SPRAY DRIFT REDUCTION WITH SHROUDED BOOM SPRAYERS

by

Ronald J. Fehringer, GRA
Richard A. Cavaletto, Assistant Professor
Agricultural Engineering Department
Oregon State University
Corvallis, OR

SUMMARY:

Downwind drift was measured from a standard boom sprayer and a shrouded boom sprayer. Using 8002 flat fan nozzles, the hooded sprayer provided a 180 to 275% reduction in drift. The effectiveness of the shroud is dependent upon the spray droplet spectrum.

KEYWORDS:

Drift, Sprayers, Applicators, Fluorescent Tracer

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SPRAY DRIFT REDUCTION WITH SHROUDED BOOM SPRAYERS

R. J. Fehringer and R. A. Cavaletto[1]

INTRODUCTION

Several techniques have been studied and employed to minimize the problem of agricultural chemical drift. Operational techniques involve careful timing of the application with the weather. Spraying is postponed during temperature inversions or when the wind is blowing towards sensitive areas. Mechanical techniques involve using different or modified equipment and chemicals. Different nozzle types or spray pressures may be used or the structure of the sprayer may be altered to contain the spray. Sometimes alternate chemicals can be selected. Although operational techniques are less expensive and less complicated, they are not always feasible. Waiting for minimal winds may mean missing the critical time window.

Recent emphasis has been placed on structurally altering the sprayer. Manufacturers are selling sprayers with hoods, shields, and air curtains, claiming that they significantly reduce or eliminate drift. The effectiveness of such alterations are uncertain due to a lack of actual field data.

FUNDAMENTAL DRIFT PROCESSES

The three stages of drift are discharge, transport, and deposition of spray material. In the discharge stage, the primary consideration is the type and size of nozzle used to apply the chemical, and the nozzle pressure. The droplet spectrum from commonly used hydraulic nozzles consists of both coarse (>400 μm) and fine (<100 μm) droplets. Coarse droplets are desirable from the perspective of drift reduction because they are less susceptible to transport due to air currents. Unfortunately, they are undesirable from the perspective of biological efficacy. Fine droplets will give more uniform coverage for the same application rate. Appleby (1990) has shown that lower rates of active ingredient are required with fine droplets.

In the transport stage, meteorological conditions begin to influence the spray droplet immediately after it leaves the nozzle. The primary factors of concern are the direction and speed of the wind, the relative humidity, and the temperature of the air. Windspeed determines whether the droplet will be swept away from its target and how far it will be

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[1]The authors are: Ronald J. Fehringer, Graduate Research Assistant, and Richard A. Cavaletto, Assistant Professor, Agricultural Engineering Dept., Oregon State University, Corvallis, OR.

carried, while wind direction determines whether the droplet will be carried to an undesired area. Relative humidity controls the evaporation rate. Given sufficient travel time, some drops may evaporate completely before landing. The air temperature of different layers above the ground influences whether the air will be turbulent or stable (Akesson and Yates, 1987).

In the deposition stage, a droplet must overcome any wind shear forces over the contact surface before landing. The flow of air parallel to a surface can deflect a droplet on its approach and carry it over the initial destination, such as a plant leaf. The importance of the shear effect varies with the type and size of target. A droplet entering a crop canopy will likely be deposited due to the variety of leaf orientations and density of leaves. A droplet approaching a single flat surface, however, may be carried over and beyond it.

OBJECTIVES

Renn-Vertec Inc.,[1] Vermillion, Alberta, Canada, a manufacturer of boom sprayers, is using a shrouded hood design developed by Rodgers Engineering, Saskatoon, Saskatchewan, Canada. Rodgers and Ford (1985), reported that the shroud and its front and rear curtain provide a wind-sheltered zone which increases the opportunity for droplet settling (Figure 1). The air-foil mounted on top of the shroud is intended to change the air currents so that the back-eddy is eliminated. Thus, the airflow parallels the shroud and the ground surface behind it.
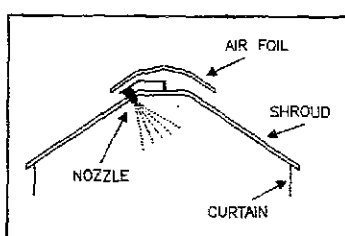

Figure 1. Renn-Vertec Shroud and Foil, Side View

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[1]The use of trade names for commercial products is for informational purposes only and does not imply endorsement of the product named, nor criticism of similar products not mentioned.

