DEVELOPMENT AND EVALUATION OF A COMPUTERIZED LEAFSPOT ADVISORY PROGRAM FOR EFFECTIVE USE OF CULTIVAR RESISTANCE, FUNGICIDE, AND SPRAY ADJUVANT TO CONTROL EARLY LEAFSPOT OF PEANUT

BY

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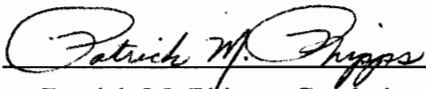
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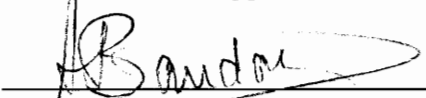
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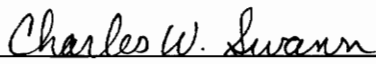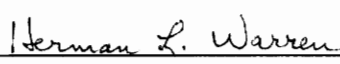
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Plant Pathology

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(ABSTRACT)

An advisory program to determine the timing of fungicide application for control of early leafspot of peanut, caused by *Cercospora arachidicola*, was developed based on growth responses of the pathogen to specific environmental conditions. The advisory program (89-ADV) assigned time-duration values to conditions conducive for infection (TDV_i). Cumulative TDV_i levels were used to determine when fungicide applications were needed. Various spray thresholds (TDV_i=48, 72, 96, 120) of the 89-ADV program were compared to a 14-day spray schedule and an advisory program that was released to growers in 1981 (81-ADV). Leafspot incidence, area under the disease progress curve (AUDPC), spray number, yield and value were used to evaluate the performance of spray programs. Preliminary trials used Florigiant peanut and the fungicide chlorothalonil (1.26 kg/ha). The 89-ADV program with TDV_i=48 performed exceptionally well for three consecutive years in field tests and in simulated disease environments reconstructed from historical weather data. Benefits of this program compared to the 81-ADV program included significant improvement of leafspot control, and improved crop yield and value. Based on performance, the 89-ADV program was delivered to growers as the on-line peanut leafspot

advisory in 1989. Subsequent evaluations of the 89-ADV program included cultivars and fungicides in large multi-factorial experiments. Three classes of cultivars were identified: class I or highly susceptible, Florigiant and NC 9; class II or moderately susceptible, NC 7 and NC-V11; and class III or moderately resistant, NC 6. The efficiency of fungicide sprays was improved through effective leafspot control with about three fewer sprays per season than the 14-day spray schedule when chlorothalonil at 1.26 kg/ha, diniconazole at 140 g/ha or terbutrazole at 126 g/ha was applied on class I cultivars according to the $TDV_i=48$ threshold of the 89-ADV program. The same efficiency was achieved when chlorothalonil or terbutrazole was applied on class II cultivars according to the $TDV_i=96$. Cupric hydroxide at 1.79 kg/ha plus sulfur at 1.04 kg/ha or terbutrazole at 126 kg/ha with $TDV_i=96$ as well as chlorothalonil at 1.26 kg/ha with $TDV_i=120$ resulted in efficient control of disease on the class III cultivar. The spray adjuvant SoyOil 937® at 0.5% of spray volume consistently improved the performance of chlorothalonil, and allowed a reduction of application rate from 1.26 to 0.95 kg/ha without sacrificing disease control. The integrated use of cultivar resistance, fungicide, spray adjuvant, and TDV_i thresholds of the 89-ADV program contributed to a reduction of fungicide input and improved disease control.

indispensable and are well appreciated. Many thanks are also due to the faculty and staff of the Tidewater Agricultural Experiment Station for making the station an enjoyable place to live and work. Most important of all, the author wishes to thank his family for the immeasurable support, love and encouragement. To all of you, I am greatly indebted.

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INTRODUCTION

Peanut (*Arachis hypogaea L.*) is a high-value crop planted for food and oil in various regions of the world. Eighteen million hectares are planted worldwide, of which 600,000 hectares are contributed by the United States from the seven major peanut production states, namely: Georgia, Alabama, North Carolina, Texas, Virginia, Oklahoma and Florida (19). Production technology varies from the labor-intensive crop management in the third world countries to the fully mechanized, high input production in the United States (20). Growers in Virginia plant about 40,000 hectares of peanuts annually which yield a farm value of about 100 million dollars (2).

STATEMENT OF THE PROBLEM

Diseases continue to be one of the most important problems in peanut production. Losses attributed to various peanut diseases were estimated at 22.9 percent or a value of ca. 29 million dollars in farm income based on the estimated total production of 148,000 tons and a mean value of $661.30 per ton in 1990 (15). Early and late leafspot caused by *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. Curt.) Deighton, respectively, were the most devastating foliar diseases of peanut. In Virginia, early leafspot was the predominant disease. Garren and Jackson (10) reported early leafspot to cause a yield loss of up to 50%. Disease control programs initially depended only on fungicides applied on a 14-day spray schedule starting from about 35 days after planting and continuing to about 21 days before harvest. The advent of benomyl, a systemic fungicide, offered a curative as well as effective protection against the pathogen. Benomyl effectively reduced

the severity of early leafspot (17), but in the span of only three years after its introduction, *C. arachidicola* developed resistance to the fungicide. Isolates of *C. arachidicola* from problem fields showed tolerance to benomyl at concentrations as high as 160 µg/ml (13). Sensitive isolates did not grow on potato-dextrose agar amended with benomyl at 0.5 µg/ml. The development of tolerance to benomyl and other fungicides with a similar mode of action was a common phenomenon, and cross resistance to these fungicides was observed (7).

Chlorothalonil, a protective fungicide with multiple sites of action, has remained as the only fungicide registered for peanut that offers excellent control of early leafspot. However, its widespread use has not been without problems. The use of chlorothalonil often increases the severity of Sclerotinia blight of peanut (18), a destructive soilborne disease caused by *Sclerotinia minor* (Jagger) Kohn. Furthermore, both benomyl and chlorothalonil may increase the severity of white mold or southern stem rot of peanut, caused by *Sclerotium rolfsii* Sacc. (1). The development of pathogen resistance to fungicides, the effects on nontarget organisms, as well as the cost of fungicide application can be minimized by limiting fungicide application to only when necessary.

The Virginia Peanut Leafspot Advisory (VPLA) was developed to identify conditions conducive for early leafspot development, and recommend fungicide applications only during those critical periods when necessary for efficient disease control. The VPLA was patterned after the disease forecasting technique of Jensen and Boyle (11), and the computerized advisory program of Parvin, Smith and Crosby (14). The VPLA was first delivered to peanut growers in southeast Virginia in 1981, and has allowed growers to reduce the number of fungicide applications per cropping season (16), but fungicide sprays according

to the VPLA in some years allowed development of disease late in the season to levels which caused concern among growers. The need to improve the leafspot advisory program was suggested (12).

OBJECTIVES OF THE DISSERTATION

The overall goal of this dissertation was to reduce fungicide input through an integrated use of currently available technologies. An expert advisory system (artificial intelligence) that could efficiently process meteorological data from sensors in remote locations and identify conditions both conducive and lethal to the pathogen was a primary component of the strategy. Inputs of secondary importance were fungicides of various chemistry, genotypes with varying degrees of susceptibility to early leafspot, and the use of a spray adjuvant to improve spray coverage and enhance fungicidal activity. Preliminary reports on portions of this dissertation have been published (3, 4, 5, 6).

The dissertation objectives were: 1) to develop a new model for the peanut leafspot advisory based on biological responses of *C. arachidicola* to weather conditions in the Virginia peanut production area, and evaluate the new advisory model in replicated field trials and under computer simulated disease environments reconstructed from historical weather data from 1983 to 1986; 2) to evaluate the efficacy of various fungicides when sprayed according to spray thresholds of the new advisory program, and determine the appropriate spray threshold for different fungicides and peanut cultivars planted in Virginia; and 3) to improve the overall efficacy of fungicide by defining the optimum rate of a spray adjuvant with chlorothalonil for enhanced leafspot control. Chapter 1 addresses the first objective by describing the development and evaluation aspects of the new advisory

program. Field evaluations were conducted using the highly susceptible cultivar Florigiant and the widely used fungicide chlorothalonil at the Tidewater Agricultural Experiment Station from 1987 to 1989. Chapter 2 addresses the second objective by expanding the Florigiant-chlorothalonil system to include alternative peanut cultivars with partial resistance as well as other fungicides with different efficacy. The use of cultivars with partial resistance along with fungicides was known to have an additive benefit for improved disease control that could result in reduced fungicide input (8, 9). As part of the multi-input strategy to effectively manage early leafspot, chapter 3 investigates the benefits of using a spray adjuvant with chlorothalonil. Various rates of SoyOil 937® (93% soybean oil and 7% emulsifier, Coastal Chemical Corp., Greenville, NC) were tested as a spray adjuvant at full and reduced rates of chlorothalonil. The use of fungicide with spray adjuvant explored the possibility of reducing fungicide rates without compromising disease control.

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DEVELOPMENT OF A PATHOGEN GROWTH RESPONSE MODEL

FOR THE VIRGINIA PEANUT LEAFSPOT ADVISORY

ABSTRACT

A computerized advisory program to determine the timing of fungicide applications to control early leafspot of peanut was developed based on growth responses of *Cercospora arachidicola* to specific environmental conditions. The advisory program (89-ADV) assigned time-duration values to conditions conducive for infection (TDV$_i$). Cumulative TDV$_i$ levels were used to determine the critical times when fungicide applications were needed. Various spray thresholds (TDV$_i$=48, 72, 96 and 120) of the 89-ADV program along with a 14-day spray schedule and the spray program used by the Virginia Peanut Leafspot Advisory since 1981 (81-ADV) were tested on Florigiant peanut from 1987 to 1989. AUDPC and leafspot incidence in plots sprayed with chlorothalonil (1.26 kg/ha) according to TDV$_i$=48 threshold of the 89-ADV program were significantly lower than those in plots sprayed according to the 81-ADV program. The higher spray thresholds (TDV$_i$=72, 96 and 120) of the 89-ADV program resulted in similar or better disease control than the 81-ADV program at fewer sprays per season. Yields (kg/ha) with the TDV$_i$=48 were better than that with the 81-ADV program during the 3 years of field testing. Similar trends in relationships of value ($/ha) were observed in 1988 and 1989. Evaluation of various spray programs under simulated disease environments reconstructed from historical weather data from 1983 to 1986 also demonstrated the superior disease control efficiency of the 89-ADV program with a TDV$_i$ of 48 over the 81-ADV program. In both field and simulated tests, the average number of sprays per season of the 89-ADV program at TDV$_i$=48 and the 81-ADV

program were about the same. Based on these results, the 89-ADV program with a spray threshold of $TDV_i=48$ was installed to the central computer of the Agro-Environmental Monitoring System (AEMS) as the on-line advisory service in Virginia for growers to use at the start of the 1989 growing season.

INTRODUCTION

Early and late leafspot caused by *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. Curt.) Deighton, respectively, are the most devastating foliar diseases of peanut (*Arachis hypogaea* L.) worldwide. Without foliar applications of fungicide, losses to these diseases have been reported to be as high as 50% of potential yield (11, 41). In the Virginia-North Carolina peanut production area, early leafspot is the predominant foliar disease. Programs to manage peanut leafspot include the use of resistant varieties (12), employment of disease suppressive crop management practices (21, 41), application of an effective fungicide (12, 41), and the use of computerized decision-support systems for fungicide application (28, 34, 40).

Agronomic practices such as burying crop residues by moldboard plowing, and crop rotation may reduce the initial inoculum in soil (41); but this approach has limited value with a polycyclic disease on a long season crop. Survival structures of the pathogen coupled with characteristics for long distance dispersal of inoculum render crop rotation a less viable option to control the disease. Breeding programs for peanut leafspot have identified sources of germplasm with promising resistance (1, 13, 20, 26), but have not resulted in the release of resistant cultivars that might preclude the use of fungicides (19).

The use of fungicide remains the single most effective method of disease control. The extensive use of fungicide, however, has not been without problems. *C. arachidicola* and *C. personatum* have been reported to develop resistance to benomyl, a benzimidazole carbamate fungicide (6, 22), and the use of chlorothalonil increases the severity of Sclerotinia blight of peanut (35). The risk of pathogen resistance to fungicides, fungicide effects on nontarget organisms (5), and the cost of fungicides can be minimized by limiting fungicide applications to only when necessary. The Virginia Peanut Leafspot Advisory (VPLA) was the first expert system to be adopted by growers for control of leafspot on a commercial scale (34). This expert advisory system identified periods conducive for disease development and reduced fungicide input in peanut production through proper timing of application.

The VPLA is an advisory program for fungicide application patterned from the disease forecasting technique of Jensen and Boyle (16, 17). Their forecasting technique was founded on the correlation of leafspot incidence in the field with an infection index. Subsequently, this correlation was used by Parvin, Smith and Crosby (28) to develop the first daily, worded computerized advisory. The VPLA was first delivered to peanut growers in southeast Virginia in 1981. As early as 1983, the program was shown to reduce successfully the number of fungicide applications from an average of 6.75 on a 14-day spray schedule to about three per season (34). In some years, fungicide sprays according to the VPLA allowed development of disease late in the season to levels which caused concern among growers. Although yields were generally similar to that with a 14-day spray program, a need to improve the performance of the peanut leafspot advisory was suggested (18). For

improved clarity, the first VPLA program will be called the 1981 advisory program (81-ADV) in this paper.

Recent research concerning the biology of *Cercospora arachidicola*, and the epidemiology of early leafspot in peanuts have offered an opportunity to improve the 81-ADV program. The work of Alderman et al. (4) on aeromycology of *C. arachidicola* showed that initial inoculum, based on spore trap data, first appeared during conditions characterized by relative humidity (RH) greater than 90% and temperature less than 17C for about 10 hr per day on a 3-day running average. Spore density increased at increasing temperature and duration of RH>90%. In 1987, Alderman and Beute (3) reported that a 48 hr period having RH≥95% and temperatures between 16 and 25C resulted in a high percentage of spore germination on leaves. Spore germination was low at temperatures between 28 and 32C. At temperatures that resulted in high and low percentages of germination, the rates of germ tube elongation were similar (3). Oso (27) and Miller (25) had previously defined the temperature range favorable for spore germination as between 15 and 33C at RH≥95%. They reported that about 37C was a lethal temperature for germinating spores. Alderman and Beute (3) reported the termination of germ tube elongation after 8 hr of dry (30-40% RH) conditions when germinating spores were exposed to a cyclic dry-wet regime. Jewell (18) confirmed the correlation between the weather-dependent infection index of Jensen and Boyle (17) and early leafspot incidence, but found a stronger correlation of disease incidence with cumulative hours of RH≥95% (18). Research by the aforementioned authors has provided information for a better understanding of conditions conducive for germination and infection.

The objectives of this research were as follows: 1) to improve the 81-ADV by developing a new advisory program, referred to hereafter as the 1989 advisory model (89-ADV), that reflects specific growth responses of the pathogen to weather conditions in the Virginia peanut production area; 2) to evaluate and compare the 81-ADV and the 89-ADV models in replicated field trials along with the 14-day spray program and; 3) to assess the utility of advisory models under simulated environments reconstructed from historical weather data from southeast Virginia.

MATERIALS AND METHODS

The 89-ADV was developed after review of research on specific growth responses of *C. arachidicola* to meteorological conditions (2, 3, 4, 18, 25, 27, 39). The computer program developed for the model included two modules that gave complementary information on sporulation, and germination, lethal conditions and infection. Conditions conducive for spore germination and germ tube elongation as well as conditions lethal to germinating spores were assigned weighted values for each hour of occurrence. The weighted values, called time-duration values (TDV), were accumulated and used to determine the critical times when fungicide applications were needed.

Conditions for sporulation, germination and infection. The first module used time-duration values to predict the occurrence of environmental conditions conducive for sporulation (TDVs). Temperatures between 16 and 32C with RH>90% were considered conducive for sporulation (3). A cumulative TDVs of 10 per day over a three day running average was defined as the threshold for initiating sporulation (Table 1). Following the first

Table 1. Time-duration values (TDV) assigned to each hour of specific meteorological conditions for sporulation, germination, infection and lethal conditions.

Condition or Class	Meteorological Parameters	Time-duration value (TDV)[a]			
		TDVs	TDVg	TDVi	TDVlc
A	RH > 90% Temp. >16≤32 C	1	0	0	0
B	RH ≥ 95% Temp.				
	>28≤32 C	1	1	1	0
	>25≤28 C	1	2	1	0
	≥16≤25 C	1	3	1	0
C	RH < 40%	0	0	0	1
	Temp.≥ 37 C	0	0	0	1
D	All other conditions	0	0	0	0
Threshold TDV[b]		10	48	96	5-8[c]

[a] TDV is the value assigned to each hour of specific conditions (TDVs=sporulation, TDVg=germination, TDVi=infection and TDVlc=lethal conditions).
[b] Threshold values reflect the estimated cumulative TDV for completion of a specific event.
[c] Lethal conditions occurred after five consecutive hours of ambient temperature ≥ 37C or eight hours of RH≤40%.

occurrence of these conditions, spores of the pathogen were presumed to be present for the remainder of the cropping season.

The second module accumulated time-duration values for germination (TDVg), infection (TDVi) and lethal conditions (TDVlc). Each hour of conditions with RH≥95% and temperatures of 16≤X≤25C, 25<X≤28C and 28<X≤32C were assigned values of 3, 2 and 1, respectively. These ranges in temperatures were previously defined (3) to favor high, moderate and low percentages of germination after 48 hr of RH≥95%. TDVi accounted for the total hours of conditions conducive for infection with RH≥95% and temperatures between 16 and 32C. This factor was a primary determinant for timing of fungicide applications after the occurrence of sporulation. TDVlc reflected the cumulative hours of conditions which could be lethal to germinating spores. Conditions at temperatures greater than 37C for five consecutive hours or conditions with RH≤40% for eight consecutive hours were considered lethal to the germinating spores. In the absence of lethal conditions, germination of spores was assumed to occur after a cumulative TDVi of 48. Germ tube elongation, stomatal tropism and initial penetration were assumed to occur after reaching the cumulative TDVi of 72. Infection was assumed to occur after a cumulative TDVi of 96, and the cumulative TDVi of 120 was assumed to be a post infection phase when initial symptoms might be visible (Table 2).

Thresholds for spray advisory. Cumulative TDVi levels of 48, 72, 96 and 120 were the advisory thresholds for fungicide application in versions 1 through 4 of the 89-ADV program, respectively. The spray thresholds were believed to coincide with stages in pathogenesis when spores were germinating, when germinated spores start to show stomatal tropism and penetration, when infection has occurred, and just prior to the appearance of

Table 2. Advisory thresholds for fungicide application as defined in the 89-ADV program.

Advisory Program	Advisory threshold[*]	Stages of pathogenesis[**]
Ver. 1	$TDV_i = 48$	Germination
Ver. 2	$TDV_i = 72$	Stomatal tropism / penetration
Ver. 3	$TDV_i = 96$	Infection
Ver. 4	$TDV_i = 120$	Colonization

[*] Thresholds for fungicide application.
[**] Predicted stage of pathogenesis at various advisory thresholds.

initial symptoms of disease or the colonization phase. Versions of the 89-ADV program were tested in the field by applying fungicide as close as possible to the spray thresholds, and then evaluating the efficiency of disease control. At a specified spray threshold, the program also indicated the level of disease pressure based on the weighted values of TDV_g. This information was anticipated as being useful for judging the type of spray response necessary for achieving an acceptable level of disease control. Disease pressure levels of low, moderate and high were assigned to cumulative TDV_g levels ≥ 48, ≥ 96 and ≥ 144 for version 1 of the 89-ADV program, respectively. Based on disease pressure, the class of fungicide required and the urgency for application can be determined. Disease pressure levels in versions 2, 3 and 4 of the 89-ADV program were determined in a similar manner (Table 3).

Agro-Environmental Monitoring System (AEMS). The Agro-Environmental Monitoring System (AEMS), a network of computers and electronic meteorological sensors in remote locations, was used to collect temperature and relative humidity data for this research (37). The central computer was located at the Tidewater Agricultural Experiment Station in Suffolk. Daily operation and maintenance was funded by the Virginia Cooperative Extension Service, the Virginia Agricultural Experiment Station, USDA-ARS, and the Virginia Peanut Growers Association. AEMS data-gathering units were at three locations in the peanut production area and named according to the community nearest the station (Capron, Holland and Waverly). It has been estimated that about 85% of the total peanut acreage in Virginia falls within a 15-mile radius of these stations. Meteorological parameters were recorded every 10 min, 24 hr a day, and transmitted daily to the AEMS

Table 3. Disease pressure indices for the various advisory thresholds of the 89-ADV program.

Advisory threshold	Disease Pressure index[a]		
	1	2	3
TDV_i=48 (Ver. 1)	≥48[b]	≥96	≥144
TDV_i=72 (Ver. 2)	≥72	≥144	≥216
TDV_i=96 (Ver. 3)	≥96	≥192	≥288
TDV_i=120 (Ver. 4)	≥120	≥240	≥360

[a] Disease pressure indices (1=low, 2=moderate and 3=high) provide an estimate of disease pressure levels at specific TDV_i threshold.

[b] The cumulative TDV_g at each advisory threshold was used as an indicator for the type of spray response. Increasing values in the disease pressure index indicate decreasing tolerance for delays in fungicide application.

central computer where data were processed according to the various advisory models. Daily advisories from the three stations were updated and reviewed each day at 4 pm.

Logic of the advisory program. The advisory program utilized ambient temperature and relative humidity data generated by AEMS. At the start of each growing season, data sets were checked for conditions conducive for sporulation. The TDV_s was assigned and values were accumulated at each occurrence of conditions conducive for sporulation. The program continued to loop for data until the initial occurrence of conditions conducive for sporulation. Thereafter, spores were presumed to be present during the remainder of the growing season.

After the initial occurrence of conditions conducive for sporulation, the second module of the program began to check for conditions conducive for germination and infection. Both TDV_g and TDV_i data were accumulated each day and evaluated. The program looped for more data until a specified advisory threshold for fungicide application was reached. The program also checked data for conditions defined as lethal to germinating spores. TDV_g and TDV_i were reset to zero whenever lethal conditions occurred. At a specified advisory threshold, an advisory to apply fungicide was issued, and an estimate of disease pressure was provided on the basis of TDV_g (Table 3). The cumulative TDV's for germination and infection were reverted to zero at the time of fungicide application. TDV_g and TDV_i were reset to zero for the 10-day period after fungicide application. This period corresponds to about the foliar half life of the fungicide chlorothalonil, the most commonly used fungicide for control of early leafspot and other foliar diseases. Conditions during the residual period were assumed to be unfavorable for spore germination and infection. The

program began collecting TDV_g and TDV_i data following the end of the 10-day residual period.

