CONTROL OF FUSARIUM WILT OF CARNATIONS BY CHEMOTHERAPY

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This is to certify that the

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CONTROL OF FUSARIUM WILT OF CARNATIONS BY CHEMOTHERAPY

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AN ABSTRACT OF A THESIS ENTITLED " CONTROL OF FUSARIUM WILT OF CARNATION BY CHEMOTHERAPY."

David A. Bosley

A chemotherapeutant, 4-chloro-3, 5-dimethyl phenoxy ethanol (Experimental Chemotherapeutant 1182F), was applied in soil solution to four varieties of carnations, Neptune, Jupiter, Midas, and Vulcan, in an effort to control Fusarium wilt. The concentrations of E. C. 1182F were 1:16,875; 1:33,750; and 1:67,500.

Visual symptoms of the disease caused by Fusarium dianthi, plus an adaptation of the commercial method of "culturing" cuttings were used to arrive at total percent disease in treated and check plots. Commercial culturing of cuttings consists of selection of shoots or cuttings from apparently healthy plants, plating of basal stem sections from these cuttings on to potato dextrose agar, incubation at temperatures favorable to the growth of Fusarium and identification of the disease on the Petri dishes.

The total percent disease in 288 plants which received E. C. 1182F until the time of inoculation was 31.9%. For 288 plants which continued to receive applications of E. C. 1182F, the total percent disease was 8.3%. Two varieties, Vulcan and Neptune, failed to become infected after inoculation in the continuous-treatment group. In the check plants, the total percent disease was 64.1%.

Cut flower records of flowers cut per plant, based on the CSW weight grading system as applied to carnations, indicates that healthy plants out-produce diseased plants by a noticeable margin. The data shows that 2.72 flowers per plant were cut from healthy check plants, while only 1.22 were cut from infected check plants. The disease apparently lessened the number of flowering shoots produced by the plant.

Indications are that the afore-mentioned material will effectively bring about a temporary resistance in the carnation to the entrance of Fusarium wilt when it is used in combination with disease-free cuttings and strict sanitary measures.

Approved By John R. Vaughn
Associate Professor of
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INTRODUCTION

The principle of chemotherapy for the control of plant diseases, while not a new concept, has received wide publicity and interest during the past ten years. With particular reference to vascular diseases which are masked under certain environmental conditions, treatment by means of chemotherapeutants shows great promise in alleviating serious diseases of this type.

Dimond et al., (9) state that chemotherapeutic control might be a result of direct fungotoxicity, inactivation of toxins produced by the pathogen, increase in the host's resistance to the disease by altering protoplasmic factors or unsetting nutritional balance, or by a change within the host of the chemotherapeutant to a configuration more toxic to the pathogen.

Because of the possibilities of commercial application of the theory of chemotherapy to greenhouse plants, as shown by Stoddard and Dimond (20), this study was started to determine the degree of control of a disease of carnations by means of soil applications of a chemotherapeutant. Also, this study attempts to distinguish between the types of control which this material might exhibit. Cut flower records are included to demonstrate differences in production between healthy and diseased plants.

While methods for determining the presence of systemic fungicides in the host are not as yet defined or standardized,

the degree of control of the disease at different concentrations of the chemotherapeutant as compared with untreated, inoculated plants is indicative of therapeutic activity, even though the exact mode of action of the material is unknown.

HISTORY OF CHEMOTHERAPY

Chemotherapy of Local Diseases

In 1891, Bolley (3) showed that potato scab, a tumor on the tuber, could be prevented from appearing by soaking the diseased potato in a mercuric chloride solution. Fifty years later, Strong and Cation (21) cured rust galls on cedar with sodium dinitro-o-cresylate, and chemotherapy of local or topical diseases began with renewed interest.

Positive action on bacterial crown gall by topical applications of sodium dinitro-o-cresylate has been reported by Ark (1); with penicillin by Brown (5) and with penicillin and streptomycin by Hampton (11).