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The primary objective of this study was to compare the downwind drift under varied wind speeds for the four following sprayer configurations:

A) Standard open-boom sprayer, 8002 nozzles, 276 kPa (40 psi)
B) Renn-Vertec sprayer, 8002 nozzles, 276 kPa (40 psi), no air-foil
C) Renn-Vertec sprayer, 8002 nozzles, 276 kPa (40 psi), air-foil
D) Renn-Vertec sprayer, 800025 nozzles, 414 kPa (60 psi), air-foil

Within this comparison, three questions were addressed:

1) Does the shrouded hood on the Renn-Vertec reduce drift? (A versus C)
2) Does the air-foil on the Renn-Vertec reduce drift? (B versus C)
3) How does the drift compare for a smaller drop size? (D versus C)

Proposed windspeed categories were 0 to 2.2 m/s (5 mph), 2.2 to 4.5 m/s (5 to 10 mph), and 4.5 to 6.7 m/s (10 to 15 mph), and the goal was to run five repetitions with each sprayer in each of these categories.

EXPERIMENTAL METHODS

FIELD EQUIPMENT

Sprayers Table 1 illustrates specific information about each sprayer configuration tested. All sprayers were operated at a ground speed of 9.7 km/hr (6 mph). The sprayer used for configuration A had a total boom width of 7.3 m with 13 active nozzles at .51 m (20 in. spacing. The Renn-Vertec sprayer used in sprayer configurations B-D had a 20 m boom with 40 active nozzles at .51 m (20 in.) spacing. For accurate comparisons, three passes were required for sprayer A, to achieve a boom width equivalent to the Renn-Vertec sprayer. The pressure adjustment for sprayer A was required to compensate for a larger application rate at 276 kPa (40 psi) as measured during nozzle calibration.

Table 1. Sprayer configurations tested.

SPRAYER CON-FIGURATION	TYPE	NOZZLES	PRESSURE kPa	RATE L/min/NOZZLE
A	Rear's Centrifugal	8002 Lurmark Kematol	248	0.757
B	Renn-Vertec RV2350 Windfoil removed	8002 Lurmark Kematol	276	0.757
C	Renn-Vertec RV2350 Windfoil in place	8002 Lurmark Kematol	276	0.757
D	Renn-Vertec RV2350 Windfoil in place	800025 Spraying Sys. Tungsten Carbide	414	0.116

Sprayer Tank Mixture & Collectors   For this project, Rhodamine-B dye was selected as a tracer and string as a drift collector. Salyani and Whitney (1988) used a Rhodamine-B (Rh-B) fluorescent dye solution in a spray deposition methodology study. They found its fluorescence to be less sensitive to light and more stable with time than other water-soluble dyes. Whitney and Roth (1985) using Rhodamine-B as a tracer, compared string and paper tape as collectors of spray drift. They hypothesized that string would increase and stabilize collection efficiency due to decreased wind shear deflection. Results indicated a higher fluorescent response for the string than for the paper tape, indicating more interception of drift.

For our sprayer comparisons, a powdered form of Rh-B dye was added to water at 176 mg/liter (0.667 g/gallon) for sprayer configurations A, B, and C, and 1150 mg/liter (4.356 g/gallon) for sprayer D. The increased concentration for sprayer D was required to provide an equal amount of active ingredient per hectare with the lower application rate. The spray drift collectors for our study consisted of 30.5 m (100 ft) lengths of string suspended above the vegetation. The string type was Coats and Clark six-strand "mercerized" white floss, as used in the Whitney and Roth study. The string was secured to anchoring stakes with sufficient tension to limit center sag to one or two inches. The string height was 0.5 m at the first four stations upwind and downwind. The rest were at 1.0 m height.

Weather Instruments   During each sprayer test, four meteorological parameters were monitored. Table 2 summarizes these parameters and the monitoring equipment used.

Table 2. Meteorological Instruments.

PARAMETER	NO.	HEIGHT (m)	EQUIPMENT
Wind Direction	2	5 1	Sierra/Misco Model 1036HM Wind Direction Vane
Wind Speed	2	5 1	Sierra/Misco Model 1036HM Cup Anemometer
Temperature	2	10 2.5	Omega Type T Thermocouple Copper-Constantan
Relative Humidity	1	1.5	Tycos Sling Psychrometer

A Campbell Scientific CR21X data logger was used to record signals from both the temperature and wind sensors. The CR21X was programmed to read wind speeds, wind

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directions, and temperatures on one-second intervals and record average values on one-minute intervals. The time (military clock) and the Julian day were also recorded each minute.