Data acquisition. In 1987 and 1988, an IBM personal computer equipped with a modem was used to retrieve data from AEMS and process the advisory. Weather data from AEMS were retrieved from the central computer using BitCom Communications Program® (BIT Software, Inc., Milpitas, CA). In 1989, the 89-ADV program was installed to the AEMS central computer, and replaced the 81-ADV program as the on-line peanut leafspot advisory for growers in southeast Virginia. The program developed daily advisories for Suffolk, Capron and Waverly in an unattended mode from June 10 to September 30. Each day, the 89-ADV program computed the sum of TDV's from the present or day_x to day_{x-n} when the cumulative TDV_i reached the designated advisory threshold. Day_{x-n} was adjusted for the 10-day residual period in cases after the initial application of fungicides. In these instances, the calendar date of $day_{x-(n+10)}$ was reported by the advisory program as the "last effective spray date". Version 1 of the 89-ADV program with a spray threshold of $TDV_i=48$ was issued to commercial growers in 1989 and 1990. The decision to spray fungicide was based on whether the last fungicide spray was applied prior to the reported "last effective spray date". Peanuts sprayed before the date were considered to be vulnerable to infection, and application of a fungicide was recommended (33). If a fungicide spray had been applied since the last effective spray date specified in the advisory, then no treatment was needed for crop protection.

Field Evaluation. Florigiant peanut was planted in a Kenansville loamy sand with a history of corn-peanut rotations at the Tidewater Agricultural Experiment Station, VPI&SU, Suffolk, Virginia. Cultural practices recommended by the Virginia Cooperative

Extension Service were followed in crop management (42). Plots, consisting of four 12.1-m rows, spaced 0.9 m apart, were arranged in a randomized complete block design with four replications. Chlorothalonil (Bravo 720®, Fermenta ASC Corporation, Mentor, OH) at 1.26 kg a.i./ha was applied to the two center rows of each plot using a CO_2-pressurized sprayer equipped with three $D_2$13 (disc-core combination) nozzles per row. The fungicide was sprayed at 345 kPa and a ground speed of 4.38 km/hr, delivering 140 L/ha. Treatments consisted of fungicide application at TDV_i thresholds of 48, 72, 96 and 120 of the 89-ADV program. Reference standards included an untreated check and treatments according to a 14-day spray schedule that started about 30 to 40 days after planting and ended about 21 days before harvest.

Leafspot incidence and defoliation were assessed either by visual estimates of the percent of leaflets with one or more spots at 30-day intervals or by a tagged plant assessment method at 2-week intervals. Leafspot incidence by the tagged plant method was assessed by counts of infected leaflets (leaflets with one or more spots) and the number of defoliated leaflets on systematically selected plants whose main stems were tagged in the early part of the season. Leafspot incidence by the tagged plant was the sum of infected and defoliated leaflets over the total number of nodes times four. Area under the disease progress curve (AUDPC) was calculated and used to assess leafspot control by the various spray programs. AUDPC was computed for each spray program by the equation reported by Shaner and Finney (38). Yield at 7% moisture (w/w) was determined by harvesting and weighing peanuts from the two treated rows of each plot. Value was determined by grading a composite sample from all four replicates of each treatment in accordance with Federal-State Inspection Service methods.

Simulated evaluation of advisory programs. Logistic (ln[Y/1-Y]), monomolecular (ln[1/1-Y]), Gompertz (ln[1/ln[1/Y]]), and a linear model (untransformed Y) were used as growth models to fit the progress of peanut early leafspot in 1987, 1988 and 1989. Line fitting of various growth models was done by least squares estimates using SAS regression procedures (SAS Institute, Inc. Cary, NC). Days after planting (DAP) and the cumulative TDV$_i$ were separately tested as regressor or predictor in regression analyses. Leafspot incidence associated with various spray programs was estimated by:

$$Y = -0.168330 + 0.001699X \times CEFF$$

wherein Y, X and CEFF were an estimate of leafspot incidence ($0 < Y < 1$), the cumulative TDV$_i$ ($99 < X < 688$), and control efficiency of a spray program based on historical data (29, 30, 31, 32), respectively. The control efficiency (CEFF) of a spray program was determined as: CEFF = 1 - (Y1/Y2), where Y1 and Y2 were leafspot incidence for a spray program and the untreated check, respectively. A program simulator that estimated leafspot incidence from fields sprayed according to the various spray programs was developed based on the best fitting linear model. Leafspot incidence associated with various advisory thresholds of the 89-ADV program was compared with the 81-ADV program, a 14-day spray schedule, and an untreated check. Parameters for evaluation of program performance included the number of spray applications per season and leafspot incidence at the end of the growing season.

Since 1981, AEMS has recorded meteorological data every 10 min, 24 hr a day. Complete records of all data have been maintained in files at the Tidewater Agricultural Experiment Station. To compare the performance of advisory programs during the years before development and field testing, the simulator was used to estimate the progress of

early leafspot of peanut using historical data. The program simulator used historical data from 1983 to 1986, and listed dates when fungicides should have been applied based on the cumulative TDV_i thresholds.

RESULTS

Field evaluation. Disease incidence in the untreated check in 1987, 1988 and 1989 approached 100% at the end of each cropping season (Figure 1). Plots sprayed according to the threshold of $TDV_i=48$ of the 89-ADV program had significantly lower leafspot incidence than plots sprayed according to the 81-ADV program. Plots sprayed with fungicide on a 14-day spray schedule had 2, 1 and 3% leafspot incidence by visual estimates in 1987, 1988 and 1989, respectively. Disease incidence according to visual estimates in plots sprayed at $TDV_i=48$ were 3, 4 and 6% in each year, respectively, and was not significantly different from levels where the 14-day spray schedule was used. Disease progress curves of early leafspot in plots sprayed according to the $TDV_i=48$ threshold of the 89-ADV program mimicked the disease progress in plots sprayed on a 14-day spray schedule (Figure 2). A test for homogeneity of regression coefficients at $P=0.05$ indicated that disease progress in plots sprayed according to the $TDV_i=48$ of the 89-ADV program was similar to that in plots treated on a 14-day spray schedule. Fungicide applications at advisory thresholds of $TDV_i=72$, 96 and 120 controlled leafspot about the same or better than applications by the 81-ADV program in 1988 and 1989. Disease assessment by the tagged plant method confirmed the results of visual estimates. The advisory threshold of $TDV_i=48$ and the 14-day spray schedule had significantly lower disease incidence than other spray programs. The mean for disease incidence over the 3-year period was 1.8, 3.5, 12.0,

Model development 21
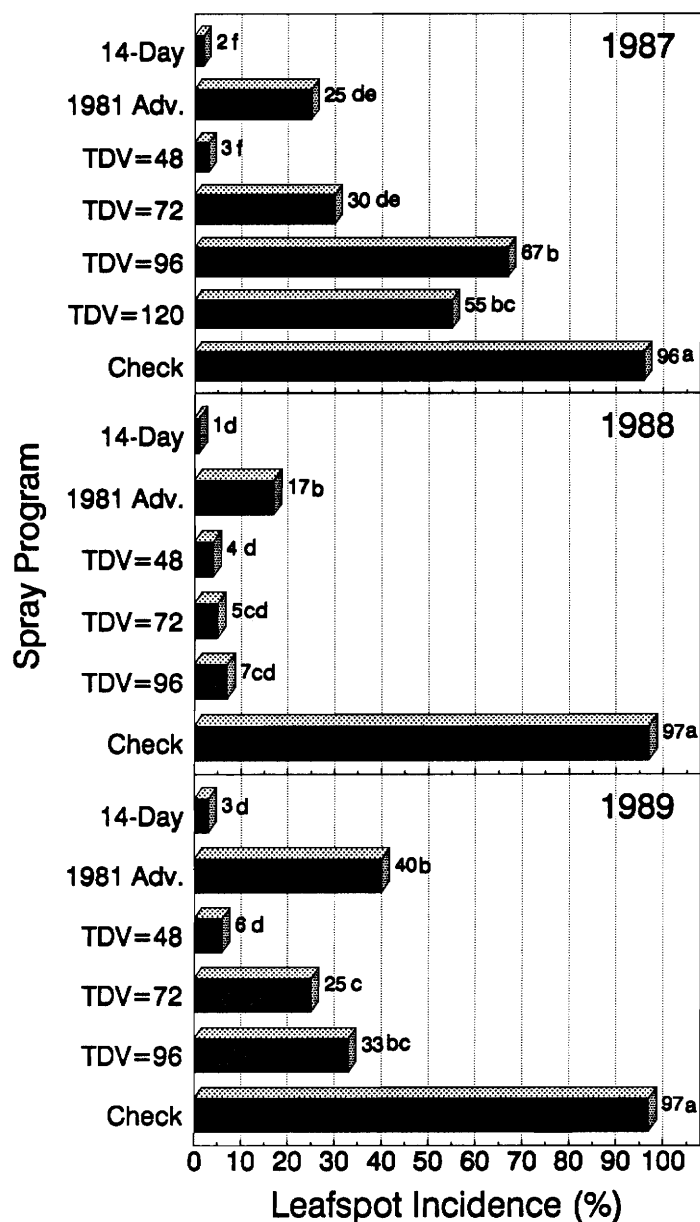
Figure 1. End-of-season visual estimates of early leafspot incidence in Florigiant peanut sprayed with chlorothalonil (1.26 kg/ha) according to various spray programs. Bars with the same letters in a given year are not significantly different at P=0.05 according to Waller-Duncan k-ratio T test procedure.

Model development 22
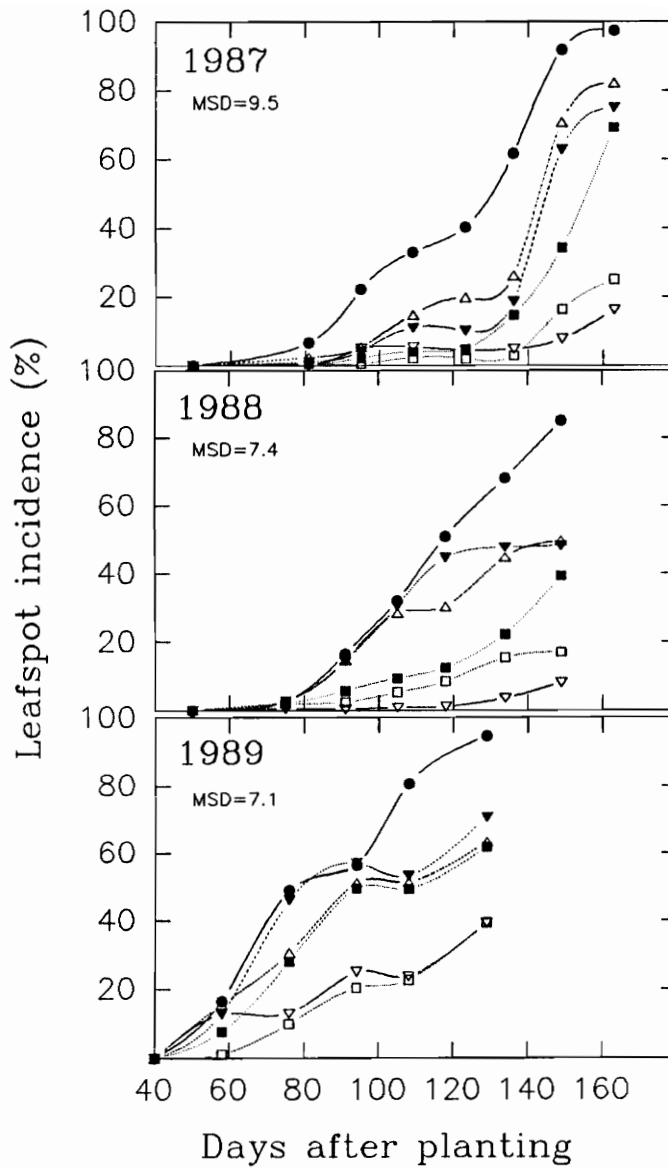
Figure 2. Disease progress curves for early leafspot as determined by the tagged plant method in Florigiant peanut when treated with chlorothalonil (1.26 kg/ha) according to a 14-day spray schedule (▽), the 89-ADV program with spray thresholds of $TDV_i=48$ (□), $TDV_i=72$ (■), $TDV_i=96$ (△), the 81-ADV program (▼), and the untreated check (●). The minimum significant difference (MSD) of 9.5, 7.4 and 7.1 for 1987 through 1989, respectively, was from the last disease rating according to Waller-Duncan k-ratio T test procedure.

20.8, 27.8, 24.8 and 95.3 for the 14-day spray schedule, the 89-ADV program thresholds of TDVi=48, TDVi=72, TDVi=96, TDVi=120, the 81-ADV program and the untreated check, respectively. AUDPC data also showed the same trend in performance of spray programs (Figure 3).

Yields with the 89-ADV spray threshold of TDVi=48 were better than that with the 81-ADV program during the 3 years of testing (Table 4). Similar trends in relationships of value ($/ha) were observed in 1988 and 1989. The number of sprays per cropping season averaged 6.7, 4.0, 4.3, 3.0, 3.0 and 2.7 for the 14-day spray schedule, the 81-ADV program, the 89-ADV program with spray thresholds of TDVi=48, TDVi=72, TDVi=96 and TDVi=120, respectively. The 81-ADV program and the 89-ADV program with TDVi=48 threshold had about the same number of fungicide applications per cropping season.

Simulated evaluation of spray programs. Coefficients of determination (r^2) for linearized logistic (ln[Y/1-Y]), monomolecular (ln[1/1-Y]) and Gompertz (ln[1/ln[1/Y]]) models used to estimate the progress of early leafspot were 60.5, 76.1 and 89.6%, respectively, using the cumulative TDVi as a regressor. Days after planting (DAP) as the regressor resulted in lower coefficients of determination, and higher root mean square error (MSE). The linear model (untransformed Y) had the highest coefficient of determination (r^2=90.67%), the lowest root MSE, and the smallest margin of standard error of parameter estimates of the above growth models (Table 5). The linear model: Y = -0.168330 + 0.001699X x CEFF was used to estimate leafspot control with fungicide applications according to various advisory thresholds of the 89-ADV program. Estimated control efficiency (CEFF) values of 91.7, 87.8, 78.4 and 40.8% were obtained for a 14-day spray schedule, the 89-ADV program with thresholds of TDVi=48, TDVi=72 and TDVi=96,
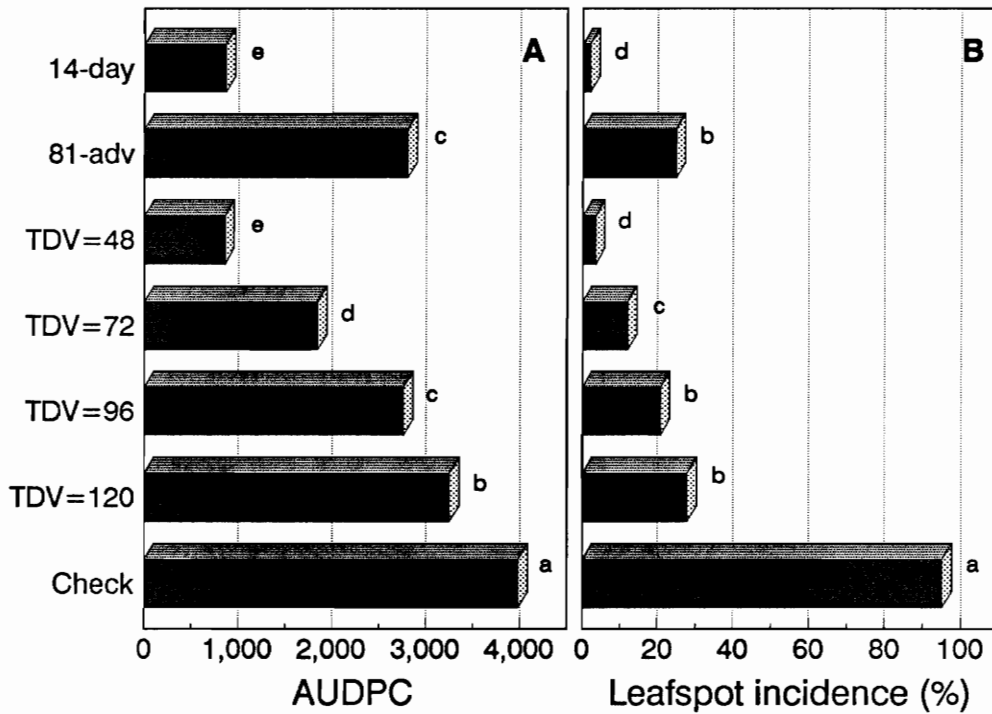
Figure 3. A) Area under the disease progress curve (AUDPC) and B) end-of-season visual estimates of leafspot incidence with spray programs using chlorothalonil (1.25 kg/ha) over a 3 yr period (1987-1989). Bars with the same letters are not significantly different at 5% level by Waller-Duncan k-ratio T test procedure.

Table 4. Effect of spray programs on yield and value of peanut.

Spray program[a]	Yield (kg/ha)[b]			Value ($/ha)[c]		
	1987	1988	1989	1987	1988	1989
14-day	4861 ab	4977 a	4350 a	3257 a	3284 ab	3126 a
81-ADV	5061 a	4096 bc	3571 b	3450 a	2861 bc	2607 b
89-ADV:						
TDV=48	5185 a	5080 a	4299 a	3422 a	3442 a	3096 a
TDV=72	4936 ab	4581 a-c	4029 ab	3356 a	2987 a-c	2941 ab
TDV=96	4674 b	4757 ab	4417 a	3039 b	3274 ab	3118 a
TDV=120	4861 ab	-	-	3254 a	-	-
Check	4375 c	3949 c	2505 c	3020 c	2750 c	1883 c

[a] Chlorothalonil at 1.26 kg/ha was applied to Florigiant peanut in each program evaluation.

[b] Yield based on weight of peanuts at 7% moisture (w/w).

[c] Value was determined by grading a composite sample of peanuts from each treatment in accordance with Federal-State Inspection Service methods. Values followed by the same letters in a column are not significantly different according to Waller-Duncan k-ratio T test procedure.

Table 5. Linear regression statistics and parameter estimates of models used to fit the 1987-1989 disease progress curves of early leafspot of peanut.

Model and (regressor)[a]	R-sq (%)[b]	Root MSE	Parameter Estimate[b]		Standard Error	
			α	β	α	β
Logistic						
(TDV$_i$)	60.46	2.27607	-6.9121*	0.0157*	1.27249	0.00303
(DAP)	44.68	2.69216	-10.163*	0.0883*	2.49115	0.02302
Monomolecular						
(TDV$_i$)	76.13	0.42573	-0.7599	0.0042*	0.23801	0.00057
(DAP)	52.84	0.59837	-1.5537	0.0229*	0.55369	0.00512
Gompertz						
(TDV$_i$)	89.61	0.43611	-2.4122*	0.0071*	0.24382	0.00058
(DAP)	64.60	0.80505	-3.8024*	0.0389*	0.74494	0.00688
Linear						
(TDV$_i$)	90.67	0.09410	-0.1699*	0.0016*	0.05261	0.00012
(DAP)	68.31	0.17343	-0.5071	0.0091*	0.16048	0.00148

[a] The logistic, monomolecular and Gompertz models were linearized by transforming disease incidence (0<Y<1) to ln(Y/1-Y), ln(1/1-Y) and ln(1/ln(1/Y)), respectively. The untransformed Y is referred to as the linear model. The cumulative time-duration value for infection (TDV$_i$) and days after planting (DAP) were tested separately as the regressor.

[b] The coefficients of determination (r^2) were adjusted for the degrees of freedom. An asterisk indicates that the t statistic of the parameters α (intercept) and β (slope) were significant (p=0.05).

respectively, over the 3-year period of testing. The advisory threshold of $TDV_i=120$ was not included in the simulation because of the high standard error for CEFF. The 81-ADV program also had a high standard error for CEFF. The simulated assessment of disease incidence using historical weather data from 1983 to 1986 averaged 7.5, 26.4, 10.9, 19.5, 53.5 and 90.3% for the 14-day spray schedule, the 81-ADV program, the 89-ADV with spray thresholds of $TDV_i=48$, 72, and 96, and the untreated check, respectively. Leafspot incidence with the $TDV_i=48$ threshold was not significantly different from the 14-day spray schedule, and was significantly lower than the 81-ADV program. Simulator generated AUDPC data from 1983 to 1986 averaged 368, 538, 956, 2618, 1734 and 4395 for the 14-day spray schedule, the 89-ADV program with TDV_i thresholds of 48, 72, 96, the 81-ADV program, and the untreated check, respectively (Figure 4). The 14-day spray schedule had an average of 6.75 fungicide applications per cropping season, while the 81-ADV program as well as the $TDV=48$ version of 89-ADV program averaged 3.75 sprays (Table 6).

Due to the remarkable performance of the $TDV_i=48$ advisory threshold in actual field tests as well as in tests from simulated disease environments, the 89-ADV program was installed to the AEMS central computer as the on-line peanut leafspot advisory. Daily advisories were provided through a toll-free number for growers throughout Virginia. The concept of reporting the "last effective spray date" offered the advantage of giving growers forewarning of the approaching need for fungicide application. This removed much of the confusion created by the 81-ADV program reporting favorable conditions for leafspot development one day, followed by unfavorable conditions a day later. Leafspot advisories were provided and updated daily at 4 pm by the Virginia Cooperative Extension Service.
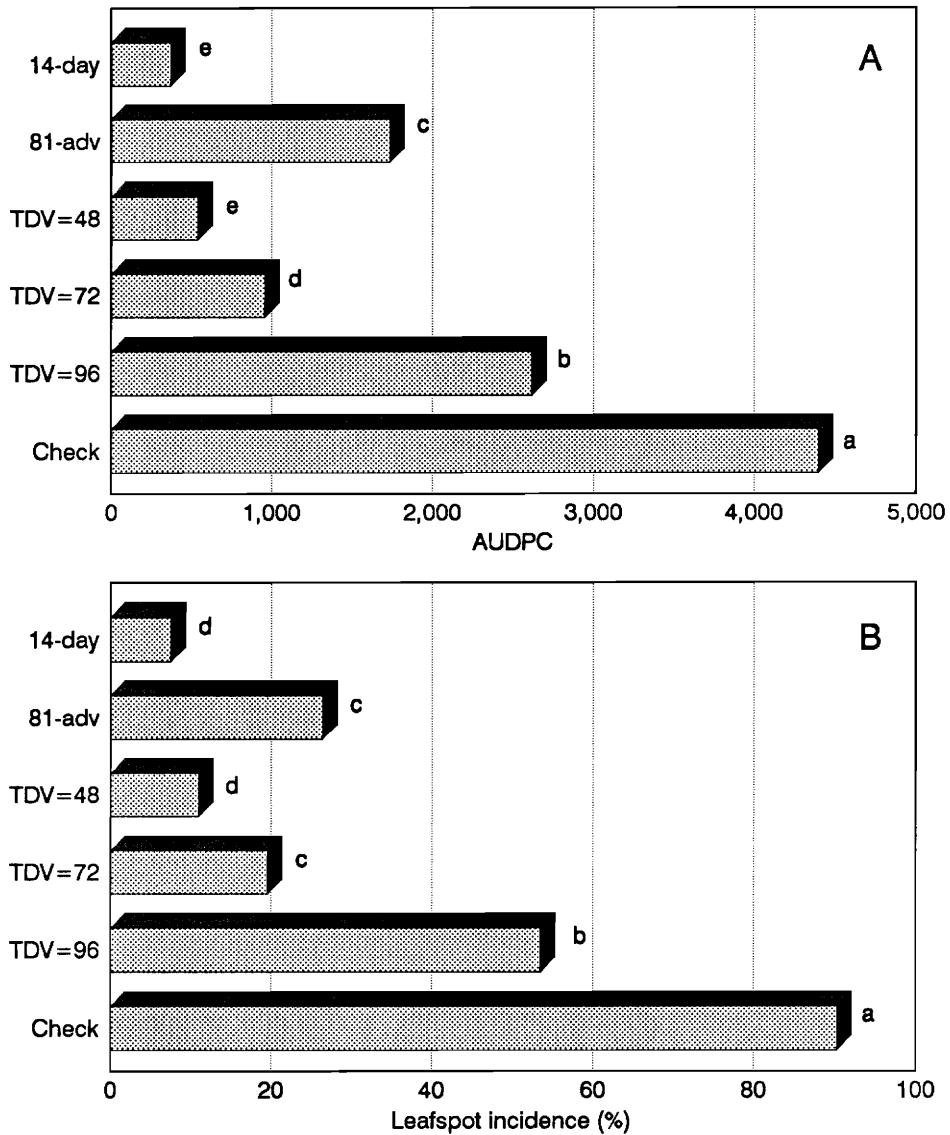
Figure 4. A) Area under the disease progress curves (AUDPC) and B) leafspot incidence at harvest in peanuts sprayed with chlorothalonil (1.26 kg/ha) according to various programs. Results are based on simulator-generated data (1983-1986). Bars with the same letters are not significantly different at 5% level by Waller-Duncan k-ratio T test procedure.

