North Dakota Aerial Spray Analysis Program

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Introduction

The uniform application of pesticides is extremely important to obtain good pest control at a reasonable cost. This applies equally to aerial and ground applicators. The applicator must be calibrated correctly and must be applying pesticides evenly over the spray swath to obtain uniform application. Pattern adjustment and calibration is easier with ground spray equipment than with aerial equpment. Ground sprayers need only use nozzles in good condition, mount them at the proper spacing and height, and operate them at the proper pressure.

Aerial applicators are not able to calibrate and modify the spray pattern of their aircraft as easily. They make adjustments following general guidelines and hope a uniform pattern emerges. Mounting nozzles over three-fourths of the wingspan to avoid discharging spray in the wingtip vortex, clustering nozzles on the right side of the fuselage and reducing nozzle numbers on the left side of the fuselage to compensate for propwash takes care of only part of the problem. Nozzle type and size, nozzle position, climatic conditions, flying height, boom positions in relation to the wing, gallons per acre applied, flying speed and various equipment on the airplane such as markers and anti-vortex wingtips add to the problem of uniform application.

All pesticides require uniform application or poor response may occur. Poor response may show up as streaks through the field. Also, if chemicals are misapplied, the chance of pesticide residue showing up in the crop is high. This may cause rejection of the crop from the marketplace.

Up until the spring of 1985, very little help to the aerial applicators was available from the North Dakota Cooperative Extension Service. In the past, pattern testing involved laying sheets of paper across the flight path of the airplane discharging a dye. The sheets of paper were examined visually for dye mark patterns and nozzle adjustments made accordingly based on density of drops. In May of 1984, a chemical manufacturing company and Washington State University sponsored a pattern testing program for aerial applicators. This involved using a much more sophisticated pattern measurement system than visual examination. The North Dakota Cooperative Extension service duplicated the Washington State method and offered the service to applicators.

In May of 1985, spray analysis testing was held at five locations throughout the state jointly sponsored by the North Dakota Agricultural Aviation Association and North Dakota State University.

Aerial Applicator Services

Operation "SAFE" is a program of education and pattern testing sponsored by the National Agricultural Aviation Association. SAFE stands for Self-Regulating Application and Flight Efficiency.

Aerial applicators are extremely concerned about reducing pesticide drift onto non-target areas. It is important to reduce to a minimum the pollution from pesticides by providing safe procedures and adequate training. Pattern testing with the ability to measure percent deposition is a means of determining the amount deposited in the target area and the amount carried downwind.

Understanding the cause and control of spray drift is an essential part of SAFE aerial application information. This is presented to applicators in a slide presentation. Some of the factors related to pesticide drift are:

1. Type of equipment used, application techniques and operator skill. All of these factors can affect droplet size, which in turn affects drift.
2. Chemical formulation and volatility.
3. Weather conditions in and near the field to be sprayed and the proximity of sprayed fields to susceptible crops are other important factors.

Information is provided to the North Dakota aerial applicators in three areas. These are:

1. Spray atomization and nature of spray along with ideas and suggestions on system care and maintenance.
2. Consideration as to where the spray goes. Is the pesticide deposited in the target area or carried downwind.
3. Spray pattern interpretation and assistance in pattern adjustment.

Aerial applicator pattern testing is beneficial to the farmer-producer as well as the applicator. If an aerial applicator knows the type of pattern his aircraft is producing, he can do the best possible job for his customer.

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Swath Pattern Measurement and Equipment

Swath pattern measurement programs have been well accepted by aerial applicators. This service will be available in future years in the North Dakota Aerial Applicator spray program.

The swath test provides information to the aerial applicator on how his aircraft performs while applying pesticides. It provides information on swath width, uniformity of coverage across the swath and the percent of spray hitting the target. A pilot can quickly determine the influence of nozzle angle, location, boom position, flying height, speed application rate and other factors affecting spray pattern. The applicator is welcome to try different nozzle arrangements and application techniques. All test information is confidential and is for the use of the applicator only.