According to Yarwood (25), in 1931, Hamilton cured apple scab with lime sulfur and organic mercury early in the disease year, and his findings went into commercial adoption. Newton et al., (16) found that catechol injected into wheat leaves, four days after inoculation with urediospores reduced rust development by almost fifty percent. Yarwood (25) found that five-day old uredial pustules of bean rust, snapdragon rust, and sunflower rust were killed, without host injury, by exposure of the plants to the vapors from lime sulfur solutions or from dilute hydrogen sulfide gas.

According to Yarwood (25), Hiltner was the first to recognize that deep infections in seeds could be cured by application through the uninjured seed coat.

He cured rye seeds, infected with Fusarium, by soaking them in mercuric chloride.

Organic mercurials soon replaced mercuric chloride, and thousands of bushels of cereal seeds, infected with Fusarium, Helminthosporium and Ustilago, are treated in many parts of the world.

In 1940, Nugent and Cook (17) cured rape seeds infected with bacterial black rot by fumigating the seeds with chloropicrin.

Systemic Chemotherapy on Local Diseases

The application of a fungicide to a given leaf, stem, or root surface and the translocation of that material to the site of infection is as close to a definition of a systemic fungicide as probably any other at the present time. Evidence of chemotherapeutic activity on local or topical diseases was noted by Kinney (14) who demonstrated that potato tubers were more free of scab on plants sprayed with Bordeaux mixture than tubers on unsprayed plants, probably because tubers on sprayed vines were higher in copper content than those on unsprayed vines.

Mc New and Sundholm (15) immersed one leaf on each tomato plant in suspensions of several 1 (substituted phenyl) - 3, 5-dimethyl - 4-nitropyrazoles for thirty-six hours. The treated leaf was severed from the plants and the other leaves were inoculated with Alternaria solani. Appreciable reduction of disease on the untreated leaves showed clearly that the compound had been absorbed through one leaf and translocated to the other leaves.

Systemic Chemotherapy on Systemic Diseases

A systemic disease like a systemic chemotherapeutant is one in which the pathogen itself or its toxic by-products move through the conducting system of the plant away from the infection court.

Howard and Caroselli proved that bleeding canker of hardwoods is a toxin-induced disease which could be mitigated if not cured by antidoting the toxin with injections of diaminoazobenzene dihydrochloride.

Fusarium wilt of tomato and carnation have also received attention by Dimond et al., (9), Stoddard and Dimond (20). The following chemotherapeutants have shown good to excellent control of one or the other of these diseases: 4-chloro-3, 5-dimethyl phenoxy ethanol, 2-norcamphane methanol, 8-quinolinol sulfate, n-octadecyl trimethyl ammonium pentachlorophenate and N-(4-nitrophenyl) -3, 4-dichloro benzene sulfonamide. Toxity to spores bears little or no relation to chemotherapeutic activity against Fusarium wilt of tomato. The carnation appears to activate 4-chloro-3, 5-dimethyl phenoxy ethanol for Fusarium wilt (13).

MATERIALS AND METHODS

A chemotherapeutant, 4-chloro-3, 5-dimethyl phenoxy ethanol, previously shown to possess active control over Fusarium wilt of carnation (9), (13), and (20), was used in comparison to untreated plants in the course of this study.

Phytoxicity Trials

From July 7, 1951 until August 28, 1951, a period of approximately seven weeks, five different concentrations of Experimental Chemotherapeutant 1182 F, as the above material is known, commercially, were applied in solution to carnation plants well established in 4-inch clay pots in the greenhouse. The concentrations were as follows: 1 part E. C. 1182F to 16,875 parts of water; 1:33,750; 1:67,500; 1:135,000; and 1:270,000. Four varieties of carnations were used: Ida, Miller's Yellow, Northland, and an unnamed white-flowered variety.

