Fusarium Stub Dieback of Carnation

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ABSTRACT

The stub dieback phase of Fusarium stem rot of carnation frequently occurs in the northeastern United States. Damage on mature flowering plants consists of dieback of cut flower stubs and subsequent girdling of main branches. *Fusarium roseum* 'Graminearum' and several other *Fusarium* species were recovered on plates of Nash and Snyder medium exposed in greenhouses where the disease was severe. Stubs showing various degrees of dieback were collected during several months and cultured. *Fusarium roseum* 'Graminearum' and other *Fusarium* species were recovered from 6 to 18% of the stubs showing severe dieback, while no fusaria were recovered from those showing minimal dieback. Samples of aspen wood fibers from cooling pads, yielded *F. roseum* 'Graminearum' and other *Fusarium* species. Corn stalk tissue from a field adjacent to the greenhouses yielded *F. roseum* 'Graminearum'. All isolates of *F. roseum* 'Graminearum' from air in the greenhouse, from carnation stubs showing dieback symptoms, from cooling pad fibers, and from corn stalks, caused a basal rot on unrooted carnation cuttings and dieback on freshly cut carnation stem stubs. Under current practices of carnation crop production, periodic outbreaks of the stub dieback disease may occur in the northeastern United States, especially during the summer months when environmental conditions favor disease development, and control of the greenhouse environment is not possible.

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Additional key words: Dianthus caryophyllus, Gibberella zeae.

The perpetual flowering carnation, *Dianthus caryophyllus* L., one of the three major cut-flower crops in the United States, had a wholesale value of over $51 million in 1972 (5). California leads in carnation production, followed by Colorado and Pennsylvania. Fusarium stem rot, caused by *Fusarium roseum,* has been a recurring disease of this crop and at certain times and locations has been the limiting factor in production (1, 2). Major losses occur as a basal cutting rot during propagation, a basal stem rot of rooted cuttings shortly after planting, and as a stub dieback of mature plants.

The early literature on Fusarium diseases of carnation and the confusion resulting from early descriptions has been thoroughly reviewed by Tammen (20). Stub dieback has been reported in the United States (9, 14, 16, 27), England (3, 7, 23, 24, 25, 26), France (8, 12), Denmark (10), Sweden (15), and New Zealand (17). Several workers (3, 23, 25, 26, 27) reported that the disease was of little consequence, that growth of the fungus rarely progressed down the stem more than a few internodes, and that fungus growth appeared to be stopped at the junction with a larger branch or the main stem. Others (9, 10, 14, 17) considered the disease a potentially serious problem. Fungi reported to cause the disease are unidentified *Fusarium* species (16, 27), *F. avenaceum* (9, 10), *F. culmorum* (3, 7, 9, 10, 17, 24, 25, 26), *F. herbarum* (= *F. avenaceum*) (7, 24), *F. poae* (= *F. tricinctum*) (9), and *F. roseum* 'Graminearum' (14). The species *F. avenaceum, F. culmorum,* and *F. herbarum* have been reclassified as *F. roseum* by Snyder and Hansen (19). The disease has been called branch rot (16), die-back (3, 7, 17, 23, 26), stub fusariosis (10), and stub dieback (14). Stub dieback is the most descriptive name and will be used throughout this paper.

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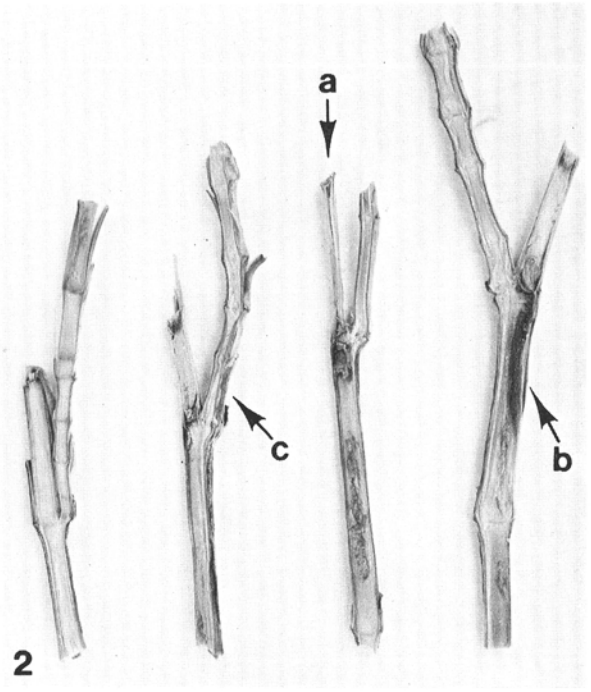