During the spring of 1985, a total of 51 airplanes were involved in pattern testing. Fly-ins were held at five locations throughout the state. The sites were Dickinson, Jamestown, Devils Lake, Grafton and Kindred. A local applicator was host at each location. Additional manpower was supplied by local representatives of pesticide manufacturers, aerial applicators and county extension agents.

Swath testing of an aircraft is relatively simple. The plane must first be calibrated. Many applicators already know their application rate in gallons per acre. Accuracy in gallons per acre applied is extremely important since the percent deposition is dependent on the application rate.

Calibration is done by adding water to a known level in the tank. The pilot then flies the plane for one minute with the boom on. Then the pilot is directed to set his plane in the original spot. The level of the water remaining in the tank is read. The discharge in gallons per minute can be determined from this information. Travel speed must be known and can be determined in one of two ways. The one commonly used by applicators is to measure the time it takes to fly one mile. Then the speed can be calculated with the following formula:

$$\text{MPH} = \frac{\text{Distance (ft.)} \times 60}{\text{Seconds} \times 88}$$

The other method is to use a radar gun. North Dakota State University has a highway department radar gun to measure flying speed during calibration and testing.

The last item needed to calculate gallons per acre (GPA) is swath width. This is obtained from the applicator based on his experience. With gallons per minute, travel speed and swath width available, the gallons per acre can be found by the following formula:

$$\text{GPA} = \frac{495 \times \text{GPM}}{\text{Speed (mph)} \times \text{Width (ft.)}}$$

Copper sulfate pentahydrate (25% cu. superfine crystals) is mixed in water and added to the spray tank at the rate of ½ lb. $CuSO_4$ per acre. This is measured out in 2.5 lb. and 5 lb. bags prior to a fly-in. With a plane calibrated for a particular GPA, the number of gallons of water added to the plane is found by the following formula:

$$\text{Gallons} = \text{lbs. Cu.} \times \text{GPA} \times 6$$

The number 6 is a standard factor. The standard factor of 6 is found by dividing 3 (for 3 passes over the test track) by .5 pounds per acre for the application rate:

$$\text{Standard Factor } 3/.5 = 6$$

The copper tracer and equipment is designed to measure copper concentrations at ½ lb. per acre. This copper is diluted in water at ⅓ rate, so three passes of the plane are combined and analyzed. Three passes reduce the effect of errors of one pass to ⅓.

Most of North Dakota has high pH water in the range of 8.0 to 9.2. This causes the $CuSO_4$ to form a precipitate. A buffer is added to the spray tank which helps reduce the rate of precipitate formation.

After the airplane is loaded with $CuSO_4$ and buffer solution, the pilot is directed to purge his spray boom and fly to the test area (Figure 1). He is directed to fly his plane at the

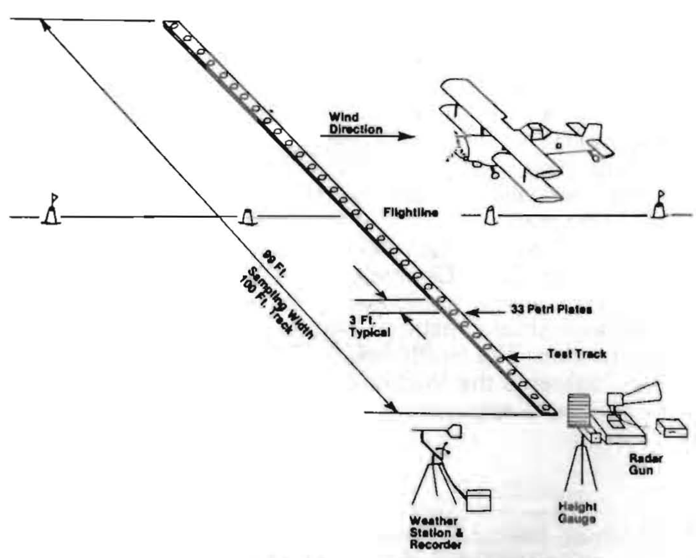


Figure 1. Test Track and Equipment Arrangement.

speed and height he normally uses when spraying. It is suggested that he fly one practice run to become familiar with the equipment set-up at the test site. Then he is to make the three passes needed for the test.