The above concentrations of E. C. 1182F were applied in water solution with a watering can. Approximately 50 ml. of each concentration were put on each 4-inch pot twice a week for a period of four weeks. At the end of this time, double the quantity of solution or 100 ml. were applied.

On August 28, at the end of the seven weeks treatment, there was no indication of phytotoxicity, loss of vigor, or disease

symptoms in any of the plants. There were three replications with four check plants in each treatment.

Preparations were made to receive a shipment of 1,100 "cultured" carnation cuttings, generously donated by Yoder Bros., Inc., Barberton, Ohio. The procedure was the steam sterilization of concrete propagation benches, sand, 3-inch clay pots, acid peat, concrete greenhouse benches and tools. All were steam sterilized separately for five hours at approximately 200°F., with high pressure steam.

Upon receipt of the unrooted carnation cuttings from Yoder Bros., Inc. on August 21, they were immediately placed in the propagating bench containing fine washed sand. Fifty random basal stem tissue sections from 1,100 cuttings were plated on potato dextrose agar containing two percent dextrose and incubated at 30° C., for seven days before readings were made. None of the plates showed any growth of Fusarium spp.

Of the total of 1,100 cuttings, there were 275 cuttings each of four varieties------Juniter, Midas, Neptune, and Vulcan. Treatments were begun immediately on 650 unrooted cuttings while 450 cuttings were maintained as checks. The concentrations of E. C. 1182 F used were 1:16,875; 1:33,750; and 1:67,500. These solutions were first watered on the unrooted cuttings August 21, and were applied twice weekly after that for a period of forty-five days. When the cuttings had formed roots approximately one-half inch long in the propagating bench, a liquid fertilizer, Plant Marvel, with an analysis of 12-31-13 was watered on the cuttings twice a week for a period of approximately three weeks.

Cuttings were left in the propagation bench and fed liquid fertilizer so that sufficient growth of roots and top would take place enabling a top "pinch" of the terminal shoot which would provide an additional infection court wound to supplement the customary root injury type of infection court when the cuttings were inoculated.

Five isolates identified as those of Fusarium dianthi by Dr. Ames, of Massachusetts State College, were transferred and maintained on potato dextrose agar minus sugar October 20. In order to build up a sufficient quantity of inoculum for the large number of cuttings involved, it was decided to use convenient procedure and equipment for growing fungus inoculum. Potato juice was made by boiling 500 grams of cleaned potatoes with skins intact in one liter of distilled water and then straining the resultant medium through cheese cloth. This solution was then placed in a 4-liter pyrex syrum bottle. The rubber stopper in the bottle contained holes for the replacement of glass tubing which connected to a vacuum pump. Another tube filled with cotton provided for the intake of one liter of air per minute per liter of medium which would be forced through the solution. The entire apparatus was autoclaved at fifteen pounds of pressure and at 240° F. for thirty minutes. Foaming was prevented by the addition of a small quantity of lard oil before autoclaving. The apparatus used to make large quantities of inoculum is shown in Figure 1.

When the sterile medium had cooled sufficiently, sections of Fusarium dianthi 5mm. in diameter, were transferred from petri

Fig. 1. Culture apparatus for growing fungus inoculum.

dishes to the medium in the jar. The vacuum pump was started and the liquid medium was constantly aerated for a period of three days. During the course of the three-day period, loops of the medium were removed every six hours to determine the exact time when the macrospores of Fusarium dianthi had begun to germinate. The presence of germ tubes substantiated the viability of the culture and also indicated the best possible time for inoculation of the rooted carnation cuttings.

Method of Inoculation

The method of inoculating the rooted cuttings was as follows: Before inoculation, the potting bench used in the greenhouse was washed thoroughly with a 1-500 solution of formaldehyde. When microscopic examination of the medium showed an abundance of visible, germinating macroconidia, 500ml. of this inoculum was diluted to a liter of inoculum with unsterile distilled water and then taken to the greenhouse for inoculation. The carnation cuttings, which by now had a heavy root growth and approximately seven to eight inches of top growth, were removed fairly roughly from the propagating bench so that there would be ample root injury thus allowing entry of the macroconidia germ tubes into the plants. Cuttings were then top "pinched" thus providing an additional infection court for the disease which, according to literature, enters the carnation plant almost entirely through wounded tissue.