Table 6. Fungicide applications summarized according to simulator and field tests of various spray programs for leafspot control in peanut.

Spray Program	Simulator trials[a]				mean	Actual field trials[b]			mean
	1983	1984	1985	1986		1987	1988	1989	
14-day	7	6	7	7	6.75	7	7	6	6.7
81-ADV	3	4	3	5	3.75	5	3	4	4.0
89-ADV:									
TDV=48	3	4	4	4	3.75	5	3	5	4.3
TDV=72	3	3	4	4	3.50	3	2	4	3.0
TDV=96	3	3	3	3	3.00	3	2	4	3.0
TDV=120	-	-	-	-	-	3	2	3	2.7

[a] Sprays per cropping season based on simulator assessments using historical data. Data from the 14-day spray schedule and the 81-ADV program reflect actual sprays in field trials.
[b] Sprays per cropping season based on actual field trials of each program.

Local radio stations also broadcast the advisory several times daily in the peanut production area.

DISCUSSION

Excellent control of early leafspot by chlorothalonil (Bravo 720®) on a 14-day spray schedule was achieved at the expense of seven applications of fungicide in a cropping season and 12.25 L of fungicide per hectare. The same level of control was achieved by 89-ADV program at the spray threshold of $TDV_i=48$ with only an average of 4.3 applications of fungicide per cropping season and 7 L of fungicide per hectare. The 81-ADV program called for about the same number of fungicide sprays per cropping season as the 89-ADV program with a threshold of $TDV_i=48$, but the 81-ADV program allowed significantly greater leafspot incidence and AUDPC levels over the 3 years of field testing. Previous studies by Phipps and Powell (34), and Matyac and Bailey (24) also showed that the incidence of early leafspot in plots sprayed according to the Jensen and Boyle model (81-ADV) was significantly higher than the 14-day spray schedule. The 89-ADV program with thresholds of $TDV_i=72$, 96 and 120 had fewer sprays per cropping season than the 81-ADV program (Table 6), and disease control was often similar or better than the 81-ADV program (Figure 3).

The logistic model was found by Matyac and Bailey (24) as the best-fitting curve to describe the progress of early leafspot using the infection index described by Jensen and Boyle (17) as a regressor. Johnson and Beute (19) employed the Gompertz model with time in days after planting as the regressor to achieve the best fitting curve. This paper, on the other hand, found the linear model (untransformed Y) with TDV_i as the regressor to

be the best-fitting model for describing the progress of early leafspot. The use of TDV_i as an epidemiological parameter for predicting disease severity resulted in the highest coefficient of determination (r^2), the lowest root MSE, and the smallest margin of standard error of parameter estimates compared to the logistic, monomolecular and Gompertz models (Table 5).

Results from actual field tests as well as the results from simulated analyses with historical data showed the 89-ADV threshold of $TDV_i=48$ for fungicide treatment would suppress disease progress to levels similar to treatment on a 14-day spray schedule. The advantage of using the 89-ADV program at $TDV_i=48$ was reflected not only in a savings of fungicide sprays per cropping season, but also increases in yield and value. In 1987 and 1988, plots sprayed according to the 89-ADV program with $TDV_i=48$ had better yield and value than those sprayed on the 14-day spray schedule. The 89-ADV program allowed more efficient disease management on Florigiant peanut compared to the 81-ADV program through improved disease control with about the same number of sprays per season. The improvement of disease control by the 89-ADV program over the 81-ADV program was achieved partly by an extended view of meteorological conditions over several days or even weeks in determining the need for fungicide application. The 81-ADV program considered only a 5-day window, with emphasis on the preceding two days of meteorological conditions in detection of disease-favorable conditions.

The higher threshold values of $TDV_i=72$, 96 and 120 in the 89-ADV program recommended fewer sprays per season, and disease control was similar to the 81-ADV program. Yield and value were better than the 81-ADV program in 1988 and 1989. The higher thresholds of the 89-ADV program may be applicable to cultivars with partial

resistance to early leafspot. Fry and Bruhn (10) have worked on the idea of incorporating host resistance into the potato late blight forecast, and ascertained the complementary effect of host resistance and reduced frequency of fungicide application (10). Matyac and Bailey (24) also incorporated the effect of cultivar selection into the Jensen and Boyle (17) advisory model by adjusting the infection index values by factors of 0.95, 0.90, 0.80, 0.75, and 0.7. The modification was intended for genotypes with partial resistance, so that fewer fungicide applications would be required (24). In a similar manner, the higher TDV_i thresholds of the 89-ADV program would result in a longer spray interval and fewer sprays per season and could be used with cultivars having partial resistance to leafspot. In the current study which used the highly susceptible cultivar Florigiant, a threshold of $TDV_i=48$ was the most appropriate. Cultivars with partial resistance to early leafspot, like NC 6 and NC 7 as discussed by Phipps and Powell (34), would probably perform well at higher TDV_i thresholds.

Adjusting the spray interval in a calendar program from 10 or 14 to 20 or 28 days to compensate for the rate-reducing effect of partial resistance in cultivars may not be dependable (12). The premise of adjusting the spray interval is solely based on the residual activity of the fungicide, and the constant rate of disease progress (43). These assumptions, however, fail to recognize the frequent overwhelming influence that environmental conditions may have on disease progress. The residual life of fungicides can be shortened by various environmental conditions, and the rate of infection can increase to an alarming degree at various times in the cropping season when conditions become extremely favorable for infection. The 89-ADV program compensates for the effect of diverse environmental conditions by recognizing conditions favorable as well as lethal to the pathogen.

The choice of fungicide is another variable that can affect the performance of a disease management program. Various degrees of leafspot control have been reported with different fungicides sprayed according to various spray programs (34). It seems quite possible that fungicides could be grouped according to performance levels, and timing of application determined by various TDVi thresholds of the 89-ADV program. The systemic and curative action of some fungicides, particularly the ergosterol biosynthesis inhibitors (EBI), may allow delays in fungicide application, and may afford fewer sprays than prophylactic or protectant fungicides like chlorothalonil and the copper/sulfur compounds. The residual activity of fungicides is another factor to consider. The 10-day residual period after each fungicide application, already explained earlier, can be adjusted to suit a particular fungicide product. The recent work of Elliott and Spurr (7) described the exponential decay of chlorothalonil residues on peanut leaves. Incorporating the residue decay model into the advisory program may result in a residual period of up to 17 days (7), and further improve the efficiency of advisory programs.

Choices as to what cultivar to plant and fungicide to apply are important management options in leafspot management. To accommodate these options, the dimensions of the advisory program should be expanded to include the effect of cultivar and fungicide selection. The 89-ADV program provides a mechanism to adjust and compensate for fungicide residual activity on leaves, classes of fungicides based on performance, and the relative resistance of various cultivars to early leafspot. Large multifactorial experiments that include different cultivars, fungicides and various advisory thresholds will be needed to generate information for development of expert advisory programs with greater efficiency and a wider margin of dependability.

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THE EFFECT OF CULTIVAR AND FUNGICIDE SELECTION ON PERFORMANCE OF THE VIRGINIA PEANUT LEAFSPOT ADVISORY

ABSTRACT

Field tests were initiated to optimize the utility and performance of the Virginia Peanut Leafspot Advisory program through cultivar and fungicide selection. Effects of fungicides and cultivars were assessed in single and multi-factorial experiments in split-plot design. Chlorothalonil (1.26 kg/ha), diniconazole (140 g/ha), terbutrazole (126 g/ha), propiconazole (126 g/ha) and cupric hydroxide (1.79 kg/ha) plus sulfur (1.04 kg/ha) were applied according to a 14-day spray program, and versions of the advisory program which used time-duration values for infection (TDVi) as thresholds for fungicide application. Three classes of cultivars were observed based on susceptibility to early leafspot: class I or highly susceptible, comprised of Florigiant and NC 9; class II or moderately susceptible, comprised of NC 7 and NC-V 11; and class III or moderately resistant, comprised of NC 6. The 14-day spray program and various spray thresholds (TDVi=48, 72, 96 and 120) of the advisory program had a 3-year average (1988-1990) of 6.7, 4.0, 3.3, 3.0 and 2.3 sprays per season, respectively. Improved fungicide efficiency was achieved through effective leafspot control with fewer sprays per season when either chlorothalonil, diniconazole or terbutrazole was applied on class I cultivars according to the TDVi=48 threshold. The same efficiency was achieved when either chlorothalonil or terbutrazole was sprayed on class II cultivars according to the TDVi=96 threshold. Cupric hydroxide plus sulfur sprayed on a class III cultivar at TDVi=96 as well as chlorothalonil and terbutrazole at TDVi=120 and 96 thresholds, respectively, resulted in improvement of fungicide efficiency.

INTRODUCTION

The Virginia Peanut Leafspot Advisory (VPLA) is an expert system for timing of fungicide applications to control early leafspot of peanut (*Arachis hypogaea* L.), caused by *Cercospora arachidicola* Hori (20). The program was first delivered to peanut growers in southeast Virginia in 1981. That program was patterned after the disease forecasting technique of Jensen and Boyle (14), and the advisory program of Parvin, Smith and Crosby (19). Fungicide applications according to this advisory program, referred to as the 1981 advisory (81-ADV), averaged 3.75 (1983-1986) in comparison to seven sprays per season with the conventional 14-day spray schedule. Although the advisory program reduced spray number and generally resulted in effective disease control (20), leafspot incidence in some years was sufficient to pose a threat to yield.

In 1986, a new advisory model was developed at the Tidewater Agricultural Experiment Station. This advisory model was based on growth responses of the pathogen following specific environmental conditions (3, 4, 6). The various spray thresholds of this advisory program were determined by time-duration values for infection (TDV_i), and performance was compared to a 14-day spray program and an untreated check. In field tests from 1987 to 1989, the new advisory program was found to be consistently superior to the 81-ADV program, both in actual field evaluations and under simulated disease environments (3, 4, 6). The new advisory program, hereafter referred to as the 89-ADV program, was first made available to peanut growers in Virginia as the on-line advisory by the Virginia Cooperative Extension Service in 1989. That version of the 89-ADV program used the $TDV_i=48$ as the spray threshold, based on the performance of sprays of chlorothalonil on Florigiant peanut. To further improve the practical application of the 89-

ADV model, the effects of different cultivars and fungicides were investigated for incorporation into the algorithm of the advisory program. The objectives of this paper were to evaluate the efficacy of various fungicides when sprayed according to different advisory thresholds of the 89-ADV program, and determine the appropriate spray threshold for commercial cultivars of peanuts planted in Virginia.

MATERIALS AND METHODS

In 1988 and 1989, Florigiant peanut was planted in a Kenansville loamy sand with a history of corn-peanut rotations at the Tidewater Agricultural Experiment Station. Cultural practices recommended by the Virginia Cooperative Extension Service were employed in crop management (26). Field plots consisted of four 12.1-m rows, spaced 0.9 m apart. Five fungicides of various chemistry were evaluated in field trials for control of early leafspot of peanut. The following fungicide treatments were tested: chlorothalonil at 1.26 kg/ha (Bravo 720®, ISK Biotech Corporation, Mentor, OH), diniconazole at 140 g/ha (Spotless 25W®, Valent U.S.A. Corp., Walnut Creek, CA), terbutrazole at 126 g/ha (Folicur 1.2 EC®, Mobay Corporation, Kansas City, MO), propiconazole at 126 g/ha (Tilt 3.6 EC®, Ciba-Geigy Corporation, Greensboro, NC), and cupric hydroxide at 1.79 kg/ha plus sulfur at 1.04 kg/ha (Kocide 404S®, Griffin Corporation, Valdosta, GA). Spray programs included the conventional 14-day spray program, and four spray thresholds in the 89-ADV program (TDV_i=48, 72, 96 and 120). Fungicide treatments were applied on the two center rows of each plot with a CO_2-pressurized sprayer having three $D_2$13 (disc-core combination) nozzles per row. Sprays were applied at 345 kPa and a ground speed of 4.38 km/hr, delivering 140 L/ha. Treatments were replicated four times in a randomized complete block design.

The response of peanut cvs. NC 6, NC 7, NC 9, NC-V 11 and Florigiant were evaluated in a separate experiment in 1989. A split plot design was used with spray programs in mainplots and cultivars in subplots. Mainplots were replicated four times in a randomized complete block design. Chlorothalonil sprays were applied using a tractor-mounted boom sprayer equipped with three $D_3 23$ (disc-core combination) nozzles per row. Sprays were applied at 310 kPa and a ground speed of 6.98 km/hr, delivering 117 L/ha. In 1990, the cultivar test was expanded to include fungicides in one large factorial experiment. Fungicides and spray programs were tested in mainplots which contained subplots of cultivars. Fungicide treatments included chlorothalonil, terbutrazole, and cupric hydroxide plus sulfur. Peanut cvs. included NC 6, NC 7, NC 9 and Florigiant. Fungicides were applied by the same equipment and methods used in the 1989 test of cultivars.

Visual estimates of the overall percent of leaflets with one or more spots and assessments by a tagged plant method were used to monitor leafspot incidence and defoliation. Leafspot incidence by the tagged plant method was assessed by counts of symptomatic leaflets (leaflets with one or more spots) and the number of abscised leaflets (defoliated leaflets) in systematically selected plants. Main stems of four plants per plot were tagged in the early part of the cropping season for purposes of identification throughout the growing season. The percentage of disease on tagged plants was the sum of infected and defoliated leaflets, divided by the total number of nodes times four. Area under the disease progress curve (AUDPC) was computed using the procedure reported by Shaner and Finney (22). Yield at 7% moisture (w/w) was determined by harvesting and weighing peanuts from the two treated rows of each plot. Value was determined by grading

a composite sample from all four replicates of each treatment in accordance with Federal-State Inspection Service methods.

Data from single factor experiments as well as factorial experiments having a split plot design were analyzed either by the analysis of variance procedure or by the general linear models procedure of SAS® (SAS Institute Inc., Cary NC 27511). In experiments with a split plot design, the appropriate error term was used when comparing: mainplot (spray program) means averaged over all subplot treatments; subplot (variety) means averaged over all mainplot treatments; subplot means in the same mainplot treatment; and mainplot means in the same or different subplot treatments (10). Data analyses were organized so that the most economical as well as effective advisory threshold could be identified and recommended for a given fungicide-cultivar combination. Duncan's new multiple range test was used for separation of means for cultivar or fungicide performance, while the Dunnett's test or the orthogonal contrast was used in pair comparisons of the standard 14-day spray program to versions of the 89-ADV program having various thresholds (TDV_i=48, 72, 96 and 120) for fungicide application. Sprays of chlorothalonil applied on the standard 14-day spray schedule were considered the performance standard for effective control of early leafspot. The highest TDV_i threshold of the 89-ADV program that provided a level of disease control similar to the performance standard was considered acceptable for a given cultivar and fungicide combination.

RESULTS

Twenty combinations of five fungicides and four spray programs, and an untreated check were evaluated in the 1988 field tests. The analysis of variance procedure with data

on disease incidence indicated treatments were significant at P=0.0001 (Table 7). A single-factor experiment in a randomized complete block design and a two-factor experiment in split-plot design were conducted in 1989. The factorial experiment consisted of five spray programs and an untreated check in mainplots, and five cultivars in subplots. The F statistic of the model factor was significant (P=0.0001), and decomposition of the model term indicated significant differences in spray programs and cultivars as well as the interaction of these factors. The 1990 field test was also a two-factor experiment in split-plot design. This test consisted of 15 combinations of five spray programs and three fungicides plus an untreated check in mainplots, and four cultivars in subplots. The analysis of variance procedure with data on disease incidence indicated significant differences (P=0.0001) in spray programs, cultivars and a significant spray program by cultivar interaction (Table 7).

Fungicide evaluation. Leafspot incidence data from 1988 and 1989 were combined and subjected to an analysis of variance procedure. No significant differences were detected in years. Leafspot incidence in plots sprayed with chlorothalonil, terbutrazole, diniconazole, propiconazole and cupric hydroxide plus sulfur according to a 14-day spray program on Florigiant peanut were 2, 6, 4, 6 and 33 percent, respectively (Table 8). Disease levels in plots sprayed with the four former fungicides were not significantly different according to Duncan's new multiple range test (P=0.05). Leafspot incidence in plots sprayed with cupric hydroxide plus sulfur was significantly higher in comparison to other fungicides, but was significantly lower than the untreated check. Chlorothalonil sprayed on a 14-day spray schedule resulted in the best level of leafspot control, and was adopted as the standard for acceptable performance. Diniconazole, terbutrazole and propiconazole on a 14-day spray

Table 7. Summary of statistics from the analysis of variance procedure of leafspot incidence data from various experiments.

Year	Exp. factor	Exp. design[d]	DF[d]	MSE[d]	F Value	Pr>F
1988	Treatment[a]	RCBD	20	128.23	24.49	0.0001
1989	Fungicide	RCBD	5	124.54	19.95	0.0001
	Spray-cultivar[b]	Split-plot				
	Spray		5	45.91	222.11	0.0001
	Cultivar		4	18.05	22.99	0.0001
	Spray X cultivar		20	56.78	3.15	0.0002
1990	Spray-cultivar[c]	Split-plot				
	Spray		15	297.17	17.29	0.0001
	Cultivar		3	62.61	68.79	0.0001
	Spray X cultivar		45	419.73	6.70	0.0001

[a] Treatments consisted of five fungicides, four spray programs, and an untreated check.
[b] The 1989 spray-cultivar experiment consisted of five spray programs and an untreated check in mainplots, and five cultivars in subplots.
[c] The 1990 spray-cultivar experiment consisted of five spray programs and three fungicides plus an untreated check in mainplots, and four cultivars in subplots.
[d] RCBD=Randomized complete block design; DF=degrees of freedom; MSE=Mean square error.

Table 8. Leafspot incidence according to visual estimates prior to harvest of Florigiant peanut in plots sprayed with fungicides according to various programs for control of early leafspot in 1988 and 1989.

Spray program[a]	Fungicide[b]				
	chlorothalonil	terbutrazole	diniconazole	propiconazole	$Cu(OH)_2$ + S
14-day (7,6)	2 (a)	6 (a)	4 (a)	6 (a)	33 (b)
89-ADV:					
TDVi=48 (3,5)	7	7	9	44*	69*
TDVi=72 (2,4)	15*	23*	54*	55*	81*
TDVi=96 (2,4)	24*	37*	66*	67*	75*
TDVi=120 (2,3)	57*	52*	65*	80*	90*

[a] The 14-day program started about 35 days after planting and continued until about 21 days before harvest. The 89-ADV program used cumulative time-duration values for infection (TDVi) to determine the timing of fungicide sprays. Numbers in parentheses represent sprays per season in 1988 and 1989, respectively. Disease incidence from the untreated plots approached 100%.

[b] Means in a column followed by an asterisk are significantly different from the standard 14-day spray schedule according to Dunnett's test (P=0.05). Means in a row of the 14-day spray schedule followed by the same letters in parentheses are not significantly different according to Duncan's new multiple range test (P=0.05).

schedule provided about the same levels of disease control as the performance standard (chlorothalonil) and were classified as acceptable alternatives to chlorothalonil (Table 8).

The 14-day spray schedule with chlorothalonil and acceptable alternative fungicides were used as the performance standards for testing the acceptance of various TDV_i thresholds of the 89-ADV program. Leafspot incidence in plots sprayed with chlorothalonil, diniconazole, and terbutrazole according to the $TDV_i=48$ threshold of the 89-ADV program were not significantly different from the performance standards (Table 8). Leafspot incidence in plots sprayed with either propiconazole or cupric hydroxide plus sulfur according to the various thresholds ($TDV_i=48$, 72, 96 and 120) of the 89-ADV program were significantly higher than the performance standard, and considered unacceptable. The use of propiconazole as an effective fungicide for leafspot control on Florigiant peanut was limited to a 14-day spray program, whereas all programs with cupric hydroxide plus sulfur on this cultivar were unacceptable.

Cultivar evaluation. Florigiant and NC 9 were the most susceptible to early leafspot (Table 9). NC 7 and NC-V 11 had significantly lower values for AUDPC and leafspot incidence compared to Florigiant and NC 9 by visual estimate and tagged plant data, and were classified as moderately susceptible. NC 6 had the lowest value for AUDPC and leafspot incidence, and was classified as moderately resistant. Application of chlorothalonil according to the 14-day spray schedule reduced leafspot incidence in NC 6, NC 7, NC 9, NC-V 11 and Florigiant to 3, 2, 4, 1 and 2 percent, respectively (Table 10). The highly susceptible cultivars (Florigiant and NC 9) sprayed with chlorothalonil according to either a $TDV_i=48$ threshold of the 89-ADV program or the 14-day spray schedule exhibited about the same levels of disease (Table 10). The moderately susceptible cultivars (NC 7 and

Table 9. Susceptibility of peanut cultivars to early leafspot in 1989 according to disease incidence at harvest in unsprayed plots.[a]

Cultivar	Tagged plant method[b]		Visual estimate method[c]	
	AUDPC	% disease	% leafspot	% defoliation
NC 6	4734 c	79.3 c	72 c	38 d
NC 7	6281 b	87.5 b	86 b	59 c
NC-V 11	6167 b	84.5 b	90 b	61 c
NC 9	7564 a	92.8 a	96 a	73 a
Florigiant	7618 a	94.5 a	95 a	69 b

[a] Means in a column followed by the same letters are not significantly different according to Duncan's new multiple range test (P=0.05).