The test track is 100 feet long with 33 petri plates (3 7/16 inches diameter) placed at 3-foot intervals. The track is located close to an airstrip but far enough away so planes can fly in any direction without interfering with other airport traffic. The test track should be located on a grassed area to reduce the influence of convective air currents from the ground on warm days. The track is situated perpendicular to prevailing winds. This allows planes to fly directly into the wind to reduce pattern distortion from crosswinds. When breezes rise above 10 mph, pattern testing is usually stopped unless the wind direction is constant.

During a pattern test, the pilot lines his aircraft up with markers located ahead and behind the test track. As the plane approaches the test track, its speed is measured with a radar gun. Flying height is measured with a height gauge located 10 feet from the end of the track. It is calibrated to measure the height of the plane at the center of the track. Weather conditions sometimes affect patterns, so wind speed and direction are recorded during each of the three passes across the track and averaged together for the computer printout. Ambient temperature and relative humidity is recorded as this affects evaporation of the spray droplets and deposition. This information is recorded by a Clima Tronics weather station.

When the aircraft has made three passes across the test track, the petri plates are picked up in sequence and taken to the analysis area along with the other data collected at the flight line.

The analysis area (Figures 2 and 3) determines the spray pattern values which are input into the computer program. An IBM portable computer with printer is used for data analysis and printout.

The petri plates are assembled on a table in the order they were obtained from the flight line. Twenty-five milliliters of copper sensitive tracer is added to each petri plate. The tracer is mixed with the copper deposited in the plates. Intensity of color change is analyzed with a colorimeter. The 460 mm. wavelength filter is used for this analysis. The colorimeter measures light transmittance from 0 to 100 percent and gives a digital readout. The 33 values are input to the computer program to give a printout as shown in Figure 4. The program will give single pattern readouts plus multiple pass analysis. A swath spacing is selected and a multiple pattern printout is obtained.

Figure 2. The change of color of the copper tracer is analyzed with a colorimeter to give a digital readout.

Figure 3. The colorimeter readings are input to the computer program for analysis and printout.

Pattern Analysis Results - 1985

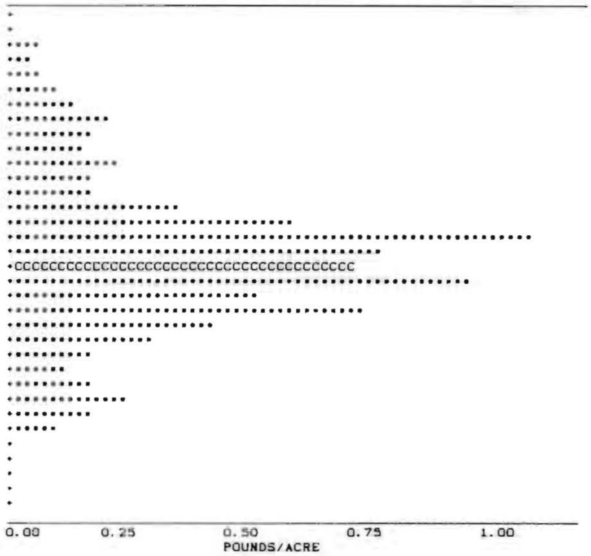
The majority of the airplanes analyzed the first year were manufactured by Cessna, Piper and Schweizer. Uniformity of spray patterns of planes tested ranged from excellent to poor.