This configuration of instruments permitted us to measure the stability ratio (SR), discussed by Akesson and Yates (1989). The ratio is an index of the atmospheric stability based on the vertical air temperature gradient. In a field study, Akesson and Yates found the SR to be a correlation factor in downwind drift.

FIELD LAYOUT

Figure 2 illustrates the layout of the test site. The layout was designed with the sprayer swath perpendicular to the prevailing northerly winds of the region during the summer months. The sprayer swath was paralleled on both sides, upwind and downwind, by a series of suspended 30.5 m (100 ft) long string collectors. The collectors were placed in a geometric series at upwind distances of -1, -2, -4, -8, -16, and -32 meters, and at downwind distances of 1, 2, 4, 8, 16, 32, 64, 128, 256, and 347 meters. Distances were measured from the edges of each side of the Renn-Vertec swath.

The length of the path over which the sprayers operated was based on plus/minus 15° angle of wind variation, the length of the parallel string collectors, and the downwind distance to the farthest collector.

FIELD PROCEDURES

Sprayer trials were run when speed and direction of the wind were acceptable, as checked on the data logger readout. Winds within 15 degrees of perpendicular to the swath were considered acceptable. The suitability of the windspeed depended upon the number of runs remaining in the particular wind category. The Renn-Vertec sprayer was operated down-and-back on the path one time, while the standard sprayer required three down-and-back cycles (to compensate for boom width, as previously discussed). The nozzles were shut off in each case while the sprayer was turned around at the end of the field. The starting and ending time, date, trial identification number, and relative humidity were recorded during each run. After a 5 to 30 minute wait to allow drifting droplets to settle, the strings were collected and placed immediately into ziplock bags. At the same time, new string was tied into place for the next trial. String samples were kept in a dark container to prevent possible damping of the fluorescent material.

LABORATORY PROCEDURES

The drift comparisons for the different sprayer configurations were based on the amount of drifting material intercepted by the string collectors. The amount of intercepted material was determined by rinsing the collectors and testing the rinse water fluorescence with a fluorometer.

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In the laboratory, 50 ml of distilled water were added to each bag containing a string sample. The sample was then kneaded for several seconds and placed on a shaker table for approximately 15 minutes, to maximize rinsing. The fluid was then squeezed off and poured into standard 35 mm plastic film canisters for storage.

Prior to testing, the fluorometer (Perkin-Elmer 650-10S Fluorescence Spectrophotometer) was zeroed with a pure distilled water sample. The excitation and emission wavelengths on the instrument were set to 546 and 590 nm, respectively, and the slit widths were set to 5 nm. Rinsewater samples were tested one at a time in 5 ml quartz cuvettes by rinsing the cuvette with a new sample, refilling, and inserting into the fluorometer. The fluorescence reading was recorded and the cuvette was then emptied, rinsed, and filled with the next sample. All readings were converted to, and comparisons made at, the 1.0 range on the fluorometer.

RESULTS AND DISCUSSION

Field data were collected between July and October of 1989. This large span of time was necessary to obtain the desired range of wind conditions. Unfortunately, there were few days with sustained winds greater than 4.5 m/s. While selecting specific wind conditions for each sprayer configuration, no effort was made to have specific temperature, relative humidity, or stability ratio conditions.

As would be expected, the amount of drift from the sprayers was highest immediately down-wind, and decreased with distance down-wind from the spray line. Figure 3 shows the average measured drift for sprayer configuration B under three different wind conditions. The higher the wind speed, the further down-wind spray material was detected. Five replications were completed in each wind category except for high winds with sprayer configuration A. The purpose of the wind speed categories was to achieve a wide range of data points. In order to make a comparison between individual tests, a drift index was developed.