The entire cutting was immersed in a liter of spore suspension for approximately thirty seconds. Check plants were dipped for thirty seconds in distilled water. After being removed from the

inoculum, the cuttings were placed in 3-inch pots. The soil mixture consisted of two parts peat, three parts clay loam, and one part sand, all of which had been steam sterilized separately. Superphosphate, at the rate of one 4-inch potful per wheelbarrel of soil mixture, was included before potting. After potting, the plants were buried in steam sterilized peat up to the top of the pots.

Night temperatures in the greenhouse, in which the inoculated plants were placed, were maintained at 60° F., with ambient day temperatures prevalent during the late fall and early spring.

Check plants were inoculated by the same method as described above. Uninoculated, but chemotherapeutically treated plants were immersed in distilled water and potted according to the method described.

Losses During Propagation

From a total of 650 unrooted treated cuttings originally placed in the propagating bench, eighteen cuttings failed to root for unknown causes. A severe infection of Alternaria dianthi developed in the propagating bench, and as a result, a total of fifty-six cuttings were lost to this disease. Since the application of any fungicides to control A. dianthi would nullify the results of this experiment, it was decided to write off the losses. Thus the final number of rooted cuttings inoculated in the treated plots was 576.

Losses in the inoculated check group and in the absolute checks amounted to forty-seven plants. The total number of rooted cuttings potted in the former group was 184, and in the latter, 219.

To discover if E. C. 1182 F had any direct fungotoxicity or merely controlled Fusarium wilt by immunizing the host or making it resistant to the disease, it was decided to separate the treated group of 576 plants into two equal plots as follows: 288 plants, all of which had received bi-weekly applications of E. C. 1182 F for approximately forty-five days, continued to receive these applications at three different concentrations------ 1:16,875; 1:33,750; and1:67,500, for a period of 125 days or from their initial application in the propagating bench, August 21, until the final application on January 24, 1952.

The remaining group of 288 treated-inoculated plants was separated from the continous-treatment plot, and these plants received no treatment of any kind after inoculation.

Several liters of inoculum grown in the same manner as described previously, and from the same original transfer of cultures received from Massachusetts, were used to re-inoculate the plants on December 5, one month after the date of the initial inoculation.

At this time, each 500ml. of potato juice containing a spore suspension of macroconidia was diluted with the same quantity of unsterile distilled water and approximately ten ml. of this inoculum was poured into a hole in the soil of each pot near the stem of the plant. The holes were made by jamming pot labels into the soil so that there would be some root injury, thus providing an infection court favorable to the entrance and development of the pathogen.

Table 1. Chart showing continous treatment and interrupted treatment plots with varieties and concentrations listed.

Number of plants and concentrations of E. C. 1182 F used in Continous treatment group.

Conc. 1182 F	Variety--- Juniter	Midas	Neptune	Vulcan
1-16,875	25	24	26	23
1-33,750	23	25	25	23
1-67,500	21	26	25	21

Number of plants and concentration of E. C. 1182 F used in interrupted treatment group.

Conc. 1182 F	Variety Juniter	Midas	Neptune	Vulcan
1-16,875	25	24	25	23
1-33,750	23	26	25	23
1-67,500	22	27	25	21

Tests of Growth Hormone Action

It had been reported in the literature by Stoddard and Dimond (18) that plants treated with E. C. 1182 F produced noticeably denser growth than plants in untreated plots when applied to the carnation variety, Miller's Yellow. As a measure of this hormone-like effect, the above authors used the number of "breaks" or terminal growing points per stem as their criterium.

