozzles should have flat-fan tips or cone tips without whirl plates and orifice diameter of nozzles should be 0.04 inch or larger. The spray boom must be at least 1.20 inches inside diameter with a minimum spray pressure of 20 p.s.i. at the end of the boom.

FOAM SPRAYS

Foaming agents are the newest spray additives designed to reduce drift. Foam sprays are easier to store, transport, mix, and apply than invert emulsions or thickened sprays. Basic components of this system are: (1) a water soluble liquid containing the foaming agent, stabilizers, and wetting agents; and (2) specially designed nozzles that mix air into the spray to create a foam.

Field trials indicate that foam sprays provide good drift control and do not reduce effectiveness of herbicides. Foam carriers were used on alder, salmonberry, and thimbleberry in a State forest and a National Forest during July and August 1972. Observation several months later indicated results comparable to the same materials in normal carriers.

Several foaming agents are available. Trade names of a few are Accutrol, Foamspray, and Fomex. Each company specifies that a certain type of foam nozzle be used with its product. **Only the nozzles recommended by the manufacturer of the foaming agent should be used.** The nozzles are designed to fit the air-to-liquid expansion ratio of the foaming agent.

Foaming agents can be used with water carriers and oil-in-water emulsions. This would include water soluble herbicides, esters of phenoxy herbicides, and wettable powders such as atrazine. **Foaming agents should not be used with oil carriers.** Rates are low--1/2 to 1 gallon per 100 gallons of spray; the higher rates are used with emulsions. Foamed sprays are applied with conventional aerial spray equipment modified only by substituting special foam nozzles in place of standard tips and cores (see page 7).

PERSONNEL AND SUPERVISION

Finally, effective drift control on any aerial spray job requires more than familiarity with special spray equipment, formulations, and additives. Well-trained personnel are a necessity to assure full benefit from this preparatory work. Above all, the keyman on any spray project is an expert pilot. His skill and judgment will assure best results from carefully selected formulations and equipment and insure that spray is applied only on the target area. If the pilot fails, all precautions and work are wasted and an area that should have been protected gets sprayed.

,At least three men are needed to properly supervise aerial spraying on forest land. One is the supervisor or COR (contracting officer's representative) at the heliport. The other **two** are observers who follow and observe the operation on the ground. All three should be thoroughly familiar with the area--especially the sites to be sprayed. Each should have his own vehicle and two-way radio. The pilot should also have a two-way radio as part of the net. In this way, the supervisor and pilot can immediately be notified of sudden changes in weather conditions or other factors on the spray areas, and the observers can be notified of any changes in plans and rerouted to alternate sites.

Before spraying begins, the COR should supply the pilot with a well-marked map that clearly shows each brush area, cutting, or part of a cutting that is to be sprayed. Also, either the COR or one of the observers should make a short reconnaissance flight with the pilot to show him the location of each area to be sprayed and their planned sequence, and to brief him on any special considerations in specific areas.

The COR remains at the heliport and works with the pilot. He makes sure that the herbicides, carriers, and additives are properly mixed, checks calibration of the spray equipment, and makes any necessary viscosity checks before and during spray operations. He is responsible for stopping operations when weather conditions exceed acceptable limits or when equipment must be cleaned or repaired to insure safe application.

The two inspectors follow the operation on the individual spray areas, one inspector to an area. In their separate vehicles, they leapfrog to cover alternating spray areas, provide continual onsite control, and help the pilot to fully utilize all possible spray time. Before the helicopter reaches a new area, they check windspeed, air temperature, and relative humidity, and radio these data to the COR with any other information that may affect spraying. While the area is being sprayed, they make periodic checks on wind, temperature, and humidity, and look for any sign of wind gusts or air movement that might cause spray drift into nontarget areas. They also watch for plugged or leaking nozzles or other defective equipment. They keep the COR and pilot advised of these and any other conditions that may require special care on the part of the pilot or cessation of operations.

CONCLUSION

In closing, one final point must be stressed. The forest environment must be protected from damage or any unnecessary changes or modification of habitats. Whenever we apply aerial sprays, we must be sure that everyone in the vicinity is aware of the helicopters in the air and the activity on the ground. We can also be sure that at least some of these people **will** be concerned about effects on the environment and critical of the spray operation. Each of us must make every effort to use herbicides properly, to spray only areas that need treatment, to use minimum amounts of herbicide, and--above all--to prevent damage to adjacent properties and ecologically sensitive areas.

Intensive forest management will require herbicides and every other effective silvicultural tool if we are to provide the forest products that will be needed by future generations. Careless work and needless damage on any spray project can nullify careful work on all others and possibly result in loss of this valuable silvicultural tool.

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Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

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