The following is an example, Figures 4 to 7, of one aircraft that completed four tests at the 1 GPA rate. The test report lists information about the aircraft and the boom configuration. The center section of the report shows the spray pattern produced. The lower section lists specifics on weather conditions, travel speed of the plane, application rate, probable swath width, and percent deposition. The wind speed is an average of the three values collected at the time the plane crossed the flightline. The crosswind vector is a calculated value of the wind effect perpendicular to the flight path of the aircraft. It is calculated from the wind speed and the wind direction. Wind direction was measured at the time the plane crossed the flightline. Gusty wind at an angle to the flight path often occurs and can distort spray patterns. A negative wind direction is from the left of the flight path and a positive value is from the right.

Probable swath width is calculated from the point on the edge of the spray pattern when the deposit reaches the 50 percent deposition level and extends to the opposite side of the swath when the deposit drops below the 50 percent level. The percent deposition is based on the accuracy of calibartion of the aircraft and is determined by comparing

NORTH DAKOTA STATE UNIVERSITY -- COOPERATIVE EXTENSION SERVICE
SPRAY ANALYSIS PROGRAM

PLANE OPERATOR:	PLANE #:
AIRCRAFT TYPE: PIPER BRAVE	ENGINE TYPE: OPPOSED
ENGINE HORSEPOWER: 300	NUMBER OF PROPELLOR BLADES: 2
WING SPAN: 40	BOOM SPAN: 29
BOOM TYPE: AIRFOIL	BOOM/CHORD POSITION: BELOW 12 INCHES
BOOM /EDGE POSITION :BEHIND 8 INCHES	BOOM HANGERS: STRAP
NIPPLE TAP POSITON: REAR	NIPPLE LENGTH: 1
LOCATION OF SHUTOFFS:	STREET L'S: YES
OPERATING PRESSURE: 25	NOZZLE ORIENTATION: DOWN 15
PUMP TYPE: WINDMILL	NOZZLE TYPE: RAINDROP D-6-45

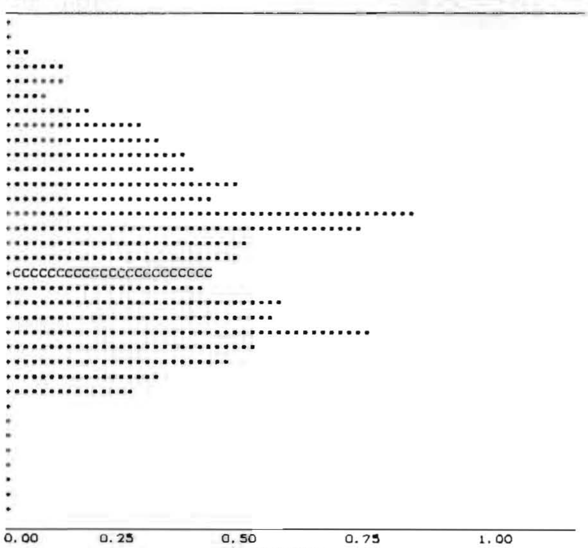


TEST DATE:	TEST #: 1
TEMPERATURE: 70	RELATIVE HUMIDITY: 37
WIND SPEED: 2	WIND DIRECTION: 87
APPLICATION HEIGHT: 3.3	GALLONS PER MINUTE: 13
GALLONS PER ACRE: 1	GROUND SPEED: 117
CROSS WIND VECTOR: 2	% DEPOSITION: 54
PROBABLE SWATH WIDTH: 27	

Figure 4. First Pass of the Example Aircraft.

NORTH DAKOTA STATE UNIVERSITY -- COOPERATIVE EXTENSION SERVICE
SPRAY ANALYSIS PROGRAM

PLANE OPERATOR:	PLANE #:
AIRCRAFT TYPE: PIPER BRAVE	ENGINE TYPE: OPPOSED
ENGINE HORSEPOWER: 300	NUMBER OF PROPELLOR BLADES: 2
WING SPAN: 40	BOOM SPAN: 29
BOOM TYPE: AIRFOIL	BOOM/CHORD POSITION: BELOW 12 INCHES
BOOM /EDGE POSITION :BEHIND 8 INCHES	BOOM HANGERS: STRAP
NIPPLE TAP POSITON: REAR	NIPPLE LENGTH: 1
LOCATION OF SHUTOFFS:	STREET L'S: YES
OPERATING PRESSURE: 25	NOZZLE ORIENTATION: DOWN 15
PUMP TYPE: WINDMILL	NOZZLE TYPE: RAINDROP D-6-45