Treatments of four carnation varieties revealed no hormone or formative effect under the conditions of this experiment. The following chart indicates the average number of "breaks" per plant

in each of the treated and check plots. There is no significant difference between the number of "breaks" or terminal growing points in the treated plants as compared to the number in the check plants. There was consistantly greater number of breaks in the check plants in the variety, Juniter than there was in the treated plants of the same variety.

Table 2. Average number of breaks per plant from a single low pinch.

Treatment	Midas		Neptune		Vulcan		Jupiter	
	A*	B*	A	B	A	B	A	B
1-16,875	3.45	3.0	3.85	4.3	3.8	5.16	3.3	4.1
1-33,750	3.42	3.53	3.66	4.3	4.2	3.8	3.5	4.7
1-67,500	3.81	3.4	3.52	3.6	4.03	4.1	3.7	4.5
Check	3.18	3.44	3.56	3.9	3.5	3.7	3.6	4.24

A* --Treated and inoculated plants
B* -- Untreated and inoculated plants
Check - Not treated ar inoculated

Fertilization of the plants, which were kept in 3-inch for 125 days, consisted of periodic applications of Plant Marvel so as to maintain soil analysis by the Spurway method as follows: 40ppm. nitrogen; 5ppm. phosphorus, and 40 ppm. potassium. The pH was kept at 6.5.

Method of Recording Disease

The "culturing" method as carried out by several commercial carnation propagators is as follows: cuttings or shoots are removed from mother block stock plants grown especially for

propagating purposes. The propagator does not use a knife in taking cuttings, but places a piece of tissue paper between his thumb and index finger which prevents his hands coming in contact with the cutting, thus lessening the possibilty of spreading any disease organisms which might be present on the plants. The cutting is snapped off with the thumb and index finger and a new piece of tissue paper is used for the next cutting. After the cuttings have been taken, they are removed to a sterile room where trained women workers remove approximately one inch of stem from the base of the cutting.

The stem section is then cut into four equal parts, and these are surface sterilized by immersion in mercuric chloride and then sodium hypochloride. Scalpels and forceps used in the cutting of the section into pieces are dipped into alcohol and flamed after each operation to prevent contamination or transfer of disease from one cutting to another.

After the four stem sections are surface sterilized, they are plated on Petri dishes containing potato dextrose agar. Usually two separate plant stem sections are placed in one dish. The Petri dishes are incubated at about 30° C., for a period of seven days. At the end of this time, if there is no evidence of Fusarium mycelium or spores or of bacterial wilt colonies, the correspondingly labeled cutting from which the sections were taken is rooted in an isolated area in the range, and later grown into a disease-free stock plant. It should be mentioned that while the stem sections are being screened for disease, the remainder of the cutting is separately

heat-sealed in cellophane and placed in a refrigerator at 4 or 5° C., during this time. The materials and tools used in culturing are shown in Figure 2.

From this method of culturing, mother blocks of thousands of disease-free stock plants are evolved from which come the finished commercial cuttings. These mother blocks of stock plants are carefully maintained by workers who do not come into contact with other carnations in the remainder of the greenhouse. Cultural practices are extremely clean so as to prevent entrance of any pathogens to the blocks, and steam sterilization of all tools and equipment is standard procedure.

The author adopted much the same techniques as described above for positive counts of diseased plants in the inoculated plants, with the added precaution of dry sterilizing the tissue in rolls for 24 hours at 180° C. Visual observation of disease symptoms also were used together with the "culturing" method to obtain the percent total disease. Fusarium was considered to be present in the plants if one section out of the four plated showed mycelial growth in culture. No sugar was used in the potato dextrose agar to allow for fast macroconidial formation which would facilitate the identification of the pathogen.