DRIFT INDEX

The drift index was defined as a measure of the amount of spray material displaced from the intended spray swath. A simple index reflecting the total volume displaced was chosen. The index is calculated by determining the area under the fluorometer reading-Station Location Curves (see Figure 3). According to the following:

$$DI = \sum_{i=1}^{347} \frac{(f_{i+1} + f_i)}{2 * 1000} * (X_{i+1} - X_i) \tag{1}$$

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where:

> DI = Drift index
> f_i = fluorometer reading at station i
> x_i = distance down-wind from spray line at station i (m)

NOTE: Divisor of 1000 was chosen for convenience in working with the drift index.

A drift index that penalized for down-wind drift was also studied. The equation for this index was:

$$DI = \sum_{i+1}^{347} X_i^n \frac{(f_i * (x_{i+1} - x_{i-1}))}{2 * 1000} \tag{2}$$

where:

> DI = Drift Index
> f_i = fluorometer reading at station i
> x_i = distance down-wind from spray line at station i (m)
> n = penalty factor

NOTE: Divisor of 1000 was chosen for convenience in working with the drift index.

This type of drift index did not provide any greater insight into the separation of the sprayer configurations as a function of driftability and therefore was not used.

ANALYSIS OF DATA

The first test performed on the data was a correlation matrix between all the factors measured in the field and the drift index. No single factor had a high correlation to the drift index. There was a high correlation between the temperature, wind speed, and wind direction at the two different elevations. For this reason, the wind speed and direction at the five (5) meter elevation was used in the model. There also was a strong inverse correlation between temperature and relative humidity. As the temperature rose, the relative humidity decreased.

A multiple regression model was used to determine which of the factors measured could be used to predict the drift index for a given sprayer. The following factors were included in the model: a) sprayer configuration; b) relative humidity; c) wind speed; d) temperature; e) stability ratio; f) sprayer configuration times relative humidity; g) sprayer configuration X wind speed; and h) sprayer configuration times temperature. The initial model was developed with all the factors included. In examining the initial model, factors

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not contributing to the model performance were removed and the model was reevaluated. This process was repeated until the final model contained the minimum number of factors necessary to represent the full model with a 95% confidence (extra sum of squares F test). The final model includes the following factors: sprayer configuration, wind speed, air temperature, sprayer configuration times wind speed, and sprayer configuration times air temperature. The final form of the model is:

$$DI = -23.707 + 33.315\ C_1 + 25.614\ C_2 + 26.162\ C_3 + 1.171\ WS + 0.899\ T$$
$$+ WS\ (-0.398\ C_1 - 1.087\ C_2 - 0.975\ C_3) + T\ (-1.161\ C_1 - 0.795\ C_2 - 0.824\ C_3)$$

where:

$C_1 = 1$ for sprayer configuration A_1, otherwise $C_1 = 0$
$C_2 = 1$ for sprayer configuration B, otherwise $C_2 = 0$
$C_3 = 1$ for sprayer configuration C, otherwise $C_3 = 0$
WS = wind speed, m/s
T = Temperature, °C

The model was evaluated in two ways to determine if there were significant differences between the sprayer configurations. The first comparison was between the intercepts of the regression lines and the second was between the slopes of the regression lines.

A plot of the drift index versus temperature with a constant wind speed shows regression lines for sprayer configurations B and C to be almost parallel (Figure 4). There were no significant differences in either their regression line intercepts or slopes. Sprayer configurations A and D had significantly different regression line intercepts and slopes. They were also significantly different from sprayer configurations B and C. These differences can also be seen in plotting drift index versus wind speed with the temperature held constant (Figure 5).

The tests indicate that the air-foil located over the shrouded hood did not contribute to a decrease in the drift index. The layout of the field tests directed the wind almost perpendicular to the boom and air-foil. This layout may have limited the ability of the air-foil to reduce drift over a hooded sprayer with no air-foil. However, in practice the air flow over a sprayer would never continuously be from the direction of travel. Thus, the benefit of the air-foil is probably minimal. The hood provided a maximum of 180 to 275% reduction in drift over the open boom sprayer. This study did not include modifications of the hood design to determine the importance of skirting on nozzle placement in reducing drift. Sprayer configuration D had the highest drift. This clearly shows the need for hood modifications when trying to contain smaller droplets. The travel speed of the sprayer across the field contributes to the escape of droplets from underneath the curtain. A slower travel speed would provide more retention time over the plant and allow these smaller droplets to settle out. Without the additional retention time, these small droplets are free to travel large distances very quickly.

