A WILT DISEASE OF THE CULTIVATED SNAPDRAGON

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Introduction

The cultivated snapdragon, Antirrhinum majus, L., is one of the most popular plants grown by the florist during the spring and winter months. Under Michigan conditions this plant responds well to the low light intensities that prevail from November until March and is also one of the most profitable flowers grown for the Easter trade.

Close planting in the benches and reduced light intensity during the winter months results in a soft succulent type of growth which renders the snapdragon susceptible to certain diseases that are practically restricted to greenhouse-grown plants. For some time a wilt disease has been observed in various sections of the state, occurring mostly from January to March and at times causing serious losses. These investigations were begun in the winter of 1931 following an unusually destructive outbreak in some of the larger greenhouses in the central and southern parts of the state. This paper presents results of the investigations which establish the fungous nature of the disease and defines the conditions concerned in its occurrence.

History and Economic Importance

Wilt of the cultivated snapdragon is a disease only recently recognized as a distinct disease of importance. Literature up to the present time contains no description of this particular type of wilt on the snapdragon in the United States, although a wilting of

this plant had been observed in 1924 at the Wisley Laboratory in England occurring on the flower parts and upper stems but not found on the basal portions of the stems as in Michigan.

Attention was first directed to this disease in 1929 when it occurred at Mount Clemens and other parts of the state and caused severe losses. Later in 1930 and 1931 plants with similar symptoms were found in Lansing and the surrounding vicinity, although not in such numbers as to constitute an epiphytotic of the disease. It is probable, however, that this disease has been present for many years without attracting attention.

Symptoms and Signs of the Disease

The first symptoms of this disease are usually seen in the snapdragon bench or bed when the first spikes are cut, or perhaps at pinching or disbudding time. The diseased plant can be detected by a pronounced wilting of the leaves with no recovery, such as occurs in wilting due to lack of water (Plate I). The wilted leaves soon take on a dried appearance with a brown color, the adjacent lower leaves down the stem becoming wilted within ten to fifteen hours after the first observation. The stems next attract attention by their pallid, light yellow color, assuming gradually a dried out appearance accompanied by a shriveling of the upper portions of the affected part. The next noticeable symptom is a dark green water-soaked ring around the stem in advance of the pallid colored zone, marking a boundary between the diseased and healthy portions of the stem. Under humid conditions in the greenhouse, a white cottony growth may be detected on the yellow dying tissue, especially if the

stem is broken over, which is frequently the case, as a result of the infection. The flower parts may become infected and show a drooping of the unexpanded buds and a bending over of the ends of the spikes (Plate II). The flowers at the base of the infected inflorescence wither, the remains of the corollas hang down, and the peduncles and the axes from which they sprang shrivel and assume a striking white color, giving the aspect of being girdled at some point lower down the stem.

Upon examination of the side branches near the point of attachment to the main stem, small light to dark brown cankers may be noticed on all parts of the branch, and in some cases, nearly encircling the stem (Plate III & IV). The progressive desiccation of the affected tissue is arrested at the soil level where the fungus grows laterally around the stem completely girdling it.

The most common points of infection are at the base of the plant where the flower spike has been removed, or where the epidermis has been injured through cultivation. Following infection through wounds or the cut ends of the flower stems, a water soaked appearance of the invaded tissue is the first noticeable symptom.

Following the death of the plant, an examination of longitudinally split infected stems reveals small, hard, black sclerotia, sometimes as large as a kernel of corn, surrounded by dried white mycelium and imbedded in the pithy portions. The presence of the sclerotia in the pith furnishes evidence as to the cause of the wilting of the plant.

On inoculated plants the first observed symptom is a pro-

nounced wilting of the foliage within five to ten hours followed rapidly by a light yellow area with a dark green water-soaked zone separating the diseased from the light green healthy tissue (Plate V, A & B). Within twenty-four hours a cottony mycelial mass can be detected on the upper portions of the discolored stem. The point of inoculation, if high on the stem, is subsequently weakened by the fungus and a breaking-over of the upper part of the spike generally occurs. At this point a copious mat of white mycelium may be found on the surface of the injured stem. The next symptom to appear is a marked shriveling of the yellowed diseased portion within twenty-four to thirty hours after the initial infection. As the fungus travels down the stem, a wilting of the leaves and lateral branches occurs until the basal portions of the side branches are reached where small cankers are formed, sometimes in such proportions as to nearly girdle the lateral stems. The fungus, after reaching the main stem, usually forms a large canker at the soil level and sometimes completely girdles the main stem. When this occurs, death of the whole plant ensues within twenty-four hours.