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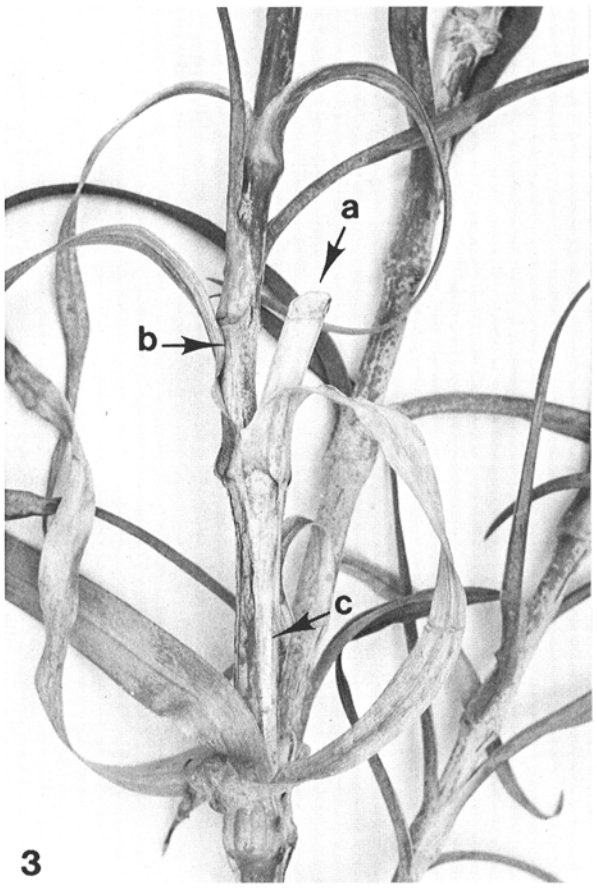

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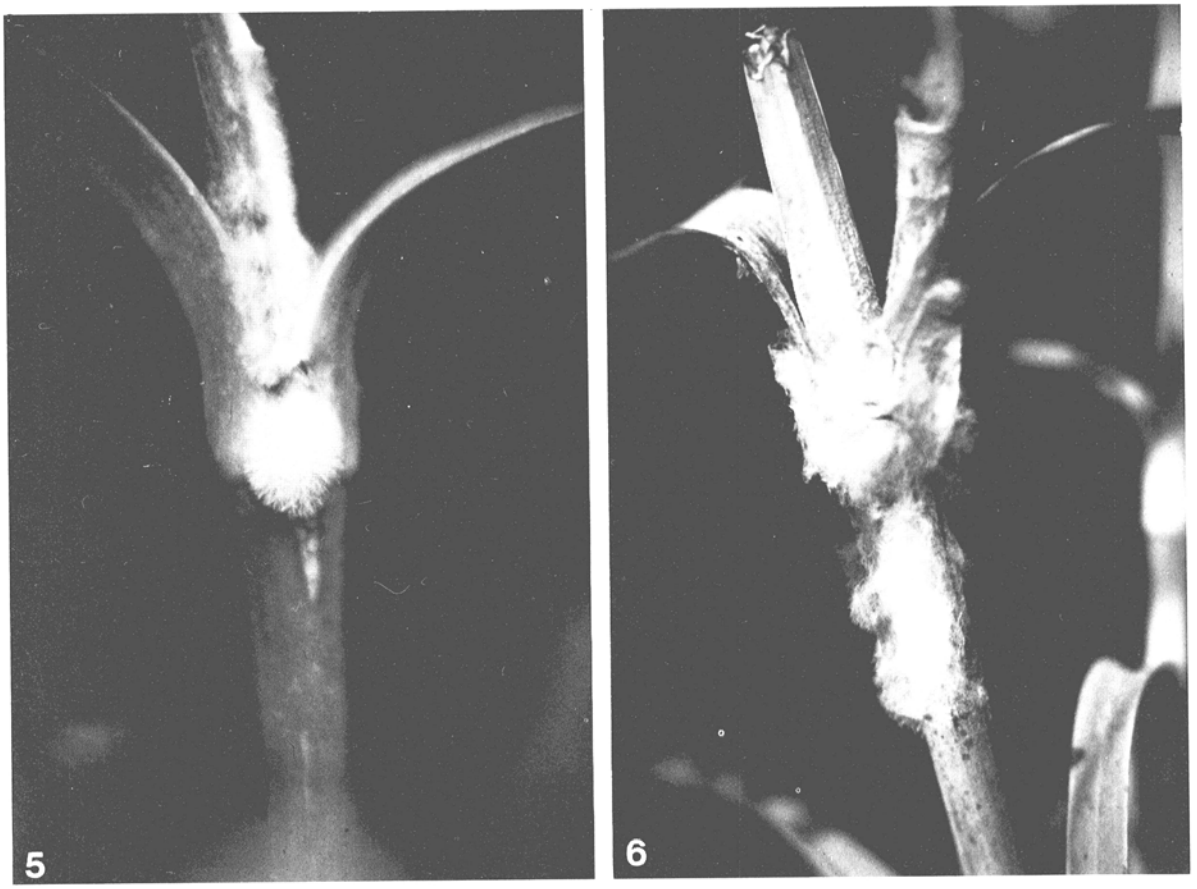