[b] Area under the disease progress curve (AUDPC). Percent disease on tagged plants was the sum of infected and defoliated leaflets, divided by the total number of nodes times four.

[c] Percent leafspot and defoliation were estimated visually as the overall percent of leaflets with one or more spots, and the overall percent of defoliated leaflets in each plot.

Table 10. Leafspot incidence at harvest in peanut cultivars sprayed with chlorothalonil according to a 14-day spray schedule and various TDVi thresholds of the 89-ADV program in 1989[a].

Spray program[b]	Cultivar[c]				
	NC 6	NC 7	NC 9	NC-V 11	Florigiant
14-day (6)	3	2	4	1	2
89-ADV:					
TDV=48 (5)	6	4	6	5	7
TDV=72 (4)	9	20*	27*	26*	27*
TDV=96 (4)	7	10	17*	7	17*
TDV=120 (3)	12	17*	34*	30*	36*
Check (0)	72*	86*	96*	90*	95*

[a] Leafspot incidence was rated visually as the overall percent of leaflets with one or more spots just prior to harvest.

[b] The 14-day spray schedule started about 35 days after planting and continued until about 21 days prior to harvest. The 89-ADV program used cumulative time-duration values for infection (TDVi) to determine the timing of fungicide sprays. Numbers in parentheses indicate the total number of fungicide applications.

[c] Means in a column followed by an asterisk are significantly different from the 14-day program according to Dunnett's test (P=0.05).

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NC-V 11) showed about the same levels of disease when sprayed with chlorothalonil according to thresholds of TDV_i=48 and 96 in the 89-ADV program or according to a 14-day spray schedule. The highest threshold of the 89-ADV program or TDV_i=120 maintained the same level of disease control as the 14-day spray schedule on the moderately resistant cultivar (NC 6).

Integrating Cultivar and Fungicide Inputs. As in previous field trials, Florigiant and NC 9 showed the highest level of cultivar susceptibility to early leafspot in 1990. The cultivar NC 7, classified previously as moderately susceptible (Table 9), showed a level of disease incidence in untreated plots that was not significantly different from the moderately resistant cultivar NC 6. The lower susceptibility of NC 7 observed in 1990 was attributed to unusually low disease pressure and the delayed development of early leafspot until late in the season. Disease levels in plots of NC 6, NC 7, NC 9 and Florigiant sprayed with chlorothalonil according to the TDV_i=48, 72, 96 and 120 thresholds of the 89-ADV program were not significantly different from the performance standard, chlorothalonil on a 14-day spray schedule (Table 11). Plots of Florigiant and NC 9 sprayed with terbutrazole according to the TDV_i=48 threshold exhibited the same levels of disease incidence as the performance standard. Significantly higher disease incidence than the performance standard was observed when cupric hydroxide plus sulfur was sprayed on Florigiant and NC 9 according to TDV_i thresholds of 48, 72, 96 and 120. Terbutrazole sprayed on NC 6 and NC 7 according to the TDV_i=120 threshold resulted in significantly higher disease incidence than the performance standard. Cupric hydroxide plus sulfur sprayed on NC 6 according to TDV_i thresholds of 48 and 96, and the same fungicide sprayed on NC 7 according to

Table 11. Leafspot incidence at harvest in peanut cultivars sprayed with various fungicides according to a 14-day spray schedule and various thresholds of the 89-ADV program in 1990[a].

Fungicide and Spray Program[b]	Cultivars[c]			
	NC 6	NC 7	NC 9	Flor.
chlorothalonil (1.26 kg/ha)				
14-day (7)	6.3	6.3	3.5	3.5
89-ADV:				
TDV_i=48 (4)	5.3	7.0	4.0	3.8
TDV_i=72 (4)	5.3	6.5	8.0	7.0
TDV_i=96 (3)	5.0	5.5	6.0	7.5
TDV_i=120 (2)	5.3	6.8	12.0	12.5
terbutrazole (126 g/ha)				
14-day (7)	6.0	9.0	16.8*	12.3
89-ADV:				
TDV_i=48 (4)	5.0	7.0	11.8	9.8
TDV_i=72 (4)	10.0	11.0	29.5*	37.5*
TDV_i=96 (3)	8.0	12.8	21.3*	30.0*
TDV_i=120 (2)	17.5*	16.8*	56.3*	60.0*
cupric hydroxide (1.79 kg/ha)				
14-day (7)	7.8	11.0	13.3	8.8
89-ADV:				
TDV_i=48 (4)	10.3	13.5	19.3*	23.8*
TDV_i=72 (4)	12.8*	12.8	35.0*	26.3*
TDV_i=96 (3)	10.5	13.3	19.0*	36.3*
TDV_i=120 (2)	18.3*	13.5	68.8*	81.8*
untreated check (0)	62.5*	52.5*	86.3*	81.8*

[a] Leafspot incidence was rated visually as the overall percent of leaflets with one or more spots just prior to harvest.

[b] The 14-day spray schedule started about 35 days after planting and continued until about 21 days prior to harvest. The 89-ADV program used cumulative time-duration values for infection (TDV_i) to determine the timing of fungicide sprays. Numbers in parentheses indicate total number of fungicide applications.

[c] Means in a column followed by an asterisk are significantly different from the performance standard (chlorothalonil sprayed on a 14-day program) by orthogonal contrast (P=0.05).

TDVi thresholds of 48, 72, 96 and 120 provided disease control that was at the same level as the performance standard.

DISCUSSION

Florigiant was previously reported to be highly susceptible to early leafspot, whereas NC 6 and NC 7 were moderately resistant (20). Field tests from 1988 to 1990 showed Florigiant and NC 9 to be highly susceptible, NC 7 and NC-V 11 to be moderately susceptible, and NC 6 to be moderately resistant. NC 7 behaved similar to NC 6 when disease pressure was low as in the 1990 field trial. The relative susceptibility of various cultivars to early leafspot can be a valuable input for determining the need, frequency and dosage of fungicides to achieve effective disease management. Fry (7, 8) advanced the idea of fungicide equivalents as the amount of fungicide required to suppress disease in a susceptible cultivar to the level seen in cultivars with resistance. Cultivars with a considerable level of resistance required lesser dosages of fungicide per application or fewer spray applications (8). The ultimate goal of utilizing the additive effect of host resistance and fungicide in disease management was the reduction of fungicide use. Gorbet et al. (11) evaluated the additive effect of fungicide with cultivar resistance in a control program for peanut leafspot by combining resistance and fewer applications of fungicide. Increasing the spray interval from 10 to 20 days beginning at 40 days after planting was found to have no effect on leafspot incidence and yield of cultivars with leafspot resistance. Cultivars with high susceptibility to leafspot, on the other hand, sustained significantly higher percentages of defoliation when the spray interval was increased from 10 to 20 days (11). Johnson and Beute (15) assessed the impact of partial resistance and rates of chlorothalonil from 0.6 to

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3.1 L/ha on disease management and yield of peanut. The intention was to reduce the use of fungicide by lowering the dosage required to control leafspot in cultivars with partial resistance. Relative to Florigiant, NC 5 was estimated to have a fungicide equivalence for chlorothalonil of 1.4 L/ha for each application. About half the rate of chlorothalonil was required to achieve the same level of disease control in NC 5 compared to the susceptible cultivar, Florigiant (15). Matyac and Bailey (17) considered a less arbitrary method for reducing the application of fungicide by utilizing the Jensen and Boyle model (14) of the peanut leafspot advisory. The effect of partial resistance on performance of the advisory program was tested by adjusting infection indices by various factors to decrease spray interval (17). The adjusted advisories resulted in fewer sprays per season than the unadjusted version of the advisory and the 14-day spray schedule. The reduction in number of sprays per season, however, resulted in a significant increase of the AUDPC, apparent infection rate and area under the defoliation curve (17).

In a similar way, this research intended to exploit the additive relationship of fungicide and cultivar resistance to reduce fungicide input without jeopardizing disease control. The 89-ADV model of the VPLA represents a disease management program that can integrate fungicide and cultivar selection for improved efficiency in management of early leafspot of peanut with fungicides. Through the use of TDV_i levels as thresholds for fungicide application, the 89-ADV model can accommodate various classes of peanut cultivars based on their relative susceptibility to early leafspot (Table 9). Among the virginia-type cultivars of peanut, Florigiant and NC 9 were highly susceptible (class I), NC 7 and NC-V 11 were moderately susceptible (class II), and NC 6 was moderately resistant (class III) to early leafspot. Chlorothalonil sprayed on class I cultivars at $TDV_i=48$ was

found to be the only advisory threshold that resulted in about the same level of disease control as the performance standard in 1989 (Table 10). The same fungicide sprayed on class II cultivars at the higher threshold of $TDV_i=96$ resulted in the same level of disease control as the performance standard.

Results in 1990, when disease pressure was low, indicated that chlorothalonil applied at thresholds up to $TDV_i=120$ on classes I and II cultivars resulted in acceptable levels of disease control (Table 11). The non-significant difference of the highest advisory threshold ($TDV_i=120$) indicated a longer spray interval could perhaps be tolerated by that particular cultivar-fungicide combination. Interpretation of the 1990 data was given careful consideration since that growing season was characterized by low disease pressure and a delay in disease development. Based on the overall results of fungicide and cultivar tests, an improvement of disease control efficiency at a minimum risk of disease resurgence was attained when either chlorothalonil (1.26 kg/ha), diniconazole (140 g/ha) or terbutrazole (126 g/ha) was applied on class I cultivars according to a spray threshold of $TDV_i=48$ in the 89-ADV program (Tables 8, 10, 11). The same level of efficiency in disease management was also achieved when either chlorothalonil, diniconazole or terbutrazole was sprayed on class II cultivars according to a spray threshold of $TDV_i=96$ in the 89-ADV program. A spray threshold of $TDV_i=120$ for application of chlorothalonil or a spray threshold of $TDV_i=96$ for application of terbutrazole or cupric hydroxide plus sulfur provided the highest efficiency of disease management on class III cultivars. Should commercial registration be granted for use of diniconazole or terbutrazole, additional field testing would be warranted for confirmation of these results.

The 89-ADV model of the VPLA allowed more efficient disease management on Florigiant peanut compared to the 81-ADV model through improved disease control with the same number of sprays per season (3, 4, 6). The improvement of disease control by the 89-ADV program over the 81-ADV program was achieved partly by an extended view of meteorological conditions in the past days or weeks in determining the need for fungicide application. The 81-ADV program considered only a 5-day window, with emphasis on the preceding 2 days of meteorological conditions in detection of disease-favorable conditions. The integration of cultivar and fungicide selection into the 89-ADV algorithm of the advisory program will have obvious benefits compared to the 81-ADV program. A wider range of fungicides and cultivars can be used by growers with greater efficiency. Aside from current fungicides used commercially by growers, three ergosterol biosynthesis inhibitor fungicides were considered in the evaluation process in anticipation of their registration for peanut use. Cultivars used in this study were the same commercial cultivars used in 1990 for planting 93% of the total peanut acreage in Virginia (1). The effect of fungicide and cultivar selection expands the utility of the VPLA by accommodating the different management options available to growers.

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EFFECT OF SPRAY ADJUVANT ON PERFORMANCE OF FUNGICIDES FOR CONTROL OF EARLY LEAFSPOT AND SCLEROTINIA BLIGHT OF PEANUTS

ABSTRACT

SoyOil 937® (93% soybean oil and 7% emulsifiers) at rates of 0, 0.5, 1, 2 and 4% of spray volume (140 L/ha) was evaluated for adjuvant effects on physical spray characteristics of chlorothalonil (Bravo 720®). SoyOil 937® was field tested with chlorothalonil and iprodione (Rovral 50W®) for control of early leafspot of peanut, caused by *Cercospora arachidicola*, and Sclerotinia blight of peanut, caused by *Sclerotinia minor*, respectively. Chlorothalonil with various levels of adjuvant was applied with $D_2 13$ nozzles and 345 kPa pressure for control of early leafspot. Iprodione with adjuvant at 1% of spray volume (335 L/ha) was applied with 8008LP nozzles and 165 kPa pressure. The addition of adjuvant at various rates to sprays of chlorothalonil did not alter spray volume, but the contact angle of spray droplets decreased as adjuvant levels increased. These results suggested an improvement in wetting of the leaf surface. The frequency polygon for deposits of spray droplets without SoyOil 937® approached a Gaussian distribution with a mean diameter of 255.4 μm. As the level of SoyOil 937® was increased, the distribution curve shifted toward a larger size in droplets. SoyOil 937® at a rate of 0.5% of spray volume consistently resulted in significant improvement of leafspot control with chlorothalonil at 1.26 kg/ha, and was significantly better than chlorothalonil alone or at reduced rates with any level of adjuvant. The reduced rate of chlorothalonil (0.95 kg/ha) with SoyOil 937® at 0.5% of spray volume had the same level of fungicidal efficacy as the full rate (1.26 kg/ha) of the fungicide without spray adjuvant. The disease control efficiency of full and reduced rates of chlorothalonil was

reduced significantly (P=0.05) with adjuvant at 4% of spray volume. The performance of iprodione for control of Sclerotinia blight of peanut was not affected significantly by use of SoyOil 937®.

INTRODUCTION

Spray adjuvants have long been advocated for enhancement of pesticide performance in crop protection. Included in the broad definition of spray adjuvants are spray additives representing diverse types of chemistry. They are generally classified as surfactants, stabilizing agents, deposit builders, foam and antifoam agents, buffering agents, activators, and others (9). Oils are another class of spray adjuvants that includes crop oil and oil concentrates. Members of each class of spray adjuvant have a unique type of action that is generally common to a class. Some spray adjuvants may also perform other types of action or impart attributes belonging to other classes of adjuvants. The classification of adjuvants based on their type of action is not mutually exclusive (9). Crop oil may improve droplet distribution, enhance translocation or systemic activity, increase area of spray coverage, improve cuticular or translaminar penetration, and offer some resistance to wash-off by rain (1, 2, 4, 7, 20). All of these factors can be expected to improve the herbicidal and insecticidal properties of pesticides. The addition of adjuvants to sprays of fungicides, however, has resulted in inconsistent results. Some adjuvants are known to enhance the performance of some fungicides while others may increase the severity of disease (14). Before an adjuvant can be recommended with a fungicide, the fungicide-adjuvant preparation should be evaluated for effects on physical spray characteristics and disease control efficacy.

Chlorothalonil and iprodione were selected as test fungicides because of their importance in the control of early leafspot and Sclerotinia blight of peanut, caused by *Cercospora arachidicola* Hori and *Sclerotinia minor* Jagger, respectively. The former fungicide is used widely in Virginia against early leafspot and the application is timed according to the Virginia Peanut Leafspot Advisory program (6, 17). The application of fungicides according to the advisory program has reduced the number of sprays from seven on a 14-day spray program to an average of 3.5 per season. In spite of the reduced number of spray applications, the advisory program has been used to achieve disease control that is comparable to those obtained by spraying on a 14-day schedule. The advisory program requires that an effective fungicide be available for control of early leafspot, and that the material be applied correctly at proper times during the growing season. Improvements in application technique, fungicide formulation and/or physical attributes of sprays are needed to boost fungicide performance and increase growers' confidence in the program. The use of spray adjuvants could enhance the efficiency of disease control either by improving fungicide efficacy or by maintenance of the current level of disease control at a reduced rate of fungicide. The former may reduce the potential yield loss attributed to leafspot disease, while the latter may reduce fungicide input.

The need to improve the performance of fungicides for control of early leafspot and Sclerotinia blight prompted the evaluation of spray adjuvants as a mechanism of enhancing fungicidal activity. Based on preliminary tests, SoyOil 937® was selected for intensive study in the laboratory and field. The objectives of the study were: 1) to evaluate the adjuvant properties of SoyOil 937® at various rates on physical spray characteristics of chlorothalonil; 2) to determine the optimum rate of SoyOil 937® with chlorothalonil for enhanced leafspot

control; 3) to test the adjuvant effect of SoyOil 937® on iprodione for enhanced Sclerotinia blight control; and 4) to explore the possibility of reducing fungicide rates without compromising disease control.

MATERIALS AND METHODS

SoyOil 937®, a commercial adjuvant containing 93% soybean oil and 7% emulsifier (Coastal Chemical Corp., Greenville, NC), was evaluated at rates of 0, 0.5, 1.0, 2.0 and 4.0% of spray volume with and without Bravo 720®, a flowable formulation of chlorothalonil containing 720 g a.i./L (ISK Biotech Corp., Painesville, OH). These rates corresponded to 0, 0.7, 1.4, 2.8 and 5.6 L of SoyOil 937® with a spray volume of 140 L/ha. Determinations of Bravo 720® spray characteristics with and without adjuvant included measurements of droplet contact angle (11), spray discharge, area of spray coverage, and droplet size after deposition. Adjuvant effects on the fungicidal activity of Bravo 720® and Rovral 50W® (iprodione, Rhone-Poulenc Ag Co., NC) were determined in field plots.

Effect on droplet characteristics. Droplet-to-surface interaction was assessed by measurement of the contact angle on a flat waxy surface that resembled a peanut leaf. The contact angle of water on the third fully expanded leaf from the apex of the main stem of peanut (cv. Florigiant) was measured using a Model 100-00 Contact Angle Goniometer (Ramé-Hart, Inc., New Jersey). A flat and durable material with about the same water contact angle as the leaf was needed to simulate a peanut leaf in droplet contact angle studies involving increased rates of adjuvant. Paraffin, polyethylene, and polypropylene were tested to find a substitute for peanut leaves. Based on results of these tests, a paraffin-coated slide was used as the stage in the humidified chamber of the goniometer.

The spray droplet contact angle for Bravo 720® at 12.5 ml/L was measured with SoyOil 937 at levels of 0, 0.5, 1.0, 2.0 and 4.0 percent of spray volume. Contact angles were transformed to cosine θ prior to statistical analysis.

Droplet size, droplet distribution, and the area of spray coverage were determined after spraying different adjuvant concentrations on gridded transparency film using a CO_2 pressurized sprayer equipped with $D_2 13$ (disc-core combination) nozzles. The fungicide-adjuvant preparations were sprayed at 345 kPa and a speed of 4.32 km/hr. Spray pressure, speed, and volume per unit area approached that for field application. The droplets per grid area were counted with the light microscope, and the diameter of 100 systematically selected droplets were measured with an ocular micrometer. Spray droplet distribution was described by the number of droplets per cm^2, and the occurrence of droplets in various size categories. These data were used to develop a frequency polygon showing the mean, median and mode of droplets. Spray coverage was calculated from the ratio of the area covered by the droplets (product of the number of droplets per grid and mean droplet size) to the area of the grid.

Field Evaluation. Florigiant peanut was planted in a Kenansville loamy sand with a corn-peanut history of crop rotation at the Tidewater Agricultural Experiment Station, VPI&SU, Suffolk, Virginia. Cultural practices recommended by the Virginia Cooperative Extension Service were followed in crop management (22). Bravo 720® was evaluated at rates of 0, 0.44, 0.88 and 1.75 L/ha in 1987; and 0, 0.88, 1.32 and 1.75 L/ha in 1988. SoyOil 937® was tested at 0, 0.5, 1.0, 2.0 and 4.0 percent of spray volume (140 L/ha). Rovral 50W® at 2.24 kg/ha with SoyOil 937® at 1% of spray volume was tested in a field with a history of Sclerotinia blight. Treatments were applied to the two center rows of each plot. Plots

consisted of four 12-m rows, spaced 0.9 m apart. Treatments were replicated four times in a randomized complete block design. Fungicide-adjuvant preparations were applied according to guidelines of the Virginia peanut leafspot advisory program (6) using a CO_2 pressurized sprayer equipped with three $D_2$13 (disc-core combination) nozzles per row. Treatments for control of leafspot were applied at 345 kPa and a ground speed of 4.38 km/hr, delivering 140 L/ha. Treatments for control of Sclerotinia blight were applied on demand, and at four and eight weeks after the first application with one 8008LP nozzle centered over each row, delivering 335 L/ha at 165 kPa and a ground speed of 4.38 km/hr.

Leafspot incidence and defoliation were assessed every 30 days by visual estimates of the percent of leaflets with one or more spots. Incidence of Sclerotinia blight was evaluated by counts of infection centers in the two center rows of each plot (16). An infection center was a point of active fungal growth and included 15.24 cm of row length on either side of the point. Yield and quality were determined from the weight of peanuts, adjusted to 7% moisture (w/w). Value was determined by grading a composite sample of peanuts from all four replicates of each treatment in accordance with Federal-State Inspection Service methods.

RESULTS

Effect of SoyOil 937® on droplet characteristics. The contact angle of water on peanut leaves averaged 127° 25', whereas that for paraffin, polypropylene and polyethylene was 106° 0', 83° 5', and 71° 3', respectively. Paraffin was selected to simulate the peanut leaf in measuring the contact angle of fungicide spray droplets with various levels of adjuvant. The contact angle of droplets with Bravo 720® at 12.5 ml/L of spray volume

measured 64° 13'. At the same rate of Bravo 720®, there was a reduction of contact angle to 56° 25', 53° 0', 50° 38' and 48° 12' as levels of adjuvant increased from 0.5, 1.0, 2.0 to 4.0 percent of spray volume, respectively (Table 12). The contact angle of droplets was transformed to cosine θ for regression analysis. The regression equation, $Y = 0.51286 +.0402X$, was obtained wherein X=rate of adjuvant in percent of spray volume and Y=cosine θ of the contact angle. The coefficient of correlation of 0.93 was significant at P=0.0067 (Figure 5). The mean diameter of spray deposits (Bravo 720® at 12.5 ml/L of spray volume) without adjuvant was 255.42 μm. There was a positive correlation of droplet size and levels of SoyOil 937® up to 2% of spray volume (Table 13). The size difference of droplets with adjuvant at 2 and 4% of spray volume was not statistically significant. In proportion to the increase in droplet size as adjuvant concentration increased, the number of droplets per cm^2 decreased at a constant rate of spray discharge (Figure 6). At the same rate of Bravo 720®, the distribution of spray droplets without adjuvant approached a Gaussian distribution with mean and median equal to 255.4 and 222.48 μm, respectively (Fig. 7, A). The distribution pattern shifted toward the larger droplet sizes (Fig. 7, B & C) as levels of adjuvant were increased from 0 to 1% of spray volume. At 2% of spray volume, the size of droplets exhibited a distinct bimodal distribution (Fig. 7, D). There was a shift of the minor mode and the major mode positions as well as an increase in droplet size at the 4% level of spray adjuvant (Fig. 7, E). The mean diameter of droplet deposits increased progressively as the adjuvant levels increased from 0 to 2% of spray volume. Although there was a numerical increase in the median diameter of droplets from the 2 to 4% levels of adjuvant, the increase was not significant.