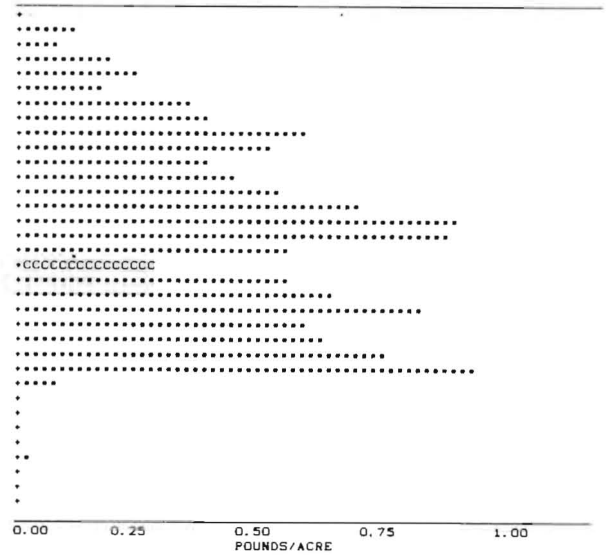


TEST DATE:	TEST #: 2
TEMPERATURE: 74	RELATIVE HUMIDITY: 30
WIND SPEED: 5.6	WIND DIRECTION: 66
APPLICATION HEIGHT: 3.6	GALLONS PER MINUTE: 11.3
GALLONS PER ACRE: 1	GROUND SPEED: 102
CROSS WIND VECTOR: 5.12	% DEPOSITION: 58
PROBABLE SWATH WIDTH: 48	

Figure 5. Second Pass of the Example Aircraft.

NORTH DAKOTA STATE UNIVERSITY -- COOPERATIVE EXTENSION SERVICE
SPRAY ANALYSIS PROGRAM

PLANE OPERATOR:	PLANE #:
AIRCRAFT TYPE: PIPER BRAVE	ENGINE TYPE: OPPOSED
ENGINE HORSEPOWER: 300	NUMBER OF PROPELLOR BLADES: 2
WING SPAN: 40	BOOM SPAN: 29
BOOM TYPE: AIRFOIL	BOOM/CHORD POSITION: BELOW 12 INCHES
BOOM /EDGE POSITION :BEHIND 8 INCHES	BOOM HANGERS: STRAP
NIPPLE TAP POSITON: REAR	NIPPLE LENGTH: 1
LOCATION OF SHUTOFFS:	STREET L'S: YES
OPERATING PRESSURE: 25	NOZZLE ORIENTATION: DOWN 15
PUMP TYPE: WINDMILL	NOZZLE TYPE: RAINDROP D-6-45

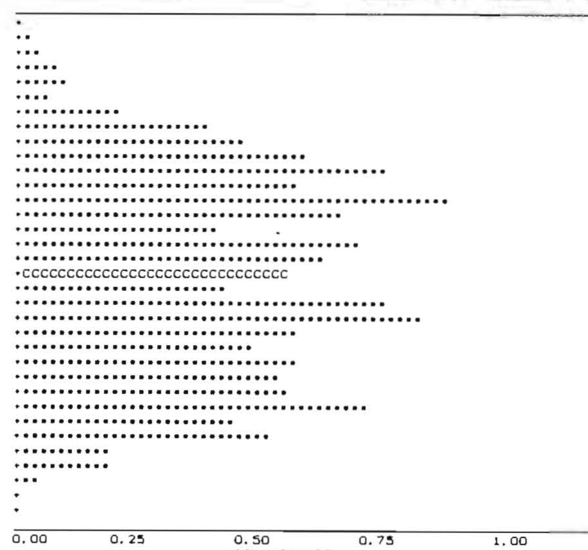


TEST DATE:	TEST #: 3
TEMPERATURE: 80	RELATIVE HUMIDITY: 28
WIND SPEED: 2.3	WIND DIRECTION: 14
APPLICATION HEIGHT: 6	GALLONS PER MINUTE: 11.5
GALLONS PER ACRE: 1	GROUND SPEED: 103
CROSS WIND VECTOR: .56	% DEPOSITION: 74
PROBABLE SWATH WIDTH: 51	

Figure 6. Third Pass of the Example Aircraft.

NORTH DAKOTA STATE UNIVERSITY -- COOPERATIVE EXTENSION SERVICE
SPRAY ANALYSIS PROGRAM

PLANE OPERATOR:	PLANE #:
AIRCRAFT TYPE: PIPER BRAVE	ENGINE TYPE: OPPOSED
ENGINE HORSEPOWER: 300	NUMBER OF PROPELLOR BLADES: 2
WING SPAN: 40	BOOM SPAN: 29
BOOM TYPE: AIRFOIL	BOOM/CHORD POSITION: BELOW 12 INCHES
BOOM /EDGE POSITION :BEHIND 8 INCHES	BOOM HANGERS: STRAP
NIPPLE TAP POSITON: REAR	NIPPLE LENGTH: 1
LOCATION OF SHUTOFFS:	STREET L'S: YES
OPERATING PRESSURE: 25	NOZZLE ORIENTATION: DOWN 15
PUMP TYPE: WINDMILL	NOZZLE TYPE: RAINDROP D-6-45



TEST DATE:	TEST #: 4
TEMPERATURE: 80	RELATIVE HUMIDITY: 24
WIND SPEED: 5	WIND DIRECTION: 7
APPLICATION HEIGHT: 5	GALLONS PER MINUTE: 11.2
GALLONS PER ACRE: 1	GROUND SPEED: 101
CROSS WIND VECTOR: .6	% DEPOSITION: 84
PROBABLE SWATH WIDTH: 60	

Figure 7. Fourth Pass of the Example Aircraft.

the amount of chemical collected at the test track against the amount being discharged from the plane. Errors may enter due to small variations occurring from changes in flying technique and calibration, and the speed is an average of the three speeds measured with the radar gun as the plane crossed the test track. This was fairly constant for all three passes for most applicators.

Figure 4 is the spray pattern produced by an aircraft prior to any adjustments. The pattern is extremely heavy in the center (the centerline of the test track is indicated with the character C) and lighter on the outside edges. The swath width is 27 feet, which is a relatively stacked, narrow pattern. Several factors appear to contribute to the narrow pattern. Aircraft speed is 117 mph which may be too fast. The average application height of 3.3 feet may be too low to allow proper spray pattern development. Also, nozzles may be improperly spaced along the boom. Too many nozzles near the center of the aircraft can cause pattern stacking in the center. Deposition is 54 percent in this first pass. These items were pointed out to the pilot and adjustments were made.

Figure 5 shows the spray pattern of the same plane after nozzle and spray speed adjustment. A noticeable change occurred in the pattern by decreasing speed to 102 mph and adjusting the nozzle positions.

Spray nozzles directly to the right of the fuselage were closed and an equal number of nozzles opened approximately midway out on each wing. Travel speed was decreased from 117 mph to 102 mph. The flying height still remained at between 3 and 4 feet. These changes produced a swath width increase from 27 feet to 48 feet. The high deposit in the center of the plane was reduce, and deposition increased from 54 percent to 58 percent. These items were discussed with the pilot, and it was suggested he increase his flying height to between 6 and 12 feet and fly another trial.

Figure 6 shows the spray pattern of the third trial flown at an average height of 6 feet. The result was a slightly wider swath width of 51 feet with a deposition of 74 percent. This shows that more spray is ending up on the sprayed surface and less is getting caught up in aircraft turbulance. The wider swath width is due to the spray pattern being allowed to develop more completely. It should also be noted that throughout all the tests, air temperature increased and relative humidity decreased. This will have an adverse affect on droplet deposition due to increased droplet evaporation.