Upon sectioning the stems longitudinally down which the fungus has progressed, hard black elongated sclerotia are sometimes found imbedded in the pith. In no cases are they found on the exterior of the plant.

In some cases small clumps of mycelium form in the axils of the leaves, where moisture collects due to condensation or to watering.

Experimental Work

Material and Methods.

Diseased plants showing stem cankers were collected from the greenhouse and a fungus isolated from the affected portions. The infected stems were first washed thoroughly with tap water, soaked in a 1 to 1000 aqueous solution of corrosive sublimate five minutes, and then washed in six changes of sterile water. Small bits of the diseased tissue were cut out with a flamed scapel and placed in petri dishes containing potato dextrose agar. Within twenty-four hours after plating, a fungous growth was evident as a white felt of mycelium one-half inch wide surrounding each piece of plated tissue.

From these dishes single hyphal tips were cut off under binoculars with a sharp sterile needle and grown in pure culture on various media such as steamed carrot plugs, corn meal agar, potato dextrose agar, malt dextrose agar (Leonian's formula), Coon's synthetic agar, Melilotus stems, Baxter's malt agar, moist blotting paper, and whole steamed oats.

After four days the surfaces of these media were covered with a matted pure white growth of mycelium, which after the fifth day became very dense in spots and began to form solid sclerotia. These at first were white to cream colored but when mature were black and bore large drops of liquid on their surfaces until the moisture content of the media was exhausted. The sclerotia then became dry and hard, corresponding in size and appearance to those produced in stems of diseased plants collected by Dr. Ray Nelson in 1930. No other

fructifications of any sort, such as micro-conidia, were ever observed in these or any subsequent pure cultures originating either from ascospores or from mycelium.

Snapdragon seeds of commercial varieties were sown in pots of clean sterilized composted soil, and the seedlings were later transplanted one inch apart in flats containing soil sterilized by steam. Five hundred and sixty plants of six popular varieties, namely, Jennie Schneider (light pink), Ceylon Court (yellow), Philadelphia Pink (pink), Sun Tan (light yellow bronze), Roman Gold (deep bronze), and White Rock (pure white) were selected. These plants were pinched back to six "breaks", or lateral branches, and shifted to sterilized soil in six inch pots where they were grown to maturity.

Proof of Pathogenicity.

Sterilized whole oats were inoculated with sub-cultures of the fungus and after two weeks time this material was used to inoculate sterilized soil in thirty six-inch pots. In similar pots, five plants of each variety were grown on sterilized soil under the same conditions. After fifteen days the plants in inoculated soil showed no symptoms of the disease. Twenty of those plants grown in inoculated soil, as well as the checks, were wounded at the soil level with a sterilized knife to simulate the breaking of the epidermis by cultivation in the snapdragon bench. Five plants so treated showed signs of the disease and wilted within three days after wounding. Within two weeks eighteen of the twenty wounded plants had become infected and showed typical wilt symptoms. The check plants were perfectly

normal at the end of the experiment and showed no symptoms or signs of the disease.

Isolations were then made from the diseased plants and the fungus again obtained in pure culture. The re-isolated fungus was identified as that of the original pure culture. Mycelium of the re-isolated fungus was then introduced into a new series of plants which gave the characteristic symptoms and signs in all cases. Diseased tissue was again plated and allowed to form sclerotia to prove Koch's postulates. Cultures of both the original and the re-isolated fungus were used for biometric studies discussed later in this paper.

Experimental work of inoculating plants by introducing bits of mycelium into incisions, some slight and others deep, on various parts of the plants (Table I) was started on February 15, using 24 plants for each group of experiments. Twelve plants were used for inoculation and the same number as checks. The inoculated plants and the checks were grown under like conditions at various temperatures and humidities in separate inoculation chambers.