Table 12. Contact angle of spray droplet deposits containing Bravo 720® and SoyOil 937®.

SoyOil 937® (% spray vol.)[a]	Contact angle	Cosine θ[b]
0.0	64° 13'	0.43 d
0.5	56° 25'	0.55 c
1.0	53° 00'	0.60 b
2.0	50° 38'	0.63 ab
4.0	48° 12'	0.67 a

[a] Rates from 0 to 4% of spray volume (140 L/ha) correspond to 0, 0.7, 1.4, 2.8 and 5.6 L/ha of SoyOil 937® with Bravo 720® at 12.5 ml/L.

[b] Contact angles were transformed to cosine θ before statistical analysis. Means followed by the same letters are not significantly different according to Waller-Duncan k-ratio procedure (P=0.05).
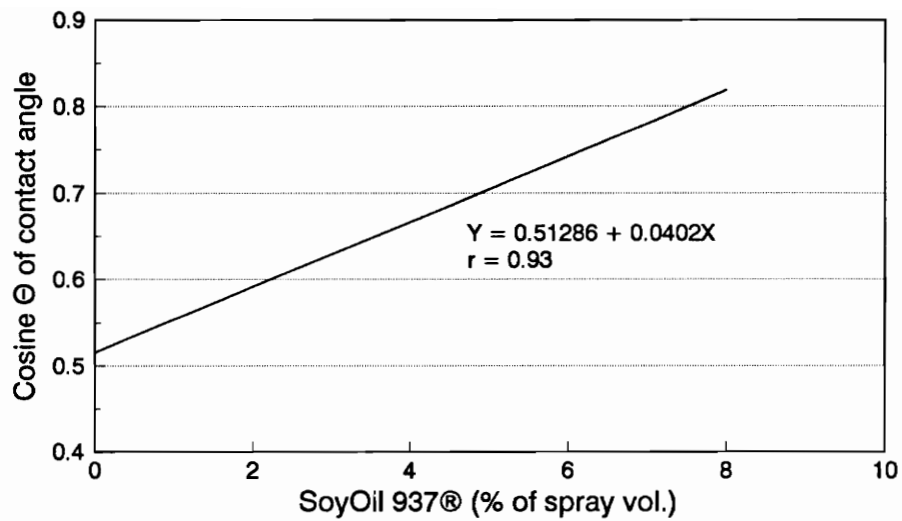
Figure 5. Correlation of cosine θ for the contact angle of spray deposits, and rate of adjuvant (P=0.0067, n=24). Sprays contained Bravo 720® at 12.5 ml/L and SoyOil 937® at 0, 0.5, 1.0, 2.0, 4.0 and 8.0 percent of spray volume.

Table 13. Characteristics of spray droplets with Bravo 720® (12.5 ml/L) and increasing levels of SoyOil 937®.

SoyOil 937® (% spray vol.)[a]	Nozzle discharge (ml/min)[b]	Droplet size (μm) after deposition[c]	Number of droplets per cm^2	Percent Spray coverage[d]
0.0	351.7 a[e]	255.4 d	197.2 a	10.10 c
0.5	351.7 a	343.0 c	121.4 b	11.22 bc
1.0	355.0 a	407.4 b	98.9 c	12.89 b
2.0	355.0 a	511.6 a	83.5 d	17.16 a
4.0	356.7 a	534.1 a	86.1 d	19.28 a

[a] Based on spray volume of 140 L/ha.
[b] Nozzle discharge was measured at a spray pressure of 345 kPa using a CO_2-pressurized sprayer with three $D_2$13 (disc-core) nozzles.
[c] Droplets per cm^2 were counted, and the size of 100 droplets was measured after deposition on gridded transparency film.
[d] Spray coverage was the product of the number of droplets per cm^2 grid and mean droplet size.
[e] Means in a column followed by the same letters are not significantly different by Waller-Duncan k-ratio procedure (P=0.05).
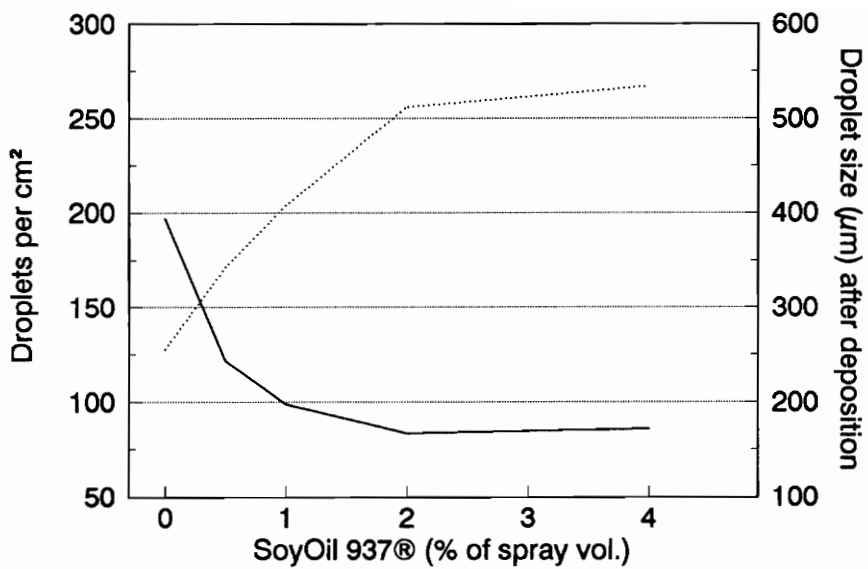
Figure 6. Droplet size (μm) after deposition (dotted line) and droplets/cm^2 (solid line) at various levels of SoyOil 937® in percent of spray volume (140 L/ha). Spray contained Bravo 720® at 12.5 ml/L.
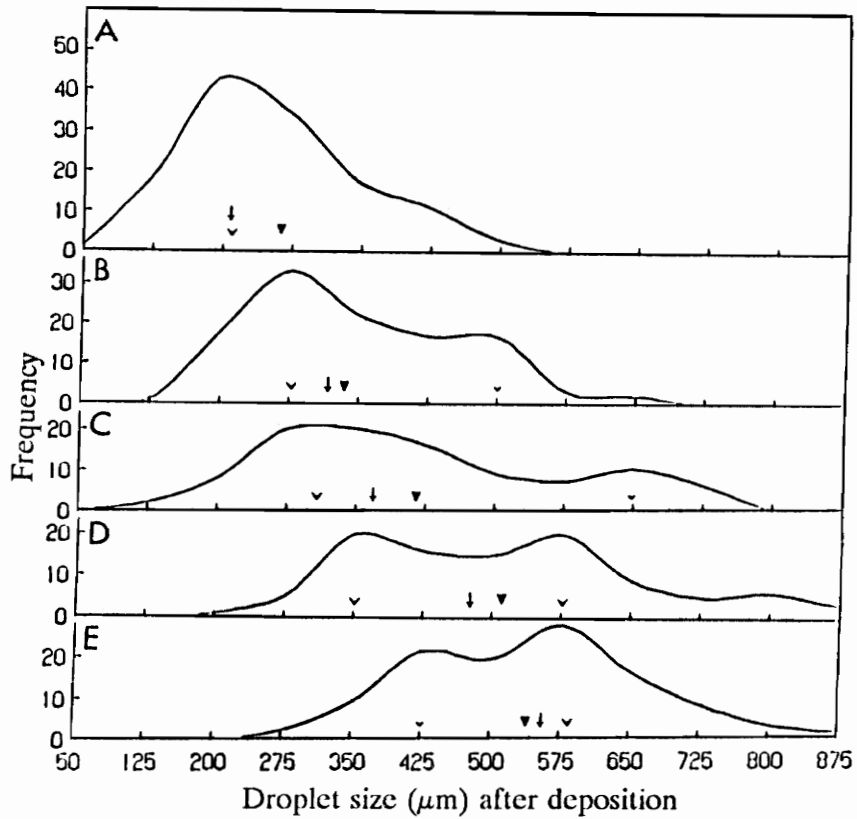
Figure 7. Size distribution of spray droplets containing Bravo 720® (12.5 ml/L) with and without SoyOil 937® (▾=mean; ↓=median; v=mode; n=100). A) Frequency distribution of spray droplets without adjuvant. B, C) Frequency distribution with 0.5 and 1.0 percent adjuvant, respectively; D, E) Bimodal distribution of droplets with 2 and 4 percent adjuvant, respectively.

Field evaluation. The evaluation of leafspot incidence during the 2-year period of field studies indicated that SoyOil 937® alone at rates up to 4% of spray volume had no effect on disease. There was a significant reduction of leafspot incidence with application of Bravo 720® alone at rates from 0.44 to 1.75 L/ha. The best level of disease control was obtained with Bravo 720® at 1.75 L/ha and SoyOil 937® at 0.5% of spray volume. A significant reduction of disease incidence occurred with the 0.5% level of adjuvant, whereas an increase in disease incidence occurred with adjuvant rates exceeding 2% of spray volume (Figure 8). Leafspot incidence in plots treated with Bravo 720® alone at 1.75 L/ha was not significantly different from that of Bravo 720® at the reduced rate (1.32 L/ha) plus SoyOil 937® at 0.5% of spray volume.

Yield data from the field study in 1987 did not show a significant improvement with the addition of SoyOil 937® at rates of 0.5% to 2.0% of spray volume. At the 4% level of adjuvant, yields were consistently reduced in comparison to treatments with Bravo 720® alone (Table 14). The field study in 1988 also showed a trend towards reduced yields at the 4% level of adjuvant compared to almost all of the other treatments. SoyOil 937® did not appear to have any adjuvant effects on performance of Rovral 50W® for control of Sclerotinia blight (Table 15). Disease incidence in plots treated with Rovral 50W with or without spray adjuvant was significantly lower than the untreated check, and the use of Rovral 50W® resulted in significantly higher yield. Significant differences in disease incidence and yield among plots treated with Rovral 50W® with and without SoyOil 937® at 1% of spray volume were not detected in the 1985 field test.
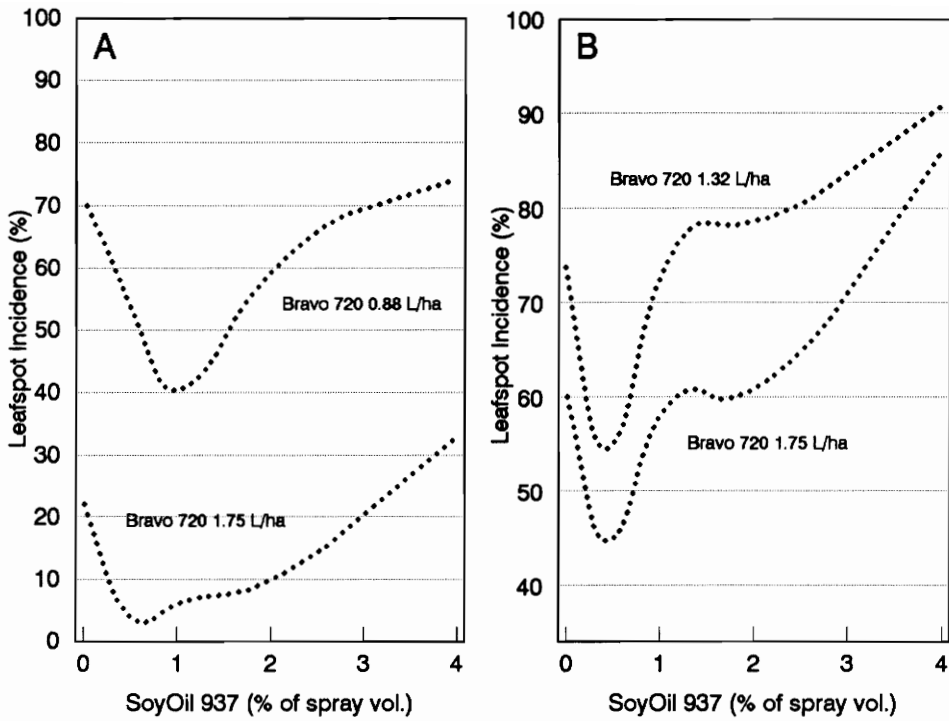
Figure 8. Control of early leafspot of peanut with various rates of Bravo 720® and SoyOil 937®. Graphs A and B are disease incidence in Florigiant peanut just prior to harvest in 1987 and 1988 field tests, respectively.

Table 14. Effect of Bravo 720® with and without SoyOil 937® on yield of peanut from field trials in 1987 and 1988[a].

SoyOil 937® (% spray volume)		Bravo 720® (L/ha)				
		0	0.44	0.88	1.32	1.75
1987	0	4068 g[b]	4957 b-e	4919 c-e	-[c]	5219 a-c
	0.5	3993 g	4731 d-f	5056 a-d	-	5307 ab
	1.0	3956 g	4831 de	5069 a-d	-	5056 a-d
	2.0	4005 g	4882 c-e	4794 de	-	5357 a
	4.0	3767 g	4406 f	4668 ef	-	4831 de
1988	0	3032 c	-	3677 a-c	4219 a	3857 a-c
	0.5	-	-	3831 a-c	3909 a-c	4116 ab
	1.0	-	-	3780 a-c	3573 a-c	4180 a
	2.0	-	-	3922 a-c	3974 ab	4013 ab
	4.0	-	-	3470 a-c	3599 a-c	3182 bc

[a] Yield (kg/ha) was determined from the weight of peanuts, adjusted to 7% moisture (w/w).
[b] Means with the same letters in a row or column for a given year are not significantly different by Waller-Duncan k-ratio procedure (P=0.05).
[c] "-" indicates the treatment was not tested.

Table 15. Sclerotinia blight incidence and yield of Florigiant peanut following treatments of Rovral 50W® with and without SoyOil 937® at 1% of spray volume.

Fungicide and adjuvant treatment	Disease incidence (Hits per plot)	Yield (kg/ha)
Rovral 50W® + SoyOil 937®	33.0 b	4035 a
Rovral 50W®	29.3 b	3884 a
Untreated check	49.0 a	2875 b

Sprays of Rovral 50W® (2.24 kg/ha) were applied at 335 L/ha spray volume on demand, and repeated at 4 and 8 weeks later (18 Jul, 14 Aug, 12 Sep) in 1985. Disease incidence was rated at harvest. Means in a column with the same letters are not significantly different by the Waller-Duncan k-ratio procedure (P=0.05).

DISCUSSION

The degree of water repellency or wettability of leaves largely depends on the composition of cuticular wax and surface roughness (11). Reducing the surface tension of spray droplets by the use of adjuvant improves the wetting characteristics of spray droplets on waxy surfaces. On the basis of water contact angle, leaves have been classified into two categories (11). Leaves with water contact angles above and below 90° were classified as waxy and non-waxy, respectively. Waxy leaves with contact angles below and above 110° were further classified into smooth waxy and rough waxy, respectively. The peanut leaf, having a water contact angle of 127° 25' was classified as rough and waxy. SoyOil 937® or other formulations of crop and paraffin-based oil concentrates can be expected to improve wetting of waxy surfaces by aqueous spray droplets (9).

Linear regression of the cosine θ of contact angles for spray mixtures of Bravo 720® and SoyOil 937® indicated a gradual improvement of wettability at increasing levels of adjuvant. The size of droplets after deposition increased with increasing concentrations of adjuvant up to 2% of spray volume. The increase in size resulted in a proportional reduction of droplet density at the same spray discharge rate (Figure 6). Sundaram and Leung (21) also reported the reduction of droplet density and the consequent increase of droplet size as spray droplet viscosity was improved with oil. Beyond a level of 2% of SoyOil 937®, the change in mean droplet size and droplet density were not significant at P=0.05 (Table 13).

The dosage-dependent effect of SoyOil 937® at levels ranging from 0 to 4% of spray volume was reflected by leafspot incidence in field trials. Leafspot incidence in plots sprayed with chlorothalonil resulted in a significant reduction of disease incidence at the

adjuvant level of 0.5%, and a significant increase of disease incidence at levels of adjuvant higher than 2% of spray volume. The dosage-dependent phenomenon was observed consistently in 1987 and 1988 field trials with Bravo 720® at rates of 0.88, 1.32 and 1.75 L/ha. This phenomenon might be attributed to an increased level of emulsifier and/or oil on the surface of leaves at high rates of adjuvant. Excessive levels of adjuvant on leaves may increase disease severity in three ways: 1) the emulsifier may dissolve the protective cuticular wax and increase susceptibility of leaves to infection and colonization by pathogens (10); 2) the emulsifier could enhance the loss of pesticide from wash-off during heavy rain; and 3) the adjuvant may bind tightly or entomb the pesticide making it unavailable. This is a common phenomenon in pesticide formulations or spray mixtures with high levels of stickers (23). The first explanation seems unlikely, since application of adjuvant alone did not affect disease severity. The second rationale is the most likely reason for the loss of disease control with Bravo 720® and the 4% level of SoyOil 937®. At high rates, the emulsifier may act as a detergent during heavy rain resulting in the redistribution and wash-off of fungicide from the leaves. This phenomenon is referred to as rewetting (23).

Bronzing of leaves was observed in plots sprayed with Bravo 720® and high rates of SoyOil 937®. The severity of bronzing increased with increasing concentrations of adjuvant from 1 to 4% of spray volume. At the 1% level of adjuvant with Bravo 720®, bronzing was hardly noticeable. Bronzing was not observed in plots sprayed with Bravo 720® or SoyOil 937® alone at various rates.

Yield data did not indicate a significant benefit of using adjuvant from 0 to 2% of spray volume with various rates of Bravo 720®. At the 4% level of adjuvant, the reduction of disease control was linked to a reduction in yield. A significant adjuvant effect of SoyOil

937® at 1% of spray volume on iprodione at 2.24 kg/ha was not detected. Both Sclerotinia blight incidence and yield did not reflect significant changes in performance of iprodione. The non-significant differences in this test, however, should not be considered conclusive since rates of Rovral 50W® and adjuvant were not varied.

The use of SoyOil 937® at 0.5% of spray volume as a spray adjuvant for Bravo 720® was demonstrated to improve the control of early leafspot of Florigiant peanut in 1987, 1988 and during the confirmatory test in 1989 (15). The reduced rate of Bravo 720® (1.32 L/ha) with SoyOil 937® at 0.5% of spray volume was shown to have the same level of fungicidal activity as the full label rate (1.75 L/ha.) of the fungicide without adjuvant. This reduction of fungicide use, if implemented in the state of Virginia, could amount to a reduction of fungicide input of about 68,800 L of the fungicide based on an average of four applications per season on 40,000 hectares of peanuts.