Stem sections were taken January 12, and 13, 1952 from all inoculated plants which had not shown symptoms by this time. In the varieties, Jupiter and Vulcan, symptoms were readily evident beginning the last week in December, 1951, and much slower to show in the varieties, Midas and Neptune. Periodic platings on potato

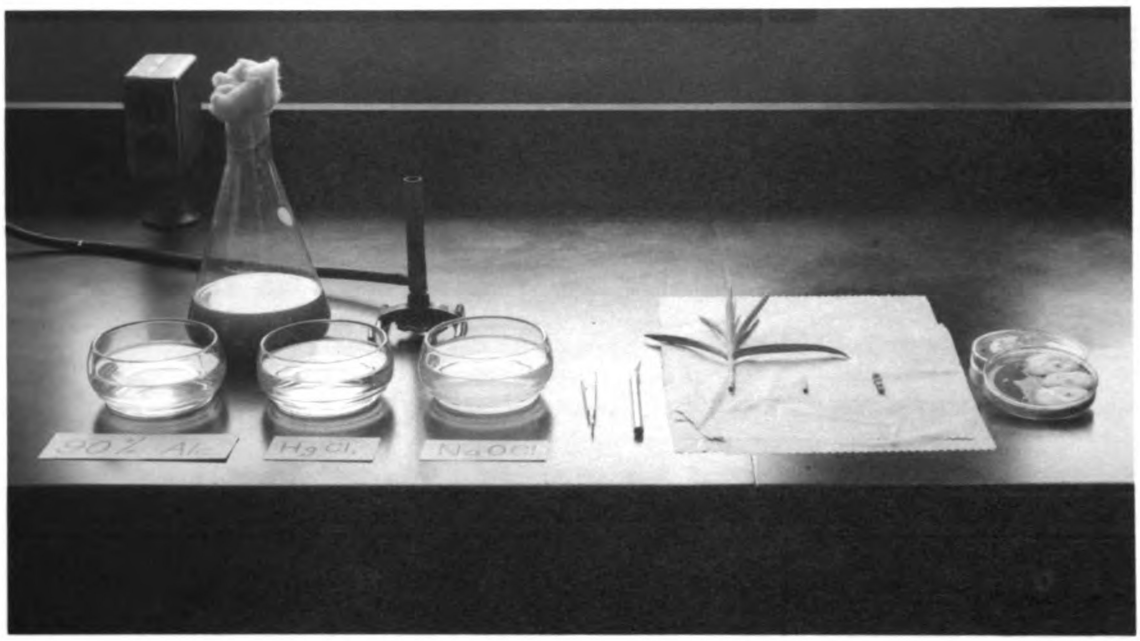

Fig. 2.. Materials used in basal stem section isolations. Note the diseased and disease-free stem sections in the Petri dish to the right.

dextrose agar were made on plants showing symptoms to check visual recording of diseased plants.

In general, symptoms of Fusarium wilt conformed to those described fully by Pickerton (2), that is, there was unilateral development in the tops, with a yellowing of the stem internodes on the infected side, a yellowing followed by withering of the leaf bases and a yellowing of the midveins of these leaves to the tip. Gradually the infected leaves became yellow, mostly on one side at first, and finally withered. These symptoms slowly progress up one side of the plant and into the lateral branches and shoots.

One of the first signs of the disease, which may not be accompanied by yellowing, is a definite outward curling of the terminal shoot which is infected. Chlorosis usually follows and the curling becomes very pronounced. In the vascular system there is a distinct discoloration which gradually gives way to a dry, shreddy reddish-brown rot. This progresses up the infected shoot. Roots usually are in tact throughout the life of the plant, but some rotting does take place, especially in the roots where the disease entered. Extensive rotting usually takes place in the roots after the disease has almost completely killed the tops of the plants.

Flower Production from Diseased and Healthy Plants

To obtain an indication as to possible effects of Fusarium upon the production of cut flowers, it was decided to bench the plants out of the 3-inch pots, and keep cut flower records according to a standard grading method. The CSW weight grading system proposed by Post (18) was used.

Before the soil in the bench was steam sterilized, five pounds of superphosphate, five pounds of calcium sulfate, and one-half pound of muriate of potash was added to the soil.