Fig. 5-6. Portions of carnation stems from naturally infected plants in a commercial greenhouse range showing mycelium of *Fusarium roseum* 'Graminearum' on the surface of stem stubs. **5)** The fungus has grown down the stub and is growing through the node. **6)** The fungus has grown down the stub, girdled the sidebreak, grown through the node and into the stem internode below.

In July 1969, a severe outbreak of carnation stub dieback occurred in the northeastern United States and as far south as Virginia and North Carolina. Damage occurred mainly as a dieback of stem stubs after flower harvest (Fig. 1, 3). In some cases, the fungus grew down the stub into the main stem or sidebreak, reducing the number of flower shoots and the productivity of the plant (Fig. 2) (14). Occasionally the fungus grew into the main stem and girdled it, causing death of the plant. Often such stem girdling took place about the time a flower was ready to be cut, resulting in wilting and loss of that flower (Fig. 4). Under conditions of high relative humidity the fungus mycelium grew profusely on infected stubs (Fig. 5, 6). Stub dieback also occurred when the young carnation plant was pinched to force the production of sidebreaks. Although stub dieback occurred at all stages of plant growth, the most severe losses were sustained on 2-year-old plants during flower harvest. The disease is caused by *F. roseum* Lk. emend Snyd. & Hans. 'Graminearum' [*Gibberella zeae* (Schw.) Petch] in the northeastern United States (14).

This study was initiated to search for sources of the pathogen as well as other aspects of the epidemiology of the disease.

MATERIALS AND METHODS.—A portion of this study was carried out in a commercial greenhouse range in Chalfont, Pennsylvania (Fig. 7). The range consisted of a total of 6,900 m^2 (75,000 ft^2) in seven different fan-and-

Fig. 1-4. **1)** Portion of a carnation plant showing a stub exhibiting dieback symptoms (arrow) caused by *Fusarium roseum* 'Graminearum'. Note the wilted leaves on the side shoot next to the stub indicating the fungus has started to girdle the shoot. **2)** Portions of a healthy carnation stem (left) and three infected stems (right) showing stub dieback. The stems have been split longitudinally to show stub dieback (a); lesion formation in the internode (b); and girdling and killing of adjacent shoots (c). Note the limited amount of dieback occurring on the healthy stub usually not associated with infection by 'Graminearum'. **3)** Close-up of a portion of the carnation stem in Fig. 1 showing stub dieback (a); girdling of the sidebreak (b); and the formation of a lesion on the stem internode below the stub (c). **4)** Portion of a carnation flower stem showing girdling of the stem (arrow) by *F. roseum* 'Graminearum' and subsequent wilting of the flower as it started to open.