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Program for Disease Progress Simulation

```
DECLARE SUB AEMS1983 (MDate, CDate)
DECLARE SUB AEMS1984 (MDate, CDate)
DECLARE SUB AEMS1985 (MDate, CDate)
DECLARE SUB AEMS1986 (MDate, CDate)
DECLARE SUB AEMS1987 (MDate, CDate)
DECLARE SUB AEMS1988 (MDate, CDate)
DECLARE SUB SIMULATOR (F$, MDate, CDate)

'COVER SCREEN
  CLS : COLOR 3: LOCATE 1, 13: PRINT CHR$(201)
    FOR N = 14 TO 68
        LOCATE 1, N
        PRINT CHR$(205)
    NEXT N
  LOCATE 4, 13: PRINT CHR$(200): LOCATE 4, 14
    FOR N = 14 TO 68
        LOCATE 4, N
        PRINT CHR$(205)
    NEXT N
    FOR N = 2 TO 3
        LOCATE N, 13
        PRINT CHR$(186)
    NEXT N
  LOCATE 1, 69: PRINT CHR$(187)
  LOCATE 4, 69: PRINT CHR$(188)
    FOR N = 2 TO 3
        LOCATE N, 69
        PRINT CHR$(186)
    NEXT N

  LOCATE 2, 22: PRINT "WELCOME TO THE PEANUT LEAFSPOT SIMULATOR"
  LOCATE 3, 15: PRINT "An interactive program for fungicide spray evaluation"
  LOCATE 8, 20: PRINT "VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY"
  PRINT TAB(15); "Dept. of Plant Pathology, Physiology and Weed Science"
  PRINT TAB(30); "Blacksburg, VA 24061"
  LOCATE 12, 15: PRINT "Developed by:"
  PRINT TAB(29); "R. M. Cu"

  LOCATE 22, 25: COLOR 25: INPUT "PRESS RETURN TO CONTINUE", B$

DO
  SCREEN 0: CLS : COLOR 3
  LOCATE 3, 27: PRINT CHR$(201)
```

```basic
    FOR N = 28 TO 57
       LOCATE 3, N
       PRINT CHR$(205)
    NEXT N

LOCATE 6, 27: PRINT CHR$(200)

    FOR N = 28 TO 57
       LOCATE 6, N
       PRINT CHR$(205)
    NEXT N

LOCATE 3, 58: PRINT CHR$(187)

    FOR N = 4 TO 5
       LOCATE N, 58
       PRINT CHR$(186)
    NEXT N

LOCATE 6, 58: PRINT CHR$(188)

    FOR N = 4 TO 5
       LOCATE N, 27
       PRINT CHR$(186)
    NEXT N

LOCATE 4, 30: PRINT "DISEASE PROGRESS SIMULATOR"
LOCATE 5, 29: PRINT "FOR EARLY LEAFSPOT OF PEANUT"
LOCATE 8, 16: PRINT "This program simulates disease progress of early"
LOCATE 9, 16: PRINT "leafspot based on historical weather data from "
LOCATE 10, 16: PRINT "the Agro-Environmental Monitoring System in Suffolk."
LOCATE 12, 16: PRINT "Leafspot incidence estimates are within the 5 percent"
LOCATE 13, 16: PRINT "confidence band of the disease progress model."
LOCATE 7, 14: PRINT CHR$(201)

    FOR N = 15 TO 70
       LOCATE 7, N
       PRINT CHR$(205)
    NEXT N

LOCATE 7, 70: PRINT CHR$(187)

    FOR N = 15 TO 70
       LOCATE 15, N
       PRINT CHR$(205)
    NEXT N

LOCATE 15, 14: PRINT CHR$(200)

    FOR N = 8 TO 14
       LOCATE N, 14
       PRINT CHR$(186)
    NEXT N
```

```
        LOCATE 15, 70: PRINT CHR$(188)

        FOR N = 8 TO 14
            LOCATE N, 70
            PRINT CHR$(186)
        NEXT N

        LOCATE 16, 20: PRINT "Please select year to run:": PRINT
        PRINT TAB(33); "1. 1988        4. 1985"
        PRINT TAB(33); "2. 1987        5. 1984"
        PRINT TAB(33); "3. 1986        6. 1983"

        LOCATE 21, 31: INPUT "Type your selection (1-6):", CH$: LOCATE 22, 18
        INPUT "Enter average maturity date of variety (Flor=150):", MDate
        LOCATE 23, 18: INPUT "Enter spray cutoff date (in days before harvest):", CDate

            SELECT CASE CH$
              CASE "1"
                CALL AEMS1988(MDate, CDate)
              CASE "2"
                CALL AEMS1987(MDate, CDate)
              CASE "3"
                CALL AEMS1986(MDate, CDate)
              CASE "4"
                CALL AEMS1985(MDate, CDate)
              CASE "5"
                CALL AEMS1984(MDate, CDate)
              CASE "6"
                CALL AEMS1983(MDate, CDate)
              CASE ELSE
                BEEP
              END SELECT

LOOP
STOP


SUB AEMS1983 (MDate, CDate)
   F$ = "A:AEMS83.DAT"
   CALL SIMULATOR(F$, MDate, CDate)
END SUB

SUB AEMS1984 (MDate, CDate)
   F$ = "A:AEMS84.DAT"
   MDATE = 134
   CALL SIMULATOR(F$, MDate, CDate)
END SUB

SUB AEMS1985 (MDate, CDate)
   F$ = "A:AEMS85.DAT"
   CALL SIMULATOR(F$, MDate, CDate)
END SUB
```

```
SUB AEMS1986 (MDate, CDate)
   F$ = "A:AEMS86.DAT"
   CALL SIMULATOR(F$, MDate, CDate)
END SUB

SUB AEMS1987 (MDate, CDate)
   F$ = "A:AEMS87.DAT"
   CALL SIMULATOR(F$, MDate, CDate)
END SUB

SUB AEMS1988 (MDate, CDate)
   F$ = "A:AEMS88.DAT"
   CALL SIMULATOR(F$, MDate, CDate)
END SUB

SUB SIMULATOR (F$, MDate, CDate)
DIM A$(12), BAR(5): A$(1) = "A": A$(2) = "B"
A$(3) = "C": A$(4) = "D": A$(5) = "E": A$(6) = "F"

'CUSTOMIZE SCREEN
   CLS : SCREEN 2: LOCATE 1, 38: PRINT "EARLY LEAFSPOT SIMULATOR"
   LOCATE 5, 40: PRINT "SIMULATING: "; F$
   LINE (250, 25)-(575, 50), , B
   LINE (250, 60)-(575, 130), , B
   LINE (250, 140)-(575, 155), , B
   LINE (450, 75)-(560, 75)

   'DRAW AXIS
   LINE (52, 164)-(52 + 8 * 13, 164)
   LINE (52, 164)-(52, 4)

   'DRAW TICK MARKS
   FOR J = 1 TO 10
       LINE (47, 164 - 16 * J)-(57, 164 - 16 * J)
       LOCATE 21 - 2 * J, 4: PRINT USING "###"; J * 10;
   NEXT J

   FOR J = 1 TO 6
       LINE (52 + 16 * J, 164)-(52 + 16 * J, 169)
       LOCATE 23, (52 + 17 * J) / 8: PRINT A$(J)
   NEXT J

   GOSUB LABELS: GOSUB VALUE
   LOCATE 23, 35: INPUT "PRESS RETURN TO CONTINUE ", B$
   LOCATE 23, 35: PRINT "PROGRAM IS RUNNING         "

OPEN F$ FOR INPUT AS #1
   DO WHILE NOT EOF(1)
     INPUT #1, M1, D1, Y1, TDI, DAP
     M1$ = STR$(M1): D1$ = STR$(D1): Y1$ = STR$(Y1)
     ATDI = ATDI + TDI: DAP$ = STR$(DAP)
     'CHECK = -24.4568 + (.2019369# * ATDI)
     CHECK = (-.16833 + (.001699 * ATDI)) * 100
```

```
        IF CHECK < 0 THEN
            CHECK1 = 0
        ELSE
            CHECK1 = CHECK
        END IF

CHECK2 = CHECK1: CHECK3 = CHECK2
CRLEFF1 = CHECK2 * .917: CRLEFF2 = CHECK2 * .8783
CRLEFF3 = CHECK2 * .7838: CRLEFF4 = CHECK2 * .4082
SPRAY14 = (CHECK2 - CRLEFF1): TDV48 = (CHECK2 - CRLEFF2)
TDV72 = (CHECK2 - CRLEFF3): TDV96 = (CHECK2 - CRLEFF4)
MODEL1 = MODEL1 + TDI: MODEL2 = MODEL2 + TDI: MODEL3 = MODEL3 + TDI

    IF MODEL1 >= 48 THEN
        FLAG1 = FLAG1 + 1
            IF FLAG1 = 3 THEN
                IF DAP < (MDate - CDate) THEN
                    SPRAY1 = SPRAY1 + 1: C1 = C1 + 1
                    SY1$(C1) = (M1$ + D1$ + Y1$): DAP1$(C1) = DAP$
                END IF
            END IF
    END IF

    IF FLAG1 > 2 THEN
        FL1 = FL1 + 1
            IF FL1 = 12 THEN
                FL1 = 0: MODEL1 = 0: FLAG1 = 0
            END IF
    END IF

    IF MODEL2 >= 72 THEN
        FLAG2 = FLAG2 + 1:
            IF FLAG2 = 3 THEN
                IF DAP < (MDate - CDate) THEN
                    SPRAY2 = SPRAY2 + 1: C2 = C2 + 1
                    SY2$(C2) = (M1$ + D1$ + Y1$): DAP2$(C2) = DAP$
                END IF
            END IF
    END IF

    IF FLAG2 > 2 THEN
        FL2 = FL2 + 1
            IF FL2 = 12 THEN
                FL2 = 0: MODEL2 = 0: FLAG2 = 0
            END IF
    END IF

    IF MODEL3 >= 96 THEN
        FLAG3 = FLAG3 + 1
            IF FLAG3 = 3 THEN
                IF DAP < (MDate - CDate) THEN
                    SPRAY3 = SPRAY3 + 1: C3 = C3 + 1
                    SY3$(C3) = (M1$ + D1$ + Y1$): DAP3$(C3) = DAP$
```

```
              END IF
            END IF
     END IF

     IF FLAG3 > 2 THEN
        FL3 = FL3 + 1
           IF FL3 = 12 THEN
              FL3 = 0: MODEL3 = 0: FLAG3 = 0
           END IF
     END IF

  N1 = N1 + 1: LOCATE 19, 57: PRINT USING "###"; DAP

  'DRAW BARS
     GOSUB VALUE
     CHECK3 = CHECK2
     BAR(1) = CHECK3 / 100: BAR(2) = SPRAY14 / 100: BAR(3) = TDV48 / 100
     BAR(4) = TDV72 / 100: BAR(5) = TDV96 / 100

   FOR J = 1 TO 5
     LINE (50 + 16 * J, 164)-(54 + 16 * J, 164 - BAR(J) * 160), , BF
   NEXT J

   IF N1 > 10 THEN
     N1 = 0
     GOSUB VALUE

   LOCATE 23, 35: INPUT "PRESS RETURN TO CONTINUE ", B$
   LOCATE 23, 35: PRINT "PROGRAM IS RUNNING          "

   'AUDPC ROUTINE
   WEEK = WEEK + 1
      'AUDPC FOR CHECK

      IF CHECK3 > 0 THEN
         AUDPC1 = (DAP - DAP1) * ((CHECK3 + CHECK4) / 2)
         AUDPC = AUDPC + AUDPC1: CHECK4 = CHECK3
      'AUDPC FOR SPRAY 14
         AUDPC2 = (DAP - DAP1) * ((SPRAY14 + SPRAY15) / 2)
         AUDPC3 = AUDPC3 + AUDPC2: SPRAY15 = SPRAY14
      'AUDPC FOR TDV 48
         AUDPC4 = (DAP - DAP1) * ((TDV48 + TDV49) / 2)
         AUDPC5 = AUDPC5 + AUDPC4: TDV49 = TDV48
      'AUDPC FOR TDV 72
         AUDPC6 = (DAP - DAP1) * ((TDV72 + TDV73) / 2)
         AUDPC7 = AUDPC7 + AUDPC6: TDV73 = TDV72
      'AUDPC FOR TDV 96
         AUDPC8 = (WEEK - WEEK1) * ((TDV96 + TDV97) / 2)
         AUDPC9 = AUDPC9 + AUDPC8: TDV97 = TDV96

         WEEK1 = WEEK
         DAP1 = DAP
      ELSE
```

```
                    WEEK1 = WEEK: CHECK4 = CHECK3: SPRAY15 = SPRAY14
                    TDV49 = TDV48: TDV73 = TDV72: TDV97 = TDV96

           END IF
       END IF
    LOOP

LOCATE 22, 35: PRINT "   SIMULATION HAS ENDED!"
LOCATE 23, 35: INPUT "DO YOU WANT RESULT PRINTOUT"; ANS$

IF ANS$ = "Y" THEN
  GOTO PROUT
ELSE
  GOTO NOPROUT
END IF


LABELS:
     LOCATE 9, 33: PRINT "SPRAY PROGRAM:": LOCATE 9, 58: PRINT "DIS(%)   AUDPC"
     LOCATE 11, 35: PRINT "A = UNTREATED CHECK"
     LOCATE 12, 35: PRINT "B = 14-DAY SCHEDULE"
     LOCATE 13, 35: PRINT "C = MODEL 1 (TDV 48)"
     LOCATE 14, 35: PRINT "D = MODEL 2 (TDV 72)"
     LOCATE 15, 35: PRINT "E = MODEL 3 (TDV 96)"
     LOCATE 16, 35: PRINT "F = 1981 ADVISORY"
     LOCATE 19, 35: PRINT "Days after planting:"
RETURN

VALUE:
     XCHECK3 = CHECK3
     IF XCHECK3 > 100 THEN
        XCHECK3 = 100
     END IF

     LOCATE 11, 54: PRINT USING "####.##  "; XCHECK3, AUDPC
     LOCATE 12, 54: PRINT USING "####.##  "; SPRAY14, AUDPC3
     LOCATE 13, 54: PRINT USING "####.##  "; TDV48, AUDPC5
     LOCATE 14, 54: PRINT USING "####.##  "; TDV72, AUDPC7
     LOCATE 15, 54: PRINT USING "####.##  "; TDV96, AUDPC9
     LOCATE 16, 54: PRINT USING "####.##  "; ADV, AUDPC10
RETURN


PROUT:
     LPRINT "MODEL1 (TDV = 48)"
     LPRINT "DATE SPRAYED, DAYS AFTER PLANTING "

     FOR N = 1 TO C1
        LPRINT N; SY1$(N), DAP1$(N)
     NEXT N

     LPRINT : LPRINT : LPRINT "MODEL2 (TDV = 72)"
     LPRINT "DATE SPRAYED, DAYS AFTER PLANTING"
```

```
        FOR N = 1 TO C2
           LPRINT N; SY2$(N), DAP2$(N)
        NEXT N

        LPRINT : LPRINT : LPRINT "MODEL3 (TDV = 96)"
        LPRINT "DATE SPRAYED, DAYS AFTER PLANTING"

        FOR N = 1 TO C3
           LPRINT N; SY3$(N), DAP3$
        NEXT N

        LPRINT : LPRINT : LPRINT : LPRINT
        LPRINT "TREATMENT    SPRAY FREQ.        DIS(%)        AUDPC"
        LPRINT "1. CHECK       0 ", XCHECK3, AUDPC
        LPRINT "2. 14-DAY      7 ", SPRAY14, AUDPC3
        LPRINT "3. MODEL 1 ", SPRAY1, TDV48, AUDPC5
        LPRINT "4. MODEL 2 ", SPRAY2, TDV72, AUDPC7
        LPRINT "5. MODEL 3 ", SPRAY3, TDV96, AUDPC9
        LPRINT "6. MODEL 4 ", ADV, AUDPC10

NOPROUT:
  'NO PRINTOUT
  CLOSE
END SUB
```

Program That Automates AEMS Data Retrieval

```
DECLARE SUB ScreenMenu ()
DECLARE SUB INITIALIZE ()
DECLARE SUB RUNADVISORY (FCD!)
DECLARE SUB PRINTADVISORY ()
DECLARE SUB BACKTODOS ()
'PROGRAM THAT AUTOMATES DATA RETRIEVAL FROM AEMS CENTRAL COMPUTER
'THIS PROGRAM REQUIRES BitCom Communications Program (BIT SOFTWARE, INC., MILPITAS, CA)
'COMMANDS FROM DIAL AND ACTIONFILE ARE NOT EXECUTED BY THIS PROGRAM BUT ARE
'USED BY BITCOMM TO ESTABLISH LINK WITH THE AEMS CENTRAL COMPUTER.
DIAL:
  'TEST.SCP contains script file used to run BitCom
     'SELECT(AEMS)
     'DOCOMM
     ':LOOP
       'TWAIT (2, "SEC")
       'IF (@CONN=1) GOTO :DONE
       'IF (@CONN=2) GOTO :WAIT
       'GOTO :LOOP
     ':WAIT
       'TWAIT (60, "SEC")
       'GOTO :LOOP
     ':DONE
       'EXIT

ACTIONFILE:
  'ACTION.ACT contains specific jobs for BitCom.
  'This file is generated by the action file generator
  'during program initialization.
     'IF (@CONN=1) GOTO STARTLOG
     ':START LOG
     'TRACE(1); CAPTURE(1)
     'CWAIT ("LOG-ON")
     'TWAIT (5, "SEC")
     '"RAMON$OD"
     'CWAIT ("'CR'")
     'TWAIT (5, "SEC")
     '"DL1:H88269.CVT$OD"
     'CWAIT ("'CR'")
     'TWAIT (5, "SEC")
     '"2$OD"

CALL ScreenMenu
CALL BACKTODOS
```

```
SUB BACKTODOS
  SYSTEM
END SUB

SUB INITIALIZE

    FOR N = 13 TO 21
          LOCATE N, 1: PRINT SPACE$(75)
    NEXT N

  LOCATE 13, 7: PRINT "PLEASE ENTER DATA:"
  LOCATE 15, 8: INPUT "LOCATION:"; L2
  LOCATE 16, 1: INPUT "DATE (MM,DD,YY):"; MM, DD, YY
  LOCATE 17, 1: INPUT "TIME (HR,MIN):"; R4, MI
  OPEN "INITIAL.DAT" FOR OUTPUT AS #1
  WRITE #1, L2, MM, DD, YY, R4, MI, TDVI1, TDVG1, TDVS1, LETHAL1, LETHAT1
  CLOSE #1

'ACTION FILE GENERATOR

  OPEN "ACTFILE.ACT" FOR OUTPUT AS #1
  A$ = "DL1:H88": B$ = ".CVT$0D": C$ = ".CVU$0d": N = 0

RECUR1:
  AA$ = "CWAIT(": AB$ = CHR$(34): AC$ = "LOG-ON"
  AD$ = ")": AE$ = "TWAIT(5,": AF$ = "SEC": AG$ = "'CR'"
  A$(0) = "IF (@CONN=1) GOTO :STARTLOG"
  A$(1) = ":STARTLOG"
  A$(2) = "TRACE(1); CAPTURE(1)"
  A$(3) = AA$ + AB$ + AC$ + AB$ + AD$
  A$(4) = AE$ + AB$ + AF$ + AB$ + AD$
  A$(5) = AA$ + AB$ + AG$ + AB$ + AD$
  PRINT #1, A$(N)

  N = N + 1: IF N < 5 GOTO RECUR1
  WRITE #1, "RAMON$0D"
  PRINT #1, A$(5): PRINT #1, A$(4)
  IF X = 1 GOTO RECUR2
  GOSUB CLEARSPACE: INPUT "FIRST CALENDAR DATE:"; FCD
  INPUT "LAST CALENDAR DATE:"; LCD

RECUR2:
  FCD$ = STR$(FCD): Q = LEN(FCD$): FCD$ = MID$(FCD$, 2, Q - 1)
  FILE1$ = A$ + FCD$ + B$: FILE2$ = A$ + FCD$ + C$: M = 5
  WRITE #1, FILE1$: GOSUB PRT: WRITE #1, FILE2$: GOSUB PRT
  FCD = FCD + 1: IF LCD >= FCD GOTO RECUR2
  WRITE #1, "2$0D": CLOSE #1: BEEP: GOTO FILENUMSTORE
PRT:
  PRINT #1, A$(M): M = M - 1
  IF M >= 4 THEN GOTO PRT
  M = 5
RETURN
```

```
CLEARSPACE:
   FOR N = 13 TO 21
     LOCATE N, 1
     PRINT SPACE$(75)
   NEXT N
   LOCATE 13, 1
RETURN

FILENUMSTORE:
' Q3.DAT
  OPEN "Q3.DAT" FOR OUTPUT AS #3
  WRITE #3, LCD
  CLOSE #3

END SUB

SUB PRINTADVISORY
  OPEN "INITIAL.DAT" FOR INPUT AS #3
    INPUT #3, LOCATION, MONTH, DATE, YEAR, HOURS, MINUTES,
          TDVI, TDVG, TDVS, LETHAL(RH), LETHAL(TEMP)
  CLOSE #3

  IF LOCATION = 1 THEN
      STATION$ = "CAPRON"
    ELSEIF LOCATION = 2 THEN
      STATION$ = "SUFFOLK"
    ELSEIF LOCATION = 3 THEN
      STATION$ = "WAVERLY"

  IF TDVG >= 144 THEN
      DISEASE$ = "High disease pressure"
    ELSEIF TDVG >= 96 AND TDVG < 144 THEN
      DISEASE$ = "Moderate disease pressure"
    ELSEIF TDVG >= 48 AND TDVG < 96 THEN
      DISEASE$ = "Low disease pressure"

  IF TDVI >= 48 THEN
      ADVISORY$ = "Conditions are favorable for leafspot development"
    ELSEIF TDVI < 45 THEN
      ADVISORY$ = "Conditions are unfavorable for leafspot development"
    ELSEIF TDVI >= 45 AND TDVI < 48 THEN
      ADVISORY$ = "Favorable conditions for leafspot development are"
              likely in the next 24 hours."


  LPRINT "VIRGINIA PEANUT LEAFSPOT ADVISORY"
  LPRINT "        89-ADV MODEL": LPRINT
  LPRINT "DATE: "; MONTH; "/"; DATE; "/"; YEAR
  LPRINT "LOCATION: "; STATION$
  LPRINT "CUMULATIVE TDVS: "; TDVS
  LPRINT "CUMULATIVE TDVG: "; TDVG
  LPRINT "CUMULATIVE TDVI: "; TDVI
  LPRINT "ESTIMATED DISEASE PRESSURE: "; DISEASE$
```

```
    LPRINT "ADVISORY: "; ADVISORY$
END SUB

SUB RUNADVISORY (FCD)

'RUN ADVISORY"
    CHAIN "VPLA"
END SUB

SUB ScreenMenu

    DO
        CLS
        LOCATE 1, 22: PRINT "VIRGINIA PEANUT LEAFSPOT ADVISORY"
        LOCATE 2, 26: PRINT "TIDEWATER RESEARCH CENTER"
        LOCATE 3, 31: PRINT "V P I  &  S U"
        LOCATE 7, 10: PRINT "This is the new model for the Virginia Peanut Leafspot Advisory"
        LOCATE 9, 10: PRINT "An AEMS-Dependent Decision Support Sysytem"
        LOCATE 13, 10: PRINT "MENU": INIT = 0
        LOCATE 15, 10: PRINT "1. Initialize the program"
        LOCATE 16, 10: PRINT "2. Run the advisory"
        LOCATE 17, 10: PRINT "3. Print advisory"
        LOCATE 18, 10: PRINT "4. Back to DOS"
        LOCATE 20, 5: INPUT "Select:"; SL1$: N = 0

        SELECT CASE SL1$

            CASE "1"
                CALL INITIALIZE
            CASE "2"
                CALL RUNADVISORY
            CASE "3"
                CALL PRINTADVISORY
            CASE "4"
                CALL BACKTODOS
            CASE ELSE
                BEEP
        END SELECT
    LOOP

END SUB
```

Program for the Virginia Peanut Leafspot Advisory
89-ADV Model (Microsoft QuickBASIC 4.5)

```
DECLARE SUB WINDOW1 (FILENUM, L2, MM, DD, YY, HR, R4, TDVI1, TDVG1, TDVS1,)
DECLARE SUB INFECTION (TS!, TDVS!, TDVS1!, TDVG1!, TDI!, TDVI!, TDG!, TDVG!, TDS!)

CALL WINDOW1
ON ERROR GOTO ERRORHANDLER

AEMSFILE:
        FILENUM = FILENUM + 1: FI2$ = STR$(FILENUM): Q = LEN(FI2$)
        FI2$ = MID$(FI2$, 2, Q - 1): FILE$ = FI1$ + FI2$ + FI3$

        OPEN "B:H881.DAT" FOR INPUT AS #1

ROUTE1:
        IF EOF(1) THEN GOTO ENDOFFILE
        LOCATE 9, 45: COLOR 31, 0: PRINT "SEARCHING !"
        LINE INPUT #1, L$: IF INSTR(1, L$, "REM") <> 0 THEN GOTO ROUTE1
        COUNT = COUNT + 1: LOCATE 16, 45: COLOR 3, 0: PRINT "COUNT:"; COUNT

'LINE INPUT

        J9 = -1: P1 = 0: L9 = LEN(L$) + 1

ROUTE2:
        P0 = P1: P1 = INSTR(P0 + 1, L$, ","): IF P1 = 0 THEN P1 = L9
        J9 = J9 + 1: L1$ = MID$(L$, P0 + 1, P1 - P0 - 1)
        R(J9) = VAL(L1$): IF P1 <> L9 THEN GOTO ROUTE2
        MO = R(0): DA = R(1): YE = R(2)
        IF MO < MM THEN GOTO ROUTE1
        MONTH=MO:DATE=DA:YEAR=YE:R3=R(3):R4=R(4):R7=R(7):R8=R(8)
        LOCATE 18, 45: PRINT FILE$: LOCATE 10, 46: PRINT MONTH
        LOCATE 10, 49: PRINT "/"; DATE: LOCATE 10, 53: PRINT "/"; YEAR
        LOCATE 13, 45: PRINT "   HRS:"; R3
        T1 = R7: T2 = R8: T3 = 5 / 9 * (T1 - 32)


'TIME STAMP

IF YEAR/4 = INT(YEAR/4) THEN
        R1$ = "0000310600091121152182213244274305335"
ELSE
        R1$ = "0000310590901201511812122432733043334"
END IF
R1$ = MID$(R1$, ((MONTH * 3) - 2), 3)
S4 = VAL(R1$)
CLDR = S4 + DATE
```

```
IF CLDR <> CLDR1 THEN GOTO DAY1
IF R3 <> HR THEN GOTO HOUR1
IF R4 >= MI THEN GOTO IRRATIONALTIME
TS = (R4 - MI) / 60: GOTO VALIDATE

HOUR1:
        IF R3 <= HR THEN GOTO IRRATIONALTIME
        TS = ((60 - MI) + R4) / 60: GOTO VALIDATE

DAY1:
        IF CLDR >= CLDR1 THEN GOTO IRRATIONALTIME
        TS1 = ((CLDR - CLDR1) * 24) - 24
        TS2 = ((23 - HR) + R3)
        TS = ((60 - MI) + R4) / 60 + TS1 + TS2

VALIDATE:
        CLDR1 = CLDR: HR = R3: MI = R4: FL = 1: GOTO RHCOMPUTE

IRRATIONALTIME:
        LPRINT "IRRATIONAL TIME FRAME!": BEEP: BEEP
        LPRINT "PLEASE CHECK DATA AT:"; R(0); R(1); R(2): GOTO ROUTE1

RHCOMPUTE:
        R9 = 3206.18: A9 = -27405.5: B9 = 54.1896: C9 = -.045137: D9 = 2.15321E-05
        E9 = -4.62027E-09: F9 = 2.41613: G9 = 1.21547E-03
        IF T2 > T1 THEN T2 = T1
        T1 = T1 + 459.69: T2 = T2 + 459.69
        T0 = T1: GOSUB VAPORPRES: P1 = P0
        T0 = T2: GOSUB VAPORPRES: P2 = P0
        R0 = 100 * (P2 / P1): GOTO SPORULATION

VAPORPRES:
        IF T0 > 491.69 THEN GOTO HIGHTEMP
        P0 = EXP(23.3924 - (11286.6 / T0) - .46057 * LOG(T0))
RETURN

HIGHTEMP:
        P0 = A9 + (B9 + (C9 + (D9 + E9 * T0) * T0) * T0) * T0
        P0 = P0 / ((F9 - G9 * T0) * T0)
        P0 = R9 * EXP(P0)
RETURN

'CONDITIONS FOR SPORULATION"

SPORULATION:
      IF T3 > 16 THEN
          IF T3 <= 32 THEN
              IF R0 > 90 THEN
                  TDVS = TS
              END IF
          END IF
      END IF
```