The inoculated plants consisted of the six varieties to determine whether color was correlated with immunity to the disease.

Inoculated plants were allowed to remain in the inoculation chamber from three to six days in all but three series, which were allowed to remain until the plants were dead in order to study sclerotial formation in the stems.

All the plants used at the beginning of the experiment had just begun to bloom and were in a succulent condition and susceptible to infection.

Table I.

Inoculations of Different Varieties at Various Points on the Plant.

Variety	No. Plants Inoculated at								Checks Wounded at								No. Plants Used
	Base		Cut flower spike		Leaf Axil		Top of Plant		Base		Cut flower spike		Leaf Axil		Top of Plant		
	Inoculated	Infected	Inoculated	Infected	Inoculated	Infected	Inoculated	Infected	Wounded	Infected	Wounded	Infected	Wounded	Infected	Wounded	Infected	
Jennie Schneider	8	5	25	24	8	3	8	6	8	0	25	0	8	0	8	0	98
Ceylon Court	8	5	20	17	6	2	8	7	8	0	20	0	6	0	8	0	84
Phila. Pink	8	5	20	14	8	3	8	8	8	0	20	0	8	0	8	0	88
Roman Gold	8	4	25	18	8	3	8	4	8	0	25	0	8	0	8	0	98
Sun Tan	8	5	20	15	7	4	8	8	8	0	20	0	7	0	8	0	86
White Rock	8	6	15	10	5	3	6	6	8	0	15	0	5	0	6	0	68
Totals	48	30*	125	98*	42	18*	46	39*	48	0	125	0	42	0	46	0	522

*Inoculations in late April and May did not cause infection in all cases due to hardening of the plant tissue.

Plants that were inoculated at the base were easily infected until April 13, when the stem tissue became hardened as a result of growing conditions. During this period, from the middle of April to the last of May, eighteen of the inoculated plants failed to become infected although 100 per cent infection resulted from earlier inoculations with the fungus.

The flower spikes were cut off near the base of the plant leaving two or three "breaks" near the soil level to produce the next crop of flowers, and mycelium was placed directly on the exposed cut surfaces. Additional plants also were inoculated in this manner as the entrance of the fungus generally occurs at this point.

The axils of leaves, where the lateral branches arise, were inoculated with the fungus when these side branches were removed by disbudding. Only eighteen of the 42 plants inoculated became infected, and these only wilted when the plants were syringed to lower the temperature and increase humidity in the inoculation chamber. The fungus usually died before infection occurred in the leaf axils, and less than one-half the inoculated plants became diseased.

In a few cases, entire tops of plants were cut off and inoculated where the growth was soft and succulent. By using this method 100 per cent of the plants so treated became infected. Twenty-three plants were wounded slightly within three inches of the tops, and twelve of these were inoculated in the wounds. Infection here resulted in five of the inoculated plants. The eleven check plants were then wounded deeply at the tops and inoculated. Evidence of infection was observed within five hours after inoculation regardless of the tempera-

ture and woodiness of the tissues. Breaking over of the tops was prevalent in these deep wounds, and copious growths of mycelium were readily observed in every instance.

In all these tests the check plants were treated exactly the same as the inoculated plants as regards temperature, light, and humidity. The checks were first wounded at the various places and the plants for inoculation wounded in similar locations. The checks in all cases were free from infection and showed no signs or symptoms of the disease.

Plants Experimentally Infected.

Inoculations were made on various other plants and the fungus found to be infectious on tulip, Regal lily, hyacinth, gladiolus, Delphinium, stock, Schizanthus, tomato, gourd, chrysanthemum, and lettuce.

The tulip, hyacinth, lily, and gladiolus plants were inoculated on freshly cut flower stems. The fungus grew down the stems causing the characteristic light yellow color on the shriveled stems. The tips of the leaves began to turn yellow and shrivel when the fungus reached the base of the plant. Examination of the bulbs and corms showed a soft odorless rot at the point of attachment of the leaves.

Lettuce plants were inoculated in the leaf cluster at the base of the plant. The first symptom of infection was a wilting of the lower leaves, which was immediately followed by the drooping of the upper ones until the entire plant was involved, giving the appearance as if the whole plant had been dipped in boiling water.