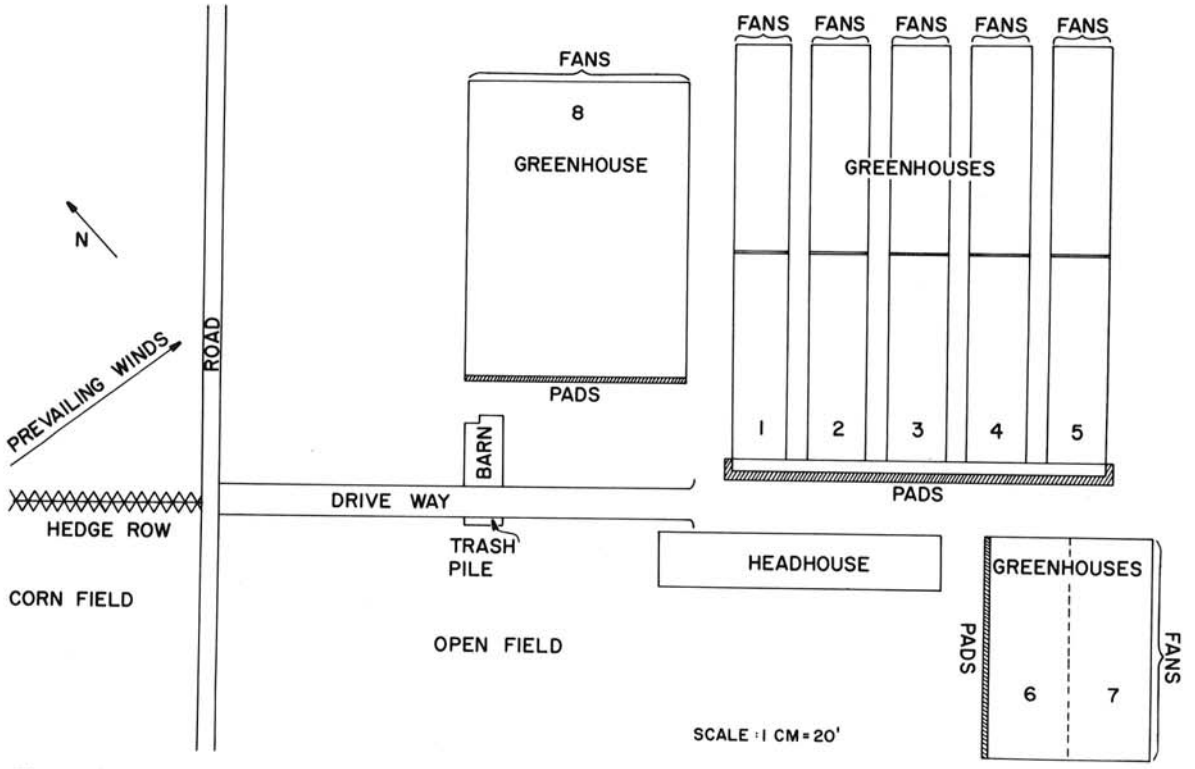

Fig. 7. Diagram showing the overall layout of the greenhouse range at Chalfont, Pennsylvania, where the field work was done. Note the direction of the prevailing winds and the location of the corn field. Fusarium stub dieback was severe in greenhouse 8 and moderate in other greenhouses.

pad cooled (11) greenhouses devoted to carnation production. The disease was severe on plants in one large greenhouse (house No. 8) from July through December, 1969, and occurred throughout the rest of the range only in July and August with minimal losses. Sampling was done in house 8 where disease was severe, and in house 7 where disease was minimal. Both houses contained 2-year-old carnation plants with infected stubs at least 1.22 m (4 ft) or more above the soil.

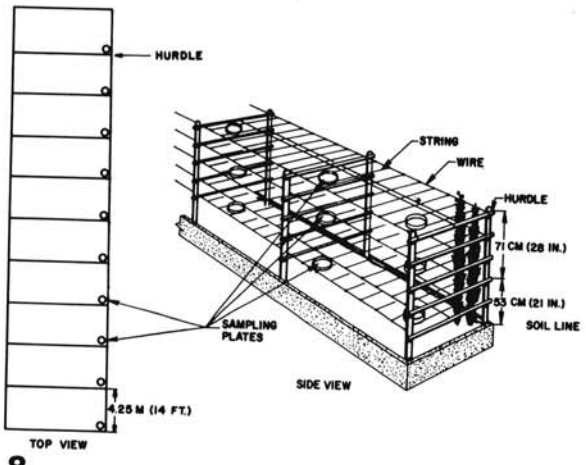

Fig. 8. Diagram illustrating a typical greenhouse bench in the Chalfont greenhouses showing the location of the petri dishes of Nash-Snyder medium used for sampling the air for fungal spores.