The distortion on the right side of the pattern (Fig. 6) is due to a wind gust from the right during the pattern test. Figure 6 shows elevated deposition on both sides of the centerline. It was suggested to close one more nozzle under the fuselage and one nozzle to the right of the right landing wheel. Then it was suggested to open one more nozzle near the end of each spray boom. It was felt that this would increase the discharge near the outer edges of the pattern.

A fourth trial was run after the suggested nozzle changes were made. Figure 7 shows the resulting pattern. Swath width increased to 60 feet and the deposition increased to 84 percent. Even though some variation in the spray pattern still exists, the pattern uniformity and percent deposition is markedly improved when Figure 7 is compared to Figure 4.

The computer program is designed to simulate multiple pass application of the spray pattern measured. A swath width and type of pattern, either a back and forth or racetrack pattern, is selected. Figures 8 and 9 show a

Figure 8. Multiple Pass Printout of Figure 4 Test Pattern.

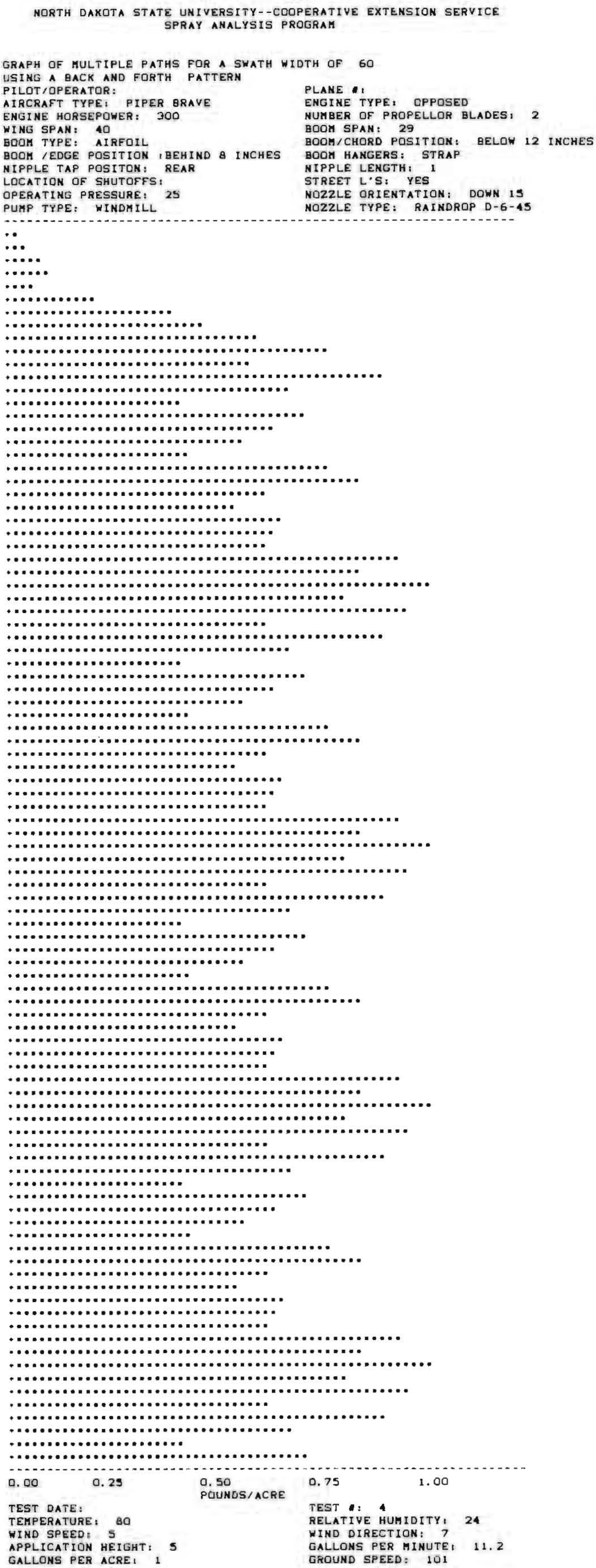


Figure 9. Multiple Pass Printout of Figure 7 Test Pattern.