' LETHAL CONDITIONS

```
    IF R0 < 40 THEN
        LETHAL = TS: LETHAL1 = LETHAL1 + LETHAL
    ELSE
        LETHAL = 0
    END IF

    IF T3 >= 33 THEN
        LETHALT = TS: LETHALT1 = LETHALT1 + LETHALT
    ELSE
        LETHALT = 0
    END IF

CALL INFECTION(TS, TDVS, TDVS1, TDVG1, TDI, TDVI, TDG, TDVG, TDS)
GOTO ROUTE1


ENDOFFILE:
        LETHAL3 = LETHAL1 + LETHAL2: LETHALT3 = LETHALT1 + LETHALT2

        IF LETHAL3 >= 8 THEN
                LETHAL$ = "LETHAL CONDITIONS EXIST"
        ELSE
                LETHAL$ = "NO LETHAL CONDITIONS"
        END IF

        IF LETHALT3 >= 5 THEN LETHALT$ = "LETHAL (T) CONDITIONS EXIST" ELSE
        LETHALT$ = "NO LETHAL (T) CONDITIONS"

'LABELS

    IF TDVG1 >= 144 THEN
        SEV$ = "HIGH DISEASE PRESSURE"
      ELSEIF TDVG1 >= 96 THEN
        SEV$ = "MODERATE DISEASE PRESSURE"
      ELSEIF TDVG1 >= 48 THEN
        SEV$ = "LOW DISEASE PRESSURE"

LPRINT "VIRGINIA PEANUT LEAFSPOT ADVISORY"
LPRINT "   TIDEWATER RESEARCH CENTER"
LPRINT "         VIRGINIA TECH"
LPRINT : LPRINT "T-D VALUE FOR INFECTION:"; TDVI1
LPRINT "RECOMMENDATION:"; REC$
LPRINT "DISEASE PRESSURE:"; TDVG1: LPRINT "SPORULATION INDEX:"; TDVS1
LPRINT SEV$: LPRINT SPORE$

OPEN "INITIAL.DAT" FOR OUTPUT AS #2
WRITE #2, L2, MONTH, DATE, YEAR, R3, R4, TDVI1, TDVG1, TDVS1, LETHAL1, LETHALT1
CLOSE #2

TDI = 0: TDG = 0: TDS = 0: LETHAL1 = 0: LETHALT1 = 0: CLOSE #1
SYSTEM
```

```
ERRORHANDLER:
    IF ERR = 53 THEN
       GOSUB SPACE3: BEEP
          LOCATE 10, 42: COLOR 4, 0: PRINT "INSERT DISK"
          LOCATE 11, 42: PRINT "WITH FILE"
          LOCATE 12, 42: PRINT FILE$
          LOCATE 14, 42: PRINT "PRESS C TO"
          LOCATE 15, 42: INPUT "CONTINUE"; C$
    END IF


          COLOR 3, 0
                IF C$ = "C" THEN
                      GOSUB SPACE3
                      FILENUM = FILENUM - 1
                ELSE
                      GOSUB SPACE3
                      LOCATE 13, 45: PRINT "END 0F JOB!"
                      FLAG = 1
                END IF
          IF FLAG = 1 THEN SYSTEM
          GOTO AEMSFILE

SPACE3:
    FOR I = 9 TO 18
          LOCATE I, 41: PRINT SPACE$(17)
    NEXT I
RETURN


' CONDITIONS FOR GERMINATION AND INFECTION"

SUB INFECTION (TS, TDVS, TDVS1, TDVG1, TDI, TDVI, TDG, TDVG, TDS)

    IF RO > 95 THEN
          IF T3 >= 16 AND T3 <= 25 THEN
                TDVG = 3 * TS
                TDVI = 1 * TS
          ELSEIF T3 > 25 AND T3 <= 28 THEN
                TDVG = 2 * TS
                TDVI = 1 * TS
          ELSEIF T3 > 28 AND T3 <= 32 THEN
                TDVG = 1 * TS
                TDVI = 1 * TS
          ELSE
                TDVG = 0
                TDVI = 0
          END IF
    ELSE
          TDVG = 0
          TDVI = 0
    END IF

TDVG1 = TDVG1 + TDVG: TDVI1 = TDVI1 + TDVI: TDVS1 = TDVS1 + TDVS
```

```
TDI = TDI + TDVI: TDG = TDG + TDVG: TDS = TDS + TDVS
LOCATE 10, 6: PRINT " TDV INFECTION:"; USING "######.#####"; TDVI1
LOCATE 12, 6: PRINT "DISEASE PRESSURE:"; USING "######.#####"; TDVG1
LOCATE 13, 1: PRINT "TDV FOR SPORULATION:"; USING "######.#####"; TDVS1
S3 = S3 + 1: LOCATE 15, 45: PRINT "DATA#:"; S3:

END SUB


SUB WINDOW1 (FILENUM, L2, MM, DD, YY, HR, R4, TDVI1, TDVG1, TDVS1,)

CLS : COLOR 3, 0, 0: DIM R(50): X = 0: Z$ = "/": FL = 0
LOCTN$(1) = "BLACKSTONE": LOCTN$(2) = "CAPRON": LOCTN$(3) = "HOLLAND"
LOCTN$(4) = "TEST DWARF": LOCTN$(5) = "WAVERLY"
FI1$ = "H88": FI3$ = ".DAT"
LOCATE 1, 22: PRINT "VIRGINIA PEANUT LEAFSPOT ADVISORY"
LOCATE 2, 26: PRINT "TIDEWATER  RESEARCH  CENTER"
LOCATE 3, 31: PRINT "V P I  &  S U"

' VIEW PORT

FOR L1 = 8 TO 19: LOCATE L1, 40: PRINT CHR$(186): NEXT L1
FOR L1 = 8 TO 19: LOCATE L1, 60: PRINT CHR$(186): NEXT L1
LOCATE 8, 40: PRINT CHR$(201): LOCATE 8, 60: PRINT CHR$(187)
FOR L1 = 41 TO 59: LOCATE 8, L1: PRINT CHR$(205): NEXT L1
FOR L1 = 41 TO 59: LOCATE 19, L1: PRINT CHR$(205): NEXT L1
LOCATE 19, 40: PRINT CHR$(200): LOCATE 19, 60: PRINT CHR$(188)

' LABEL

LOCATE 9, 45: PRINT "CHOICES:": LOCATE 11, 45: PRINT "1. BLKSTONE"
LOCATE 12, 45: PRINT "2. CAPRON": LOCATE 13, 45: PRINT "3. HOLLAND"
LOCATE 14, 45: PRINT "4. T-DWARF": LOCATE 15, 45: PRINT "5. WAVERLY"

GOSUB SPCAE1
LOCATE 9, 45
PRINT "FORM !": LOCATE 11, 45: PRINT "MM,DD,YY": LOCATE 14, 45
PRINT "WHERE:": LOCATE 16, 47: PRINT "MM = MONTH": LOCATE 17, 47
PRINT "DD = DAY": LOCATE 18, 47: PRINT "YY = YEAR": LOCATE 7, 5
PRINT "DATE START:": LOCATE 8, 4: PRINT "FILE NUMBER:"

OPEN "INITIAL.DAT" FOR INPUT AS #3
INPUT #3, C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11
L2 = C1: MM = C2: DD = C3: YY = C4: HR = C5: R4 = C6: TDVI1 = C7: TDVG1 = C8: TDVS1 = C9:
LETHAL2 = C10: LETHALT2 = C11
CLOSE #3

GOSUB SPACE2
     LOCATE 7, 5: PRINT LOCTN$(L2), DATE$: PRINT TAB(15); TIME$
GOSUB SPACE1
     FILENUM = FILENUM - 1
GOTO JUMPER
```

```
SPACE1:
    FOR I = 9 TO 18
        LOCATE I, 41: PRINT SPACE$(17)
    NEXT I
RETURN

SPACE2:
    FOR I = 7 TO 10
        LOCATE I, 1: PRINT SPACE$(25)
    NEXT I
RETURN

JUMPER:
END SUB
```

The Virginia Peanut Leafspot Advisory
Current AEMS Program (89-ADV model in DECBASIC)

REMARKS: THIS PROGRAM WAS INSTALLED TO THE CENTRAL COMPUTER OF THE AGRO-ENVIRONMETAL MONITORING SYSTEM ON 4 APRIL 1989. MODIFICATIONS OF THIS PROGRAM INCLUDE THE COMPUTATION OF THE "LAST EFFECTIVE SPRAY DATE", GENERATION OF THE VIRTUAL TABLE WITH "EMTY" SLOTS, AND THE USE OF SYSTEM CLOCK TO INITIALIZE THE PROGRAM A DAY BEFORE THE STARTING DATE. THIS PROGRAM IS INVOKED THROUGH A "CHAIN" COMMAND FROM AEMS MAIN PROGRAM.

```
100 REM "THIS PROGRAM WAS WRITTEN IN DECBASIC FOR AEMS"
101 REM "VPLA2.BAS PROGRAM RECALCULATES THE LAST EFFECTIVE SPRAY DATE"
102 REM "DK: SHOULD INCLUDE XINIT.DAT FILE"
103 COMMON N8,N9,U$,F1$,P9,P8 \ PRINT "WHICH STATION"; \ INPUT N8
104 D$=DAT$ \ O1$="," \ T$=CLK$ \ Z$="HBCW"
105 GOSUB 319 \ GOSUB 307 \ O9=J8 \ REM CALENDAR DAY FROM CURRENT DATE
106 O$="LP:" \ D1=31 \ M1=5 \ Y1=90
107 GOSUB 307 \ O8=J8 \ REM CALENDAR DAY TO START ADVISORY
108 IF SEG$(DAT$,1,6)="31-MAY" THEN  GOTO 331
109 DIM R(50) \ Z0$="DL1:" \ Z2$=".CVT"
110 DIM #5,V1$(150)=15 \ F5=0
111 REM "INIT.DAT DEF"
112 I$=SEG$(Z$,N8+1,N8+1) \ N$=I$+"INIT.DAT" \ GOSUB 266
113 Y9=Y9+1 \ Z6$=STR$(Y9) \ Q=LEN(Z6$)
114 Z6$=SEG$(Z6$,1,Q) \ F$=Z0$+I$+"90"+Z6$+Z2$
115 OPEN O$ FOR OUTPUT AS FILE #8
116 PRINT "INPUT IS ";F$
117 OPEN F$ FOR INPUT AS FILE #1
118 IF END #1 THEN 180
119 LINPUT #1:L$ \ IF SEG$(L$,1,3)="REM" THEN 118
120 REM "LINE INPUT"
121 J9=-1 \ P1=0 \ L9=LEN(L$)+1
122 P0=P1 \ P1=POS(L$,",",P0+1) \ IF P1=0 THEN P1=L9
123 J9=J9+1 \ L1$=SEG$(L$,P0+1,P1-1)
124 R(J9)=VAL(L1$) \ IF P1<>L9 THEN 122
125 M0=R(0) \ D0=R(1) \ Y0=R(2)
126 PRINT M0;",";D0;",";Y0;" ";R(3);":";R(4)
127 IF M0<>INT(M0) THEN 118
128 IF M0=0 THEN 118
129 IF D0=0 THEN 118
130 IF Y0=0 THEN 118
131 IF D0<>INT(D0) THEN PRINT D0;" ";INT(D0) \ GOTO 118
132 IF Y0<>INT(Y0) THEN PRINT "Y0= ";Y0;"INT Y0= ";INT(Y0) \ GOTO 118
133 IF M0<M3 THEN PRINT "M0=";M0;" ";" M3=";M3 \ GOTO 118
```

```
134 M1=M0 \ D1=D0 \ Y1=Y0 \ R3=R(3) \ R4=R(4) \ R7=R(7) \ R8=R(8)
135 T1=R7 \ T2=R8 \ T3=5/9*(T1-32)
136 REM "TIME STAMP"
137 R1$=STR$(M1)
138 GOSUB 307 \ IF F5=0 THEN J7=J8 \ F5=1
139 IF J8<>J7 THEN 145
140 IF R3<>H1 THEN 143
141 IF R4<M2 THEN 150
142 T5=(R4-M2)/60 \ GOTO 149
143 IF R3<H1 THEN 150
144 T5=((60-M2)+R4)/60 \ GOTO 149
145 IF J8<J7 THEN 150
146 T6=((J8-J7)*24)-24
147 T7=((23-H1)+R3)
148 T5=((60-M2)+R4)/60+T6+T7
149 J7=J8 \ H1=R3 \ M2=R4 \ F1=1 \ GOTO 152
150 PRINT "IRRATIONALTIMEFRAME!" \ REM BEEP \ REM BEEP
151 PRINT "PLEASE CHECK DATA AT \ ";R(0);R(1);R(2) \ GOTO 118
152 REM "AT & DPT TO RH"
153 R9=3206.18 \ A9=-27405.5 \ B9=54.1896 \ C9=-.045137 \ D9=2.15321E-05
154 E9=-4.62027E-09 \ F9=2.41613 \ G9=1.21547E-03
155 IF T2>T1 THEN T2=T1
156 T1=T1+459.69 \ T2=T2+459.69
157 T0=T1 \ GOSUB 160 \ P1=P0
158 T0=T2 \ GOSUB 160 \ P2=P0
159 R0=100*(P2/P1) \ GOTO 247
160 REM "VP"
161 IF T0>491.69 THEN 164
162 P0=EXP(23.3924-(11286.6/T0)-.46057*LOG(T0))
163 RETURN
164 P0=A9+(B9+(C9+(D9+E9*T0)*T0)*T0)*T0
165 P0=P0/((F9-G9*T0)*T0)
166 P0=R9*EXP(P0)
167 RETURN
168 REM "CONDITIONS FOR GERMINATION AND INFECTION"
169 IF R0<95 THEN 175
170 IF T3>31 THEN 175
171 IF T3>=28 THEN V1=1*T5 \ V3=1*T5 \ GOTO 176
172 IF T3>=25 THEN V1=2*T5 \ V3=1*T5 \ GOTO 176
173 IF T3>=17 THEN V1=3*T5 \ V3=1*T5 \ GOTO 176
174 IF T3>=16 THEN V1=1*T5 \ V3=1*T5 \ GOTO 176
175 V1=0 \ V3=0 \ GOTO 176
176 REM "VITUAL TABLE DEF"
177 V2=V2+V1 \ V4=V4+V3
178 V7=V7+V3 \ V8=V8+V1
179 S3=S3+1 \ PRINT "DATA#:";S3 \ L2$=L$ \ GOTO 118
180 V9=V9+V6
181 CLOSE #1 \ IF SEG$(F$,LEN(F$)-2,LEN(F$))="CVT" THEN
    F$=SEG$(F$,1,LEN(F$)-3)+"CVU" \ GOTO 116
182 GOSUB 280
183 REM "LABEL"
```

```
184 REM "DISEASE PRESSURE INDEX"
185 IF V7=>48 AND IF V7<96 THEN 186 ELSE 187
186 C$="CONDITIONS ARE CHARACTERIZED BY LOW DISEASE PRESSURE" \ GOTO 287
187 IF V7 =>96 AND IF V7<144 THEN 188 ELSE 189
188 C$="CONDITIONS ARE CHARACTERIZED BY MODERATE DISEASE PRESSURE."
195 GOTO 287
189 IF V7=>144 THEN 190
190 C$="CONDITIONS ARE CHARACTERIZED BY HIGH DISEASE PRESSURE!"
196 REM "WHEN CONDITION BECOMES FAVORABLE"
197 GOTO 287
198 OPEN N$ FOR OUTPUT AS FILE #2
199 PRINT #2,M1;",";D1;",";Y1;",";R3;",";R4;",";Y9;",";V4;",";V2;",";V9;",";L2;",";L1;",";A1
200 PRINT #8:"PROGRAM - VPLA.BAS                ";D$ \ PRINT #8:
201 PRINT #8:"VIRGINIA PEANUT LEAFSPOT ADVISORY";CHR$(8);CHR$(13)
202 PRINT #8:"            - 1989 MODEL-"
203 N1$="HOLLAND       CAPRONWAVERLY" \ N2$=SEG$(N1$,N8*7+1,N8*7+7)+" STATION"
204 PRINT #8:"      AEMS CENTRAL COMPUTER" \ PRINT #8:
205 PRINT #8: \ PRINT #8:"YESTERDAY'S VALUES: ";C1;C2;C3;C4;C5;C6;C7;C8;F6;B0;B1;B2
206 PRINT #8:"------------------------------------------------------------------"
207 PRINT #8:"***** ";M1;"-";D1;"-";Y1 \ PRINT #8:"***** LOCATION: ";N2$;"          ";
208 PRINT #8:"TODAY'S FILE - ";SEG$(F$,5,LEN(F$))
209 PRINT #8:"***** LAST EFFECTIVE SPRAY DATE: ";P$
210 PRINT #8:"------------------------------------------------------------------"
211 PRINT #8 \ PRINT #8:"ACCUMULATED TDVI: ";V4
212 PRINT #8:"DISEASE PRESSURE INDEX:  ";V7
213 PRINT #8:"ESTIMATED DISEASE PRESSURE:  ";C$
214 PRINT #8:S$ \ PRINT #8:
215 PRINT #8:"DAILY T-D VALUES: ";CHR$(13);"_____"
216 PRINT #8:"TDVI=";V7 \ PRINT #8:"TDVG=";V8
217 PRINT #8:"TDVS=";V6 \ PRINT #8:"LETHAL1=";L2
218 PRINT #8:"LETHALT1=";L1
219 V7=0 \ V8=0 \ V6=0 \ L2=0 \ L1=0
220 IF F2<>1 THEN 223
221 PRINT #8: \ PRINT #8:"This is day ";
222 PRINT #8:USING "##",A1-1; \
    PRINT #8:USING "'LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL"," after a favorable advisory!"
223 PRINT #8: \ PRINT #8:"DAILY TDV TABLE      ";F2$ \ PRINT #8:
224 IF W7=1 THEN PRINT #8:"PLEASE CHECK ";F2$ \ W7=0
225 FOR I=1 TO 30
226 G$=V1$(I)
227 G5=I \ GOSUB 235
228 G$=V1$(I+30) \ G5=(I+30) \ GOSUB 235
229 G$=V1$(I+60) \ G5=(I+60) \ GOSUB 235
230 G$=V1$(I+90) \ G5=(I+90) \ GOSUB 235
231 G$=V1$(I+120) \ G5=(I+120) \ GOSUB 235
232 PRINT #8:
233 NEXT I
234 GOTO 244
235 P6=0 \ IF G$="EMPTY" THEN 243
236 IF G$="" THEN 243
237 P6=POS(G$,",",P6+1) \ P7=POS(G$,",",P6+1) \ P8=POS(G$,",",P7+1)
```

```
238 G2$=SEG$(G$,1,P8-1) \ G3$=SEG$(G$,P8+1,LEN(G$))
239 G3=VAL(G3$)
240 PRINT #8:USING "###",G5;
241 PRINT #8:USING "'RRRRRRR",G2$;
242 PRINT #8:USING "###.########";G3; \ PRINT #8:" ";
243 RETURN
244 CLOSE \ IF N9=0 THEN 246
245 CHAIN "MAIN.AEM" LINE 1100
246 STOP
247 REM "CONDITIONS FOR SPORULATION"
248 IF R0=100 THEN IF T3>31 THEN V5=0 \ GOTO 256
249 IF R0=100 THEN IF T3>=24 THEN IF T3<=28 THEN V5=5*T5 \ GOTO 256
250 IF R0=100 THEN IF T3>=20 THEN IF T3<24 THEN V5=4*T5 \ GOTO 256
251 IF R0>=90 THEN IF T3>28 THEN IF T3<=31 THEN V5=1*T5 \ GOTO 256
252 IF R0>=90 THEN IF T3>=20 THEN IF T3<=28 THEN V5=3*T5 \ GOTO 256
253 IF R0>=90 THEN IF T3>=16 THEN IF T3<20 THEN V5=2*T5 \ GOTO 256
254 IF R0>=90 THEN IF T3>=15 THEN IF T3<16 THEN V5=1*T5 \ GOTO 256
255 V5=0
256 REM "LETHAL CONDITIONS"
257 IF R0>39.9 THEN 259
258 L3=T5 \ L2=L2+L3
259 IF T3<37 THEN 261
260 L4=T5 \ L1=L1+L4
261 L3=0 \ L4=0
262 REM "CHECKS FOR SPORULATING CONDITIONS"
263 V6=V6+V5
264 IF V6<10 THEN IF V9<10 THEN  GOTO 118
265 GOTO 168
266 PRINT "VIRGINIA PEANUT LEAFSPOT ADVISORY"
267 PRINT "TIDEWATER RESEARCH CENTER"
268 PRINT "V P I  &  S U"
269 PRINT DAT$ \ REM  LOCATE6,1 \ PRINT CLK$
270 PRINT "PLEASE WAIT ADVISORY IS RUNNING."
271 OPEN N$ FOR INPUT AS FILE #1
272 INPUT #1,C1,C2,C3,C4,C5,C6,C7,C8,V9,B0,B1,B2
273 M3=C1 \ D3=C2 \ Y3=C3 \ H1=C4 \ R4=C5 \ Y9=C6 \ V4=C7 \ V2=C8
274 L5=B0 \ L6=B1 \ A1=B2 \ F6=V9
275 IF A1<1 THEN 279
276 IF A1<12 THEN 278
277 F2=0 \ A1=0 \ V4=0 \ V2=0 \ GOTO 279
278 F2=1
279 CLOSE #1 \ RETURN
280 REM "LABELS FOR L3 CONDITIONS"
281 L7=L2+L5 \ L8=L1+L6
282 IF L7>=8 THEN L3$="LETHAL CONDITIONS EXIST" \ GOTO 284
283 L3$="NO LETHAL CONDITIONS"
284 IF L8>=5 THEN L4$="LETHAL (T) CONDITIONS EXIST" \ GOTO 286
285 L4$="NO LETHAL (T) CONDITIONS"
286 RETURN
287 REM "ROUTINE THAT RECALCULATES TDV FOR LAST EFFECTIVE SPRAY DATES"
288 X1=Y9
```

```
289 F2$=I$+"TDV.DAT" \ OPEN F2$ AS FILE #5
290 X3=V7 \ X2=Y9-O8 \ X4=0 \ P6=0 \ X8=X2
291 X$=STR$(M1)+O1$+STR$(D1)+O1$+STR$(Y1)+O1$+STR$(X3) \ V1$(X2)=X$
292 X4$=V1$(X2) \P6=POS(X4$,",",P6+1) \ P7=POS(X4$,",",P6+1) \ P8=POS(X4$,",",P7+1)
293 IF X4$="EMPTY" THEN W7=1 \ X4=0 \ GOTO 295
294 X4=VAL(SEG$(X4$,P8+1,LEN(X4$)))
295 X5=X5+X4
296 IF X5>=48 THEN 299
297 X2=X2-1 \ IF X2<1 THEN 303
298 P6=0 \ GOTO 292
299 X5=0 \ X2=X2-11 \ IF X2<1 THEN 303
300 P6=0 \ P$=V1$(X2) \ P6=POS(P$,",",P6+1) \ P7=POS(P$,",",P6+1) \ P8=POS(P$,",",P7+1)
301 P$=SEG$(P$,1,P8-1)
302 GOTO 198
303 REM "ERROR TRAPPING"
304 REM IF ERR=53 THEN 9520
305 P$="DATA NOT AVAILABLE!"
306 GOTO 198
307 REM- COMP CALENDAR DAY(J8)GIVEND1,M1,Y1
308 D8$="3128313031303313130313031"
309 J8=0 \ IF (Y1/4)<>INT(Y1/4) THEN 311
310 D8$=SEG$(D8$,1,3)+"9"+SEG$(D8$,5,LEN(D8$))
311 IF M1<=12 THEN 312 \ PRINT "INVALID MONTH!" \ P9=P9+1 \ J8=0 \ GOTO 318
312 IF D1<=VAL(SEG$(D8$,M1*2-1,M1*2)) THEN 314
313 PRINT "INVALID DAY OF MONTH!" \ P9=P9+1 \ J8=0 \ GOTO 318
314 FOR M=1 TO M1-1
315 J8=J8+VAL(SEG$(D8$,M*2-1,M*2))
316 NEXT M
317 J8=J8+D1
318 RETURN
319 D1=VAL(SEG$(D$,1,2))
320 M$="JANFEBMARAPRMAYJUNJULAUGSEPOCTNOVDEC"
321 M1$=SEG$(D$,4,6)
322 FOR I=1 TO 12
323 IF M1$=SEG$(M$,((I-1)*3)+1,((I-1)*3)+3) THEN 326
324 NEXT I
325 PRINT "INVALID MONTH GO SET DATE" \ STOP
326 M1=I \ IF I>1 THEN IF I<12 THEN 328
327 STOP
328 Y1=VAL(SEG$(D$,8,9))
329 Y$=SEG$(DAT$,8,9)
330 RETURN
331 REM TO INITIALIZE THE INITIAL AND DAILY TDV FILES
332 I$=SEG$(Z$,N8+1,N8+1)
333 N$=I$+"INIT.DAT"
334 REM  5 , 31 , 90 , 0 , 0 , 151 , 0 , 0 , 0 , 0 , 0 , 0
335 D1=31 \ M1=5 \ C1=M1 \ C2=D1
336 C3=Y1 \ GOSUB 307 \ J7=J8
337 GOSUB 307 \ S9=J8 \ REM CALENDAR DAY TO START ADVISORY
338 OPEN N$ FOR OUTPUT AS FILE #1
339 H1=0 \ R4=0 \ V4=0 \ V2=0 \ C6=O8 \ V6=0 \ L2=0 \ L1=0 \ A1=0
```

```
340 PRINT C1;",";C2;",";C3;",";H1;",";R4;",";C6;",";V4;",";V2;",";V6;",";L2;",";L1;",";A1
341 PRINT #1,C1;",";C2;",";C3;",";H1;",";R4;",";C6;",";V4;",";V2;",";V6;",";L2;",";L1;",";A1
342 CLOSE #1
343 OPEN N$ FOR INPUT AS FILE #1
344 IF END #1 THEN 118
345 LINPUT #1:L$ \ IF SEG$(L$,1,3)="REM" THEN 344
346 PRINT L$
347 CLOSE #1
348 PRINT
349 N$=I$+"TDV"+".DAT"
350 OPEN N$ AS FILE #5
351 FOR P=1 TO 150
352 V1$(P)="EMPTY"
353 PRINT P;" ";V1$(P)
354 NEXT P
355 CLOSE
356 GOTO 244
```

List of Program Variables of the VPLA (89-ADV model)

A1 = advisory code in the program cycle
B0 = lethal TDV for RH
B1 = lethal TDV for TEMP
B2 = advisory code stored or retrieved from XINIT file
C$ = spray recommendation
C1 = month
C2 = day
C3 = year
C4 = hour
C5 = minutes
C6 = file number
C7 = accumulated TDV_i
C8 = accumulated TDV_G
D$ = system date
D8$ = string of the number of days in every month
F$ = AEMS CVT or CVU file in the form of "H89120.CVT"
F2 = flag for 10-day residual period
F2$ = virtual file (XTDV.DAT for current file or XTDV.HST for historical file)
F5 = flag for program cycle (f5=0 for the first cycle and f5>0 for the nth cycle)
F6 = accumulated tdvs read from xinit file
G$ = string of line at line I of the virtual file (table printing)
G2$ = date in string found in 150 lines of the virtual file
G3 = daily TDV_i stored in the virtual file
G5 = line number of the printed virtual file table
H1 = hour of the previous line
I$ = station code "H=Holland; W=Waverly; C=Capron"
J7 = calendar day of the previously read string
J8 = calendar day of the currently read string
L$ = data line from CVT file read as a string
L1 = lethal condition TDV (TEMP)
L2 = lethal condition TDV (RH)
L2$ = string of previous line from CVT or CVU file
L3 = TDV_{lc} (RH) at 10 min interval
L3$ = label for lethal condition (RH)
L4 = TDV_{lc} (TEMP) at 10 min interval
L4$ = label for lethal condition (TEMP)
L5 = daily TDV_{lc} for RH
L6 = daily TDV_{lc} for TEMP
L7 = accumulated lethal condition (RH)
L8 = accumulated lethal condition (TEMP)
M$ = string of all months in a year
M0 = month currently read
M2 = minutes of the previous line
M3 = month previously read
N$ = file for "XINIT.DAT"

N1$ = string of all stations
N2$ = station name
N8   = station number
O$ = lprint file
O8   = calendar day to start the advisory
P$ = string for last effective spray date
R0   = relative humidity
R3   = hour of the current line
R4   = minutes of the current line
S$ = severity label
S3   = data number
S9   = calendar day to stop
T$ = system time
T1   = dew point temp (F)
T2   = ambient temp (F)
T3   = ambient temp (C)
T5   = time frame computed from (LINE-(LINE-1))
T6   = intermediate value for T5
T7   = intermediate value for T5
V1   = TDVG at 10 min interval
V1$ = string of line in a virtual file (XTDV.DAT OR .HST)
V2   = daily TDVG
V3   = TDVi at 10 min interval
V4   = daily TDVi
V5   = TDVs at 10 min interval
V7   = accumulated TDVG
V8   = accumulated TDVi
V9   = updated accumulated TDVs
W7   = flag that warns for improper virtual file setup
X$ = string for month, day and year in the virtual file
X1   = file number
X4   = daily TDVi at line X2 of the virtual file
X4$ = string of a line in the virtual file at line X2
X5   = TDVi value used for "LAST EFFECTIVE SPRAY DATE" computation
Y0   = year
Y9   = file number
Z$ = "HBCW" station code
Z0$ = file address "DL1:"
Z2$ = file extension ".CVT"
Z6$ = string for file number

VPLA.BAS   = program used for current advisory
VPLA.HST   = program used to run historical data
VPLA.NPR   = version of VPLA.HST without lprint commands
VPLAVF.BAS   = program that updates the virtual file
INITT.BAS   = program that initializes the virtual file
INITF.BAS   = program that initializes xinit file
PVRTTB.BAS   = program that lprints (table) the specified virtual file
XINIT.DAT   = memory update of previous data set at time t-1 (current)
XINIT.HST   = memory update of previous data set at time t-1 (hist)
XTDV.DAT   = virtual file containing daily tdvi at x station (current)
XTDV.HST   = virtual file containing daily tdvi at x station (hist)

APPENDIX F

SUMMARY OF CROP CULTURAL AND MANAGEMENT ACTIVITIES

CROP YEAR 1987

Location:	Tidewater Agricultural Experiment Station, Suffolk, VA
Crop history:	Peanut in 1985, and Corn in 1986
Land prep.:	Moldboard plow and disk
Soil type:	Kenansville loamy fine sand

Fertility report:

pH = 6.1	Mn = 2.5 ppm	Ca = 240 ppm
P = 44 ppm	Zn = 0.4 ppm	Mg = 18 ppm
		K = 48 ppm

Cultivar:	Florigiant
Planting date:	1 May 1987
CBR control:	Vapam at 93.5 L/ha (April 14)

Herbicides:

Pre-plant (April 21)
Alanap at 4.4 L/ha
Dual 8E at 1.75 L/ha

Pre-emergence
Lasso 4E at 4.68 L/ha (May 6)

Post-emergence
Blazer at 0.58 L/ha (May 15)
Butyrac 200 at 0.292 L/ha (May 15)

Basagran at 1.75 L/ha (Jun 8)
Butyrac 200 at 0.438 L/ha (Jun 8)

Enide 90W at 2.46 kg/ha (Jul 1)

Insecticide:

Soil-applied
Temik 15G at 7.8 kg/ha (May 1, in-furrow)
Dyfonate 10G at 22.4 kg/ha (Jul 13)

                  <u>Foliar spray</u>
                        Lorsban at 1.75 L/ha (Aug 21)
                        Pydrin at 0.292 L/ha (Aug 13 & Sept 9)
                        Sevin 80W at 1.4 kg/ha (Jul 15)

Nematicide: Furadan 15G at 14.57 kg/ha (May 1)

Acaricide: Kelthane 4F at 2.34 kg/ha (Aug 13)

Other materials: Landplaster at 897 kg/ha (Jun 22)
                     Solubor at 2.8 kg/ha (Jul 15)

Cultivation: June 22 and July 13, 1987

Harvest: October 20, 1987

CROP YEAR 1988

Location: Tidewater Agricultural Experiment Station, Suffolk, VA

Crop history: Corn in 1985, Peanut in 1986 and corn 1987

Land prep.:   Moldboard plow and disk

Soil type: Kenansville loamy sand

Fertility report:

pH = 6.6	Mn = 3.0 ppm	Ca = 348 ppm
P = 39 ppm	Zn = 0.4 ppm	Mg = 38 ppm
		K = 53 ppm

Nematode assay:

Root knot	70/500 cc soil
Ring	60/500 cc soil
Stunt	290/500 cc soil

Cultivar: Florigiant

Planting date: 3 May 1988

CBR control: Vapam at 93.5 L/ha   (April 7)

Herbicides: <u>Pre-plant (April 15)</u>
                     Alanap at 4.4 L/ha
                     Dual 8E at 1.75 L/ha

Insecticide:	Soil-applied
	Temik 15G at 7.8 kg/ha (May 3, in-furrow)
	Dyfonate 10G at 22.4 kg/ha (Jul 6)
	Foliar spray
	Lannate L 1.17 L/ha (Sep 3)
	Savit 4F at 2.34 L/ha (Jun 17)
	Sevin 80W at 1.4 kg/ha (Aug 17)
Nematicide:	Furadan 15G at 14.57 kg/ha (May 3)
Other materials:	Landplaster at 897 kg/ha (Jun 27)
	Solubor at 2.8 kg/ha (Jul 15, Aug 12)
	Tecmangam at 4.48 kg/ha (Jul 11)
Cultivation:	July 6, 1987
Harvest:	October 17, 1988

CROP YEAR 1989

Location:	Tidewater Agricultural Experiment Station, Suffolk, VA
Crop history:	Corn in 1986, Peanut in 1987 and corn 1988
Land prep.:	Moldboard plow and disk
Soil type:	Kenansville loamy fine sand

Fertility report:

pH = 6.0	Mn = 3.3 ppm	Ca = 240 ppm
P = 39 ppm	Zn = 0.7 ppm	Mg = 19 ppm
		K = 51 ppm

Nematode assay:

Root knot	157/500 cc soil
Ring	177/500 cc soil
Stunt	1340/500 cc soil
Sting	4/500 cc soil
Stubby root	7/500 cc soil
Lance	4/500 cc soil

| Cultivar: | Florigiant | NC 9 | NC -V11 |
| | NC 6 | NC 7 | |

Planting date:	13 May 1989
CBR control:	Vapam at 93.5 L/ha (April 26)

Herbicides:

Pre-plant (April 27)
  Alanap at 4.4 L/ha
  Dual 8E at 1.75 L/ha

Pre-emergence
  Lasso 4E at 4.68 L/ha (Apr 27)
  Blazer at 2,34 L/ha (Apr 27)

Insecticide:

Soil-applied
  Temik 15G at 7.8 kg/ha (May 13, in-furrow)
  Lorsban 15G at 14.6 kg/ha (Jul 25)

Foliar spray
  Sevin XLR Plus at 2.34 L/ha (Aug 22)

Nematicide:	Nemacur 15G at 14.57 kg/ha (May 13)

Other materials:

Landplaster at 897 kg/ha (Jun 27)
Tracite liquid boron 10% 2.34 L/ha (Jul 31)
Tecmangam at 4.48 kg/ha (Jul 11)

Cultivation:	June 27, 1989
Harvest:	October 16, 1989

CROP YEAR 1990

Location:	Tidewater Agricultural Experiment Station, Suffolk, VA
Crop history:	Corn in 1987, Peanut in 1988 and corn 1989
Land prep.:	Moldboard plow and disk
Soil type:	Kenansville loamy fine sand

Fertility report:	pH = 6.3	Mn = 5.5 ppm	Ca = 408 ppm
	P = 53 ppm	Zn = 1.0 ppm	Mg = 30 ppm
			K = 67 ppm

Cultivar: Florigiant   NC 9
               NC 6   NC 7

Planting date: 15 May 1990

CBR control: Vapam at 93.5 L/ha   (April 23)

Herbicides: Pre-plant (April 29)
                        Alanap at 4.4 L/ha
                        Dual 8E at 1.75 L/ha

                 Pre-emergence
                        Lasso 4E at 4.68 L/ha (May 18)
                        Gramoxone at 0.8 L/ha (May 18)

                 Post-emergence
                        Storm at 1.75 L/ha (Jun 27)
                        Butyrac 200 at 1.17 L/ha (Jun 27)

Insecticide: Soil-applied
                        Temik 15G at 7.8 kg/ha (May 15, in-furrow)
                        Lorsban 15G at 14.6 kg/ha (Jul 24)

                 Foliar spray
                        Asana XL at 0.292 L/ha (Aug 16)

Nematicide: Nemacur 15G at 14.57 kg/ha (May 17)

Other materials: Landplaster at 897 kg/ha (Jun 29)
                     Tracite liquid boron 10% 2.34 L/ha (Jul 16)
                     Rovral 4F at 2.34 L/ha + Nufilm 17 at 0.58 L/ha (Sep 5)

Harvest: October 31, 1990

APPENDIX G

List of Crop Management Chemicals

HERBICIDE

Alanap L	Uniroyal Chem. Co.	naptalam(e)	Sodium 2-[(1-naphthalenylamino) carbonyl] benzoate
Basagran	BASF Corp.	bentazon(e)	3-(1-Methylethyl)-1H-2,1,3benzothiadiazin-4(3H)-one 2,2-dioxide
Blazer	BASF Corp.	acifluorfen	Sodium 5-[2-chloro-4-(trifluoromethyl) phenoxy]-2nitrobenzoate
Butyrac 200	Rhone Poulenc	4(2,4DB)	4-(2,4-Dichlorophenoxy)butyric acid, dimethylamine salt
Dual 8E	Ciba-Geigy Corp.	metolachlor	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide
Enide 90W	Nor-Am Chem. Co.	diphenamid	N,N-Dimethyl-2,2-diphenylacetamide
Gramoxone	ICI Americas Inc.	paraquat	1,1'-dimethyl-4,4'-bipyridinium ion; present as dichloride salt or dimethyl sulfate salt
Lasso 4E	Monsanto Agri. Co.	alachlor	2-chloro-2'-6'-diethyl-N-(methoxymethyl)-acetanilide
Poast	BASF Corp.	sethoxydim	2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexen-1-one
Storm	BASF Corp.	bentazone and acifluorfen	(same as above)

INSECTICIDE

Asana	E.I. du Pont de Nemours & Co., Inc.	esfenvalerate	(S)-cyano(3-phenoxyphenyl)methyl-(S)-4chloro-alpha-(1-methylethyl) benzene acetate
Di-syston 15G	Mobay Corp.	disulfoton	O,O-Diethyl S-[2-(ethylthio) ethyl] phosphorodithioate
Dyfonate 10G	ICI Americas	fonofos	O-Ethyl-S-phenylethylphosphonodithioate
Lannate	E.I. du Pont Co.	methomyl	S-Methyl-N((methylcarbamoyl)oxy) thioacetimidate
Lorsban 15G	Dow Chem Co.	chlorpyrifos	O,O-Diethyl O-(3,5,6-trichloro-2-pyridyl)-

phosphorothioate

Mocap 10G	Rhone-Poulenc Ag. Co.	ethoprop	O-Ethyl S,S-dipropyl phosphorodithioate
Pydrin	E.I. du Pont de Nemours & Co., Inc.	fenvalerate	alpha-cyano-3-phenoxybenzyl 2-(4-chlorophenyl)-3-methylbutyrate
Sevin XLR	Rhone-Poulenc Ag. Co.	carbaryl	1-Naphthyl N-methylcarbamate
Temik 15G	Rhone-Poulenc Ag. Co.	aldicarb	2-methyl-2(methylthio) propionaldehyde O(methylcarbamoyl) oxime

FUNGICIDE

Botran	Nor-Am Chem Co.	dichloran	2,6 Dichloro-4-nitroaniline
Bravo 720	ISK Biotech	chlorothalonil	tetrachloroisophthalonitrile
Folicur	Mobay Corp.	terbutrazole	a-[2-(4-Chlorophenyl)ethyl]-a-(1,1-dimethyl ethyl)-1H-1,2,4-triazole-1-ethanol
Kocide 404S	Griffin Corp.	copper-sulfur	Cupric hydroxide plus Sulfur
Rovral 4F	Rhone-Poulenc Ag.	iprodione	3-(3,5-dichlorophenyl)-N-(1-methylethyl)2,4-dioxo-1-imidazolidinecarboxamide
Tilt	Ciba Geigy Corp.	propiconazole	1-[2-(2,4dichlorophenyl)4-propyl-1,3-dioxolan-2-ylmethyl]-1H-1,2,4-triazole
Spotless 25WP	Chevron Chem. Co.	diniconazole	(E)-1-(2, 4-Dichlorophenyl) - 4, 4 dimethul-2-(1,2,4triazol-l-yl)-1-penten-3-ol
Terraclor 10G	Uniroyal Chem.	PCNB or quintozene	Pentachloronitrobenzene

FUMIGANT

Vapam	ICI Americas	metam-sodium	Sodium N-methyldithiocarbamate
Vorlex	Nor-Am Chem.	1,3-D + MIT	Methylisothiocyanate 1,3-dichloropropene and other chlorinated C_3 hydrocarbons

NEMATICIDE

Furadan 15G	FMC Corp.	carbofuran	2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate
Nemacur 15G	Mobay Corp.	fenamifos	Ethyl 3-methyl-4-(methylthio) phenyl (1-methylethyl) phosphoramidate

ACARICIDE

Kelthane 4F	Rohm and Haas Co.	dicofol	4,4-Dichloro-alpha-trichloro-methyl benzhyldrol

SPRAY ADJUVANT

Nufilm 17	Miller Chem.	pinolene	Di-1-p-menthene
SoyOil 937	Coastal Chem.	crop oil	soybean oil 93.7%, and emulsifier 6.3%
Triton Ag-98	Rohn and Haas Co.	non-ionic surfactant	Alkyl aryl polyoxyethylene glycol (80%)

OTHER MATERIALS

Land Plaster	U.S. Gypsum Company	Calcium sulfate	85% $CaSO_4$
Solubor	U.S. Borax & Chem. Corp.	boron	Sodium octoborate tetrahydrate Calcium sulfate
Tecmangam	Manganous sulfate	manganese	Mangenese oxide (MnO) and Manganese Sulfate ($MnSO_4$)
Liquid Boron	Stoller Chem. Co.	Boron	Boron derived from boric acid complexed with phenolic acid. 10% B_2O_3

VITA

Ramon M. Cu, son of the late Jose "Cu Cuy Sing" and Felicitas Cu, was born on May 10, 1958 in Bacolod City, The Philippines. He received his elementary and secondary education at St. John's Institute, and attended Xavier University in Cagayan de Oro City, where he graduated (*cum laude*) in 1981 with a Bachelor of Science degree in Agriculture majoring in Agricultural Economics and Agronomy. In the same year, he was employed by Hoechst Far East Marketing Corporation as the Promotional Sales Representative for Negros Island with responsibilities in conducting regular technical meetings for sugarcane planters, vegetable growers and rice farmers, and coordinating field research and product demonstration with private and government agencies involved in agriculture. In 1985, the author joined the Training and Technology Transfer Department of the International Rice Research Institute (IRRI) in Los Baños, where he taught various topics for short courses in rice production and conducted multi-location testing for nitrogen use efficiency in rice. He started his graduate education in 1986 at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. The graduate program included a unique blend of academic instruction in the Department of Plant Pathology, Physiology and Weed Science, and field as well as laboratory research at the Tidewater Agricultural Experiment Station in Suffolk under the research direction of Drs. P. M. Phipps and R. J. Stipes. During his tenure as a graduate student, the author received one best research paper award from the Potomac Division of the American Phytopathological Society, and two similar awards from the American Peanut Research and Education Society. He was awarded the degree of Doctor of Philosophy in Plant Pathology on May 3, 1991.

Ramon Cu