Culture medium.—The medium of Nash and Snyder (13) modified by the addition of Neomycin sulfate (22) was used for all spore and plant sampling. About 20 ml of the melted medium were dispensed into glass or plastic petri dishes, 100 × 15 mm. Isolates were transferred to potato-dextrose agar slants and carnation-leaf agar plates by means of single conidia and identified (22). This procedure was followed for all fungi isolated in this study.

Air sampling in the greenhouses.—The solidified Nash-Snyder medium in petri dishes was exposed to the air in houses 7 and 8 for 15 minutes in late morning or early afternoon. Samples were taken at 2-week intervals from 29 July to 24 September, 1969. Samples were taken at 4.25-m (14-ft) intervals on a greenhouse bench at soil level, 53 cm (21 inches) and 124 cm (49 inches) above the soil at each sampling site (Fig. 8). The dishes at the two lower sampling heights were in the foliage canopy while the upper plate was above the foliage canopy at flower bud level.

Collection of stubs showing dieback symptoms.—Fifty stub samples were collected from houses 7 and 8 at bi-weekly intervals between 20 July and 24 September, 1969. An additional 50 stubs were collected from house 8 on 17 October 1969. The samples showed symptoms ranging from dead tissue extending only a few millimeters back from the cut surface, to stubs that were killed back to the

next branch or the main stem. All were cultured, and the fungal isolates identified as described previously.

Collection of aspen wood fibers from cooling pads.—Greenhouses used for carnation production are cooled with a fan-and-pad cooling system during the summer (11). Water is run over pads composed of aspen wood fibers mounted at one end of the greenhouse, and air is pulled into the greenhouse through the pads by several large fans mounted in the opposite wall. In August and September 1969, 64 samples of wood fibers from pads on the carnation greenhouses at Chalfont, four samples from Long Island, New York, and ten samples from the Lancaster, Pennsylvania, area were collected and cultured as described previously.

Sampling of air outside the greenhouse.—On 10 and 24 September 1969, petri dishes of Nash-Snyder medium were placed on the ground outside house 8 in two rows leading from the cooling pads to the site of the carnation trash pile (Fig. 7). The dishes were exposed for 1 hour early in the afternoon. Twenty-four dishes were exposed on each date. In addition, dishes were placed on the carnation trash pile, and on carnation trash in a trailer near the headhouse, and exposed for 15 minutes.

Collection of corn stalk samples from the adjacent field.—The field across the road from house 8 was planted with corn when house 8 was under construction in late summer and fall of 1967. The corn stalks were not plowed down and the basal portion of the stalks were still present in the summer of 1969. In September 1969, eight samples of old corn stalks were collected and cultured as described previously.

Pathogenicity tests.—All isolates of *F. roseum* 'Graminearum' and a representative number of isolates of other *Fusarium* species isolated from stubs were tested for pathogenicity on the bases of unrooted carnation cuttings, and on freshly cut stem stubs of carnation plants. Pathogenicity tests on the cuttings were accomplished by soaking the bases in a heavy macroconidial suspension in sterile distilled water for 1 hour, inserting the cuttings into a steam-treated mixture of equal parts of peat and perlite in a propagating bench in the greenhouse, and holding them under intermittent mist for 30 days.

Pathogenicity tests on freshly cut stem stubs were done on young carnation plants 2-3 weeks after potting when they were ready to be pinched, or on flowering plants 6-8 weeks after potting when the first flowers were ready to be cut. Stems were cut using a scalpel or razor blade dipped in 95% ethyl alcohol and flamed. Plastic bags were placed over the cut stem immediately and fastened shut and a single drop containing approximately 50 macroconidia of *F. roseum* 'Graminearum' in sterile distilled water was placed directly on the cut stub surface with a sterile hypodermic syringe by inserting the needle through the plastic bag. The plastic bags were removed after 72 hours.

RESULTS.—*Fusarium* species recovered on Nash-Snyder medium from various sources in and around the carnation greenhouses are listed in Table 1. *Fusarium roseum* 'Graminearum' was the only species to consistently cause a serious and rapid basal rot on unrooted cuttings and a dieback on freshly cut stubs in greenhouse pathogenicity tests. In these tests stub dieback occurred on plants inoculated at the time they were first pinched as well as when the first flowers were harvested. Consequently, attention was placed mainly on this fungus.

Fusarium roseum 'Graminearum' was not isolated from air outside the greenhouses or around carnation trash piles. The fungus was isolated from corn stalk tissue from the field adjacent to house 8 and from cooling pad fibers in house 8. *Fusarium roseum* 'Graminearum' was isolated from stubs showing dieback symptoms on all collection dates from both houses 7 and 8. However, it was isolated more frequently from house 8 (approximately 6 to 18% of the stubs) than house 7 (approximately 4% of the stubs). The fungus was recovered from the air in house 8, where the disease was most severe, on all sampling dates and at all three sampling heights except in late July. The peak recovery occurred on 24 September 1969 and corresponded to the time perithecia of *Gibberella* sp. were first observed (14). In house 7, where disease was minimal the fungus was recovered only in late July and early August, and only from petri dishes exposed at soil level.

DISCUSSION.—The majority of reports in the literature list *F. roseum* 'Culmorum' as the cause of stub

TABLE 1. *Fusarium* species and cultivars collected from various locations in and around a carnation greenhouse range at Chalfont, Pennsylvania

Fusarium Species and Cultivars	Location				
	Air inside greenhouse	Air outside[a] greenhouse	Cooling pads	Stem stubs	Corn[b] stalks
F. roseum 'Graminearum'	+[c]		+	+	+
F. roseum 'Gibbosum'	+	+	+	+	
F. roseum 'Culmorum'	+			+	
F. roseum 'Avenaceum'			+		
F. roseum[d]	+		+	+	+
F. tricinctum	+	+	+	+	+
F. moniliforme	+	+	+	+	+
F. oxysporum	+	+	+	+	+
F. solani		+	+		
F. episphaeria		+	+		

[a]Includes air sampling around outside of greenhouse and near carnation trash piles.
[b]Old stalks from an adjacent field planted to corn when the greenhouse was built.
[c]+ = fungus collected; blank space = no collection.
[d]Saprophytic isolates of *F. roseum* not given a cultivar designation.

dieback (3, 7, 9, 10, 24, 25, 26). *Fusarium roseum* 'Avenaceum' is also listed as the cause of the disease in four reports (7, 9, 10, 24). In this study *F. roseum* 'Culmorum' was isolated only once from a carnation stub and *F. roseum* 'Avenaceum' only from the cooling pad fibers. Apparently the report of Nelson, et al. (14) is the first which implicated *F. roseum* 'Graminearum' *(Gibberella* sp.) as the cause of carnation stub dieback in the northeastern United States. Therefore, all three cultivars of *F. roseum* may cause carnation stub dieback.

The results of air sampling in the greenhouse indicate that propagules of *F. roseum* 'Graminearum' occur 124 cm or more above the soil surface. Such a vertical distribution is probably too great for macroconidia splashed from sporodochia formed at the base of the plant, indicating that infection at this stage is probably by ascospores. Ascospore infection is further suggested by the fact that the peak recovery of colonies of *F. roseum* 'Graminearum' occurred when perithecia of *Gibberella* sp. were first observed.

Air sampling for fungus propagules by exposing petri dishes of an agar medium to air is a nonquantitative method and thus limits the usefulness of data obtained. In this study, the method was used to obtain preliminary qualitative information relating to the presence of propagules of *Fusarium* species in and around a carnation greenhouse range in Pennsylvania. Continuous sampling gives an accurate daily picture of the populations of aerial propagules and this information will be presented in a later paper.

The growth of *F. roseum* 'Graminearum' from cooling pad fibers was probably the result of ascospores ejected inside the greenhouse and lodging in the pads rather than from propagules pulled into the pads from the outside. This conclusion is further substantiated by the fact that *F. roseum* 'Graminearum' was not recovered from air sampling just inside the pads to check the air being pulled in from the outside.