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CONCLUSIONS

The use of shrouded hoods over boom sprayers can greatly reduce the amount of drift in most conditions. Modifications to the hood may further reduce the amount of drift. These modifications may include types of curtains that are used to seal the hood to the crop canopy. The air-foil on the hooded sprayer did not contribute to reduced drift from the sprayer. Drift from hooded ground sprayers is highly dependent upon the droplet spectrum. Decreasing the spray droplet spectrum VMD from 320 μm (8002 nozzle @ 276 kPa) to 100 μm (800015 @ 414 kPa) increased the drift three-fold. This is unfortunate because of earlier studies indicating that reduction in droplet sizes will increase the efficacy and possibly reduce the amount of active ingredient per hectare needed to achieve adequate vegetation control. Further testing is needed on methods of modifying the shrouded hood to allow the use of smaller droplet spectrums so that increased efficacy can be achieved while decreasing spray drift.

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Figure 2. Field layout.
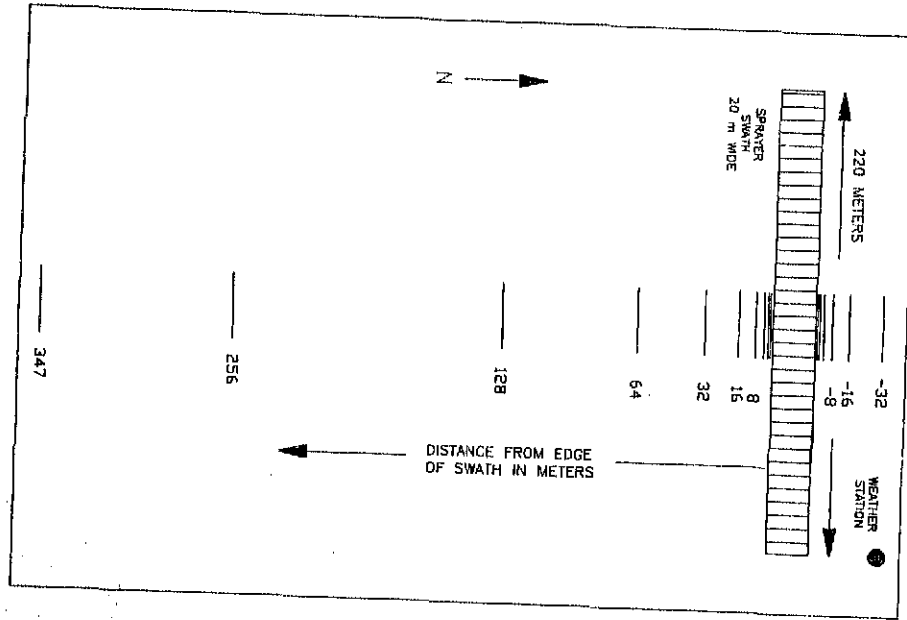
SPRAY DRIFT COMPARISON
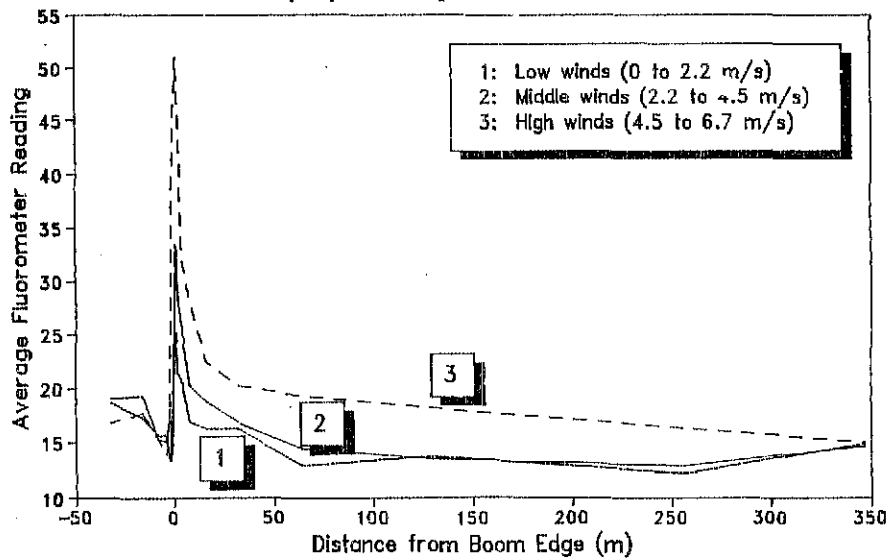### Sprayer Configuration B

1: Low winds (0 to 2.2 m/s)
2: Middle winds (2.2 to 4.5 m/s)
3: High winds (4.5 to 6.7 m/s)

Figure 3. Example of fluorescent response with distance.