60-foot swath using the back and forth method with the spray patterns from Figures 4 and 7. Figure 8 shows definite voids in the pattern, and the swath spacing would need to be reduced to approximately 27 feet to achieve any degree of uniformity. Figure 9 shows the 60-foot swath width using the spray pattern from Figure 7. It is considerably more uniform and would do a much better job of applying pesticides.

The change in percent deposition and swath width for 51 aircraft is shown in Figure 10. The percent deposition is a comparison of individual aircraft on one pass to another at equal application rates. This indicates the effect of nozzle orientation, placement, flying height and other variables on the amount deposited in the target area. Swath width is affected by nozzle placement, orientation and flying technique. The change produced at the five sites is shown:

Figure 10. Change in Deposition and Swath Width.

	No. of Aircraft	% Deposition Increase	Swath Width Increase (ft)
Dickinson	8	14.8	4.8
Jamestown	15	24.0	10.3
Devils Lake	9	5.4	13.3
Grafton	12	4.2	7.0
Kindred	7	5.0	6.7

The percent increase in deposition ranges from 4.2% to 24.0%. This indicates that with pattern testing, more of the spray is deposited in the target area and less is carried downwind in swath displacement and drift. Average spray swath width increases varied from 6.7 ft. to 13.3 ft. increase. This helps applicators make fewer trips across the field resulting in a better spray pattern from less overlap and a better profit margin from their spraying job.

Summary

One way an aerial applicator can determine how well his spray plane is applying pesticides is to do pattern analysis. This study demonstrated that pattern analysis followed by needed boom and nozzle adjustment and application procedure modifications, aircraft spray patterns can be greatly improved.

The measurement of percent deposition enables determination of relative deposit levels on the target when comparing pattern tests of the same plane and application rates. It is also important in determining the relative amount of spray deposited on the target and drift reduction.

This method of spray pattern evaluation is not capable of determining droplet size and plant canopy penetration. Ongoing research is addressing techniques of evaluation of droplet size and canopy penetration that will be incorporated into future programs. Future pattern testing will also evaluate the effect of spray adjuvants that reduce drift.

Continued on page 39

percentage of personal income accounted for by farm income is more than four and one half times that of the WNC region. This suggests that North Dakota continues to rely much more on agriculture than its neighboring states do.

References

[1]**Survey of Current Business**, Bureau of Economic Analysis, U.S. Department of Commerce, monthly publication.

[2]**North Dakota Farm Research**, Agricultural Experiment Station, North Dakota State University, Vol. 42, No. 1, (July-August, 1984).

[3]**Survey of Current Business**, Bureau of Economic Analysis, U.S. Department of Commerce, Vol. 64, No. 8 (August, 1984).

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Related Literature

1. ASAE Yearbook, 1983. ASAE Standard 5386.1, pp. 252-254. American Society of Agricultural Engineers, St. Joseph, MI 49085.
2. Huitink, Gary. 1980. "Pattern Your Ag. Spray Plane," Bulletin No. MP-183. Cooperative Extension Service, University of Arkansas, Fayetteville, AR 72701.
3. Rester, D. May 1982. "Calibrate Your Ag. Spray Plane," Bulletin DCR1. Cooperative Extension Service, Louisiana State University, Baton Rouge, LA 70803.
4. Kuhlman, D.K., D.C. Cress. December 1981. "Aerial Application Handbook for Applicators," Cooperative Extension Service, Kansas State University, Manhattan, KS 66502.
5. Thomasson, G. 1984. Personal correspondence, Cooperative Extension Service, Washington State University, Pullman, WA 99163.