Because of losses from Fusarium, an irregular number of plants was benched, thus making the results of doubtful significance. The CSV method of grading cut flowers is based on stem length and flower weight which includes the stem. The following table after Post (18), shows the method of grading employed with carnations:

CARNATION GRADES

Grade	Weight per flower in ounces	Minimum stem length- ins.
Special	1 and over	24"
Fancy	3/4 to 1	24"
Extra	1/2 to 3/4	18"
No. 1	1/4 to 1/2	12"
No. 2	Less than 1/4	12"

Table three shows a record of average cut flower production of all four varieties. From a total of 239 plants benched, 81 were untreated and uninoculated check plants, 108 were treated and inoculated, but were healthy, 35 were diseased checks, and 15 were diseased plants taken from the treated and inoculated plots. The average number of cut flowers per plant is achieved by dividing the number of plants into the number of flowers cut in each group.

Table 3. Average number of flowers cut regardless of grade from various treatments. All varieties are included.

Check	2.72	Flowers	per	plant
Check diseased	1.22	"	"	"
1-16,875	2.84	"	"	"
1-33,750	2.28	"	"	"
1-67,500	2.17	"	"	"
Diseased				
1-16,875	2.0	"	"	"
1-33,750	4.0	"	"	"
1-67,500	2.0	"	"	"

There was no relationship between grade of the flower and diseased or healthy plants, since representative grades were found almost to the same extent in the diseased plants as they were on the healthy check plants.

EXPERIMENTAL RESULTS

Counts of diseased plants in the various treatments were a combination of observations of visual symptoms of Fusarium wilt, substantiated by periodic isolations, plus stem section isolations from all symptomless inoculated plants, as previously described under Materials and Methods. Since no chemical test on plant tissue that substantiates the actual presence of a chemotherapeutant is known at the present time, the criterium for assuming that the material is absorbed by the plants must necessarily be its activity in the host or pathogen.

Table 4 shows the results of the inoculations in percent of diseased plants in the interrupted treatments.

Table 4. Percent of disease in 288 plants in which treatments were stopped at time of inoculation.

Conc. 1182F	Juniter	Midas	Vulcan	Neptune
1-16,875	32.0	33.3	21.7	40.0
1-33,750	43.4	38.4	21.7	36.0
1-67,500	40.9	33.3	14.2	24.0
Check	71.05	77.4	26.6	68.08

The average percent of disease for the group of 288 plants shown in Table 4 was 31.9.

Table 5 illustrates the average percent of disease in that group of 288 inoculated plants in which the treatments were continued for eighty days past the date of the first inoculation.

Table 5. Percent of disease in 288 plants in which treatments were continued after inoculation.

Conc. 1182F	Jupiter	Midas	Vulcan	Neptune
1-16,875	20.0	16.6	0.0	0.0
1-33,750	17.3	16.0	0.0	0.0
1-67,500	14.2	15.3	0.0	0.0
Check	71.05	77.4	26.6	68.08

The average percent of disease in the above plot was 8.3. The significance of this is doubtful since no infection was obtained in the two varieties, Vulcan and Neptune. Possible causes of this are poor techniques, incubation time was too short, symptoms were masked by some internal factor, or the chemotherapeutant provided absolute protection against the disease's entrance.

The average percent of disease in the check inoculated plants was 64.1.

The check plants which were dipped in distilled water and were not treated or inoculated did not become diseased.

Symptomless Diseased Plants

A record was kept of the varieties plated for attempted isolation of Fusarium from symptomless plants which had been inoculated. All stem sections were taken from apparently healthy plants which showed no symptoms of Fusarium.

Table 6 shows that the varieties, Vulcan and Neptune might possibly be symptomless carriers of Fusarium, since a large percentage of the stem sections taken from apparently healthy plants were shown to be

infected with the disease when placed on potato dextrose agar.

Table 6. Percent symptomless plants shown by stem sections isolations from apparantly healthy plants.

Variety	Percent Diseased
Jupiter	22.2
Midas	33.3
Vulcan	62.5
Neptune	73.03

DISCUSSION

Despite the failure of two varieties in the continuous treatment lot of 288 plants to become infected, there is an indication here that the chemotherapeutant in question is exerting two effects -- one upon the host and another on the pathogen. Since the interrupted treatment showed a reduction of disease from 64.1 percent in the check-inoculated plants to 31.9 percent in the interrupted group; and since the chemotherapeutant was not applied after the time of inoculation, the reduction in disease must be a result of the action of E. C. 1182 F upon the host and not upon the pathogen. In the continuous treatment plot, if we disregard the two varieties which failed to become infected, it could be noted that the total percent infection in Jupiter and Midas is only 16.6, a still greater reduction from the percent disease in the interrupted treatment. This could indicate that 1) E. C. 1182 F exerts some direct fungotoxicity, 2) the material is keeping the plant in a more or less constant state of resistance to the entrance of the pathogen by its constant presence in the plant, 3) or a combination of the two possibilities is operating to lower the disease percentage of the continuously treated plants below that of the interrupted treatment.

These experiments are based on a temperature of 60° F. Since a higher percent of infection by Fusarium occurs at temperatures

of 75 to 80° F., when inoculation is through the roots, it might be conjectured that in the treated plots, the degree of control might not have been so great at higher temperatures.

Cut flower records indicate that Fusarium-infected plants produce a much lower number of flowers than do disease-free plants, thus pointing to the desirability of "cultured" cuttings in the carnation industry. This reduction in cut flower production is probably a result of a decreased production of vegetative and flowering shoots.

CONCLUSIONS

From the preceding experiment, suggested recommendations for the control of Fusarium wilt of carnation can be evolved.

Primarily, the procurement of disease-free cuttings from reputable carnation propagators is of great importance. If purchased, or self-propagated, cuttings are free from Fusarium wilt, the other two precautions exert much more influence upon the maintainance of the disease-free state of these plants throughout their life in the greenhouse.

Assuming that the cuttings are disease-free, then strict sanitary measures must be employed in the rooting, potting, benching and cutting of the plants and flowers for their entire life in the greenhouse. These clean habits of growing will not only hinder the entrance of Fusarium into the plants, but will also prevent its spread should it enter in spite of these precautions.

Lastly, in combination with, and supplementing these two practices, a chemotherapeutant, such as E. C. 1182 F, could be applied bi-weekly throughout the life of the plants up to and including the flowering stage, so that the plants are constantly in a state of resistance to the entrance of the disease organism. While this material is not the final answer to control of Fusarium wilt of carnation and will undoubtedly be superseded by newer, more powerful chemotherapeutants in the future, it shows sufficiently good results to warrant its use in commercial carnation greenhouses

SUMMARY

A chemotherapeutant, 4-chloro-3, 5-dimethyl phenoxy ethanol, was applied in soil solution to four varieties of carnations in an effort to control Fusarium wilt.

Visual symptoms of the disease caused by Fusarium dianthi, plus an adaptation of the commercial method of "culturing" cuttings were used to arrive at the following total percents disease: check, 64.1; treatment stopped at the time of inoculation, 31.9; and continuous treatment, 8.3. Two varieties failed to become infected after inoculation in the latter group.

Cut flower records of flowers cut per plant, based on the CSW weight grading system as applied to carnations indicates that healthy plants out-produce diseased plants by a noticeable margin. The data shows that 2.72 flowers per plant were cut from healthy check plants, while only 1.22 were cut from infected check plants. The disease apparantly lessened the number of flowering shoots produced.

The use of disease-free cuttings and strict sanitary measures in the growing of carnations is strongly recommended. Bi-weekly applications of one part E. C. 1182 F in 67,500 parts of water have been shown under the conditions of this experiment to provide a sizeable reduction in Fusarium wilt.

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