The recovery of *F. roseum* 'Graminearum' from old corn stalk tissue in the adjacent field, and the fact that these isolates are pathogenic to carnation, is of special interest. Since these isolates were pathogenic to carnation, it is possible that this field served as the initial source of inoculum for the outbreak of stub dieback in house 8. This greenhouse was under construction in 1967 when the adjacent field was last planted to field corn and it is possible that propagules such as ascospores, macroconidia, or chlamydospores may have been blown over and established the fungus in soil or on plants in the greenhouse. In the spring of 1968, there were probably perithecia of *Gibberella* species formed on the old corn stalks and when ascospore discharge occurred some of these spores may have reached the greenhouse through the open vents prior to the annual installation of cooling pads and established the fungus on carnation plants. White (25) reported that in carnation houses in England located near a wheat field infested with *F. roseum* 'Culmorum', it sometimes was necessary to deal with the source of the infection to control dieback on the carnation. This implies that *F. roseum* 'Culmorum' propagules from the wheat field may have served as the primary inoculum for carnation stub dieback.

The fact that isolates of *F. roseum* 'Graminearum' from corn are pathogenic on carnation agrees with the findings of Schneider (18) and Tammen (21), indicating that pathogenic clones of *F. roseum* are not biologically specialized with respect to host plant. This is in contrast to the report of Snyder and Hansen (19) indicating that biological specialization does occur among pathogenic clones of *F. roseum*. Tammen (21) indicated that the forma specialis *cerealis* should be retained and used to indicate pathogenicity, but it seems doubtful that this is necessary.

There is some naturally occurring dieback or tissue death on a stub at certain times of the year. Many of the stubs collected showed dieback only a few millimeters back from the cut surface (Fig. 2). At the time of the stub collections, some stubs of this type were collected along with those showing more extensive dieback. Later in the year, stubs showing limited natural dieback were distinguished easily from those infected by the fungus because there was minimal death of the stub tissue, while in infected stubs the tissue was killed back to the main stem which occasionally was girdled along with the side shoots.

Several species of *Fusarium,* as well as several cultivars of *F. roseum,* were present in the air and in stubs showing dieback symptoms (Table 1). With the exception of *F. tricinctum,* these are not considered pathogenic on carnation. *Fusarium tricinctum* causes a bud rot of carnation in association with the mite *Pediculopsis graminum* (4). Bud rot was present in plants in the greenhouses when this study was underway. The other fusaria may be secondary invaders of infected stubs and serve to intensify the disease.

At present, reasons for the outbreak of stub dieback in 1969, and the continued high incidence of the disease since then, are not well understood. However, some changes in cultural practices used in crop production during the last few years may contribute to a more favorable environment for disease development. Commercial growers add CO_2 to the greenhouse atmosphere during late fall, winter, and early spring at the rate of 1,000 to 1,500 μliter/liter (11). The additional CO_2 helps compensate for the low light intensity that occurs in the northeastern United States during the winter, and aids in maintaining flower quality and size. The injection of CO_2 into the atmosphere from a burner also raises the relative humidity in the greenhouse atmosphere which in turn favors disease development.

Nutrition programs used in carnation production have been improved and refined over the past several years (11). During the summer, plants may receive fertilizer with each watering resulting in plants with a high nitrogen content and a great deal of lush, soft growth. Dorworth and Tammen (6) have shown that such conditions favor development of Fusarium stem rot.

The extensive use of a fan-and-pad cooling system (11) also may contribute to creating a more favorable environment for disease development due to an increase in the relative humidity in the greenhouse when the system is in use. In addition, some growers install a false ceiling about 60 to 90 cm above the top of the plants to confine the cool air in the space around the plants and prevent it from being dissipated in the greenhouse peaks. Use of the false ceiling results in longer periods of high relative humidity than might occur without its use.

Although the carnation plant is suceptible whenever a

freshly cut or broken stub is available, the most severe damage usually occurs on 2-year-old plants. This may be related to the physiological age of the stem tissue, or simply to the fact that the foliage canopy is so thick it aids in keeping the relative humidity high.

It would appear that under the current practices of carnation crop production, periodic outbreaks of the stub dieback disease will occur in the northeastern United States. This will be especially true during the summer months when it is not possible to control greenhouse environmental conditions which favor disease development.

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