MODEL PREDICTIONS
Drift Index vs. Temperature

WIND HELD CONSTANT, 3.6 m/s
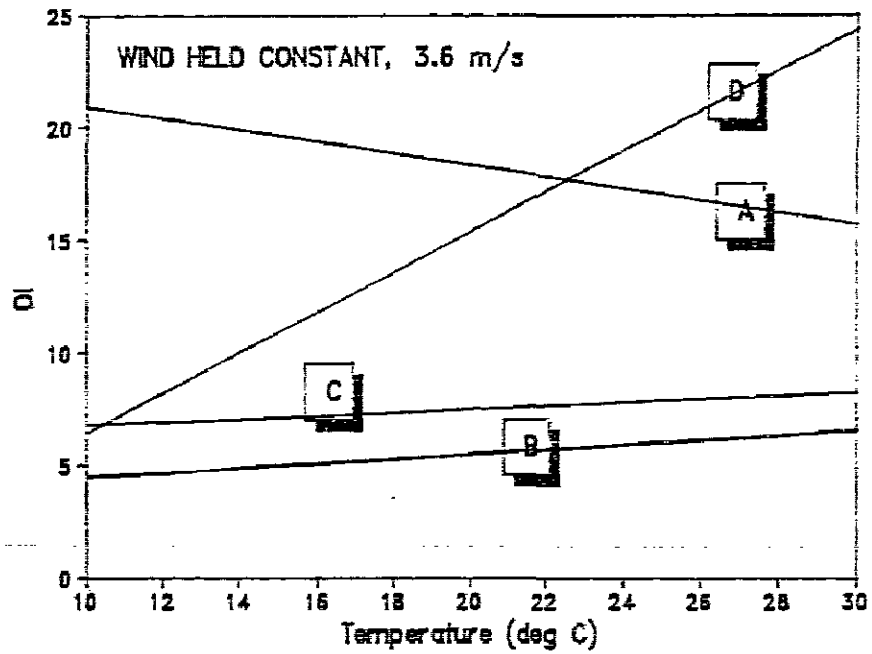
Figure 4. Model DI variation with temperature.

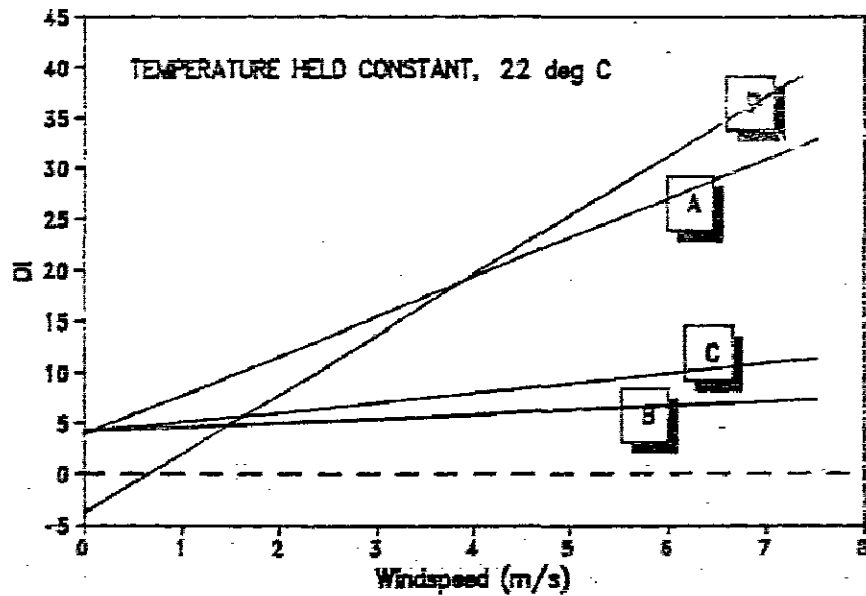## MODEL PREDICTIONS
Drift Index vs. Windspeed

TEMPERATURE HELD CONSTANT, 22 deg C

Figure 5. Model DI variation with windspeed.