Near the moist portions of the stem end of the dead plant the white cottony growth of the fungus was quite evident on the under sides of the leaves. When the plant began to decay, sclerotia which varied in size from 0.5 x 5 to 0.5 x 9 mm. were formed in the decomposed tissue.

Gourd and tomato plants were very susceptible to the disease, and healthy plants became infected when they came in contact with the leaves or stems of diseased plants. The fungus grew more rapidly in the tomato and gourd than it did in the snapdragon, due to a greater succulence of these plants when grown at cool temperatures. When inoculated on bruised leaves, the fungus grew rapidly and caused death of the blooming plants within a week. Symptoms of the disease were similar to those on the snapdragon with the exception that the fungus grew more rapidly and formed sclerotia more freely in the stems.

When Schizanthus, stock, Delphinium, and chrysanthemum were inoculated in the tops, the development of the fungus was slower than any of the previously infected plants, but the leaves and the stems gave the characteristic symptoms in wilted, drooping vegetative parts. There was a lighter tint to the diseased stems and fewer sclerotia were formed in the pith.

On hyacinths, when the fungus had completely killed the foliage, the bulbs were dug, rested six weeks, and again planted in bulb pans. The bulbs were solid at the time of planting but soon decayed in the ground as the result of the renewed activity at the time of root formation of the mycelium which had remained dormant in the bulb tissue.

The Causal Fungus.

Physiology.

The fungus grew readily on all types of media used, but best growth occurred on potato dextrose agar at 17° to 21° C. The fungus grew, however, at temperatures ranging from 7° to 30° C., but growth was slow at both extremes. High humidity gave the best results in the culture chamber stimulating rapid growth of the fungus. Ascospores were readily discharged when mature apothecia were subjected to a moist atmosphere following comparatively dry conditions in small flasks.

Growth rate measurements were taken by inoculating the tops of snapdragon plants with the fungus and marking the stems of the plants with india ink at quarter-inch intervals. When the water-soaked area coincided with the first marked interval on the stem, the time was recorded and observations were made intermittently as the fungus traveling down the stem reached the marked graduations. The fungus was found to progress 1.18 cm. a day on mature flower spikes, and as rapidly as 3.58 cm. a day on young succulent growth.

The fungus was grown on agar slants upon which were placed six inch lengths of number 40 white thread previously soaked in dilute agar. When the mycelium had completely grown into the threads they were removed with flamed forceps and cut into quarter-inch pieces with sterile scissors and placed on potato dextrose agar in petri dishes. These were put in the differential thermastat where the temperatures ranged from 7° to 33° C. to determine at which temperatures the best growth took place. This was accomplished by

measuring the growth of the mycelium extending from the thread in the petri dish at 9:00 A. M. and 5:00 P. M. daily. The best progress of the fungus was noted between the temperatures of 17° and 21° C.

On January 13, 70 sclerotia collected in April, 1931 were dipped in alcohol, flamed, and placed in 250 cc. sterilized flasks containing sand previously baked in an electric oven for thirty-six hours. Six to ten sclerotia were placed in the flasks and the sand moistened with sterilized water. The flasks were stored at various temperatures and light intensities to record time of germination and production of apothecia (Table II).

Table II.

Condition of Formation of Apothecia from Sclerotia.

Location of flasks	No. of sclerotia	Temperature	Light intensity	Date of stipe formation	Date of apothecia formation
1. Electric ice box	8	7.2° C.	Dark	March 2	March 16
2. Greenhouse	7	15.5° C.	Diffused sunlight	Feb. 16	March 1
3. Greenhouse	10	10° C.	Shaded--diffused sunlight	Feb. 8	Feb. 26
4. Greenhouse	6	29.4° C.	Diffused sunlight	Feb. 7	Feb. 18
5. Dark room	6	22.2 C.	Total darkness	Feb. 24	March 13
6. Outside on window sill	7	4.1° -- 7.2° C.	Full sunlight	Feb. 27	March 23
7. Inside on window sill	6	22.2° C.	Diffused sunlight	Feb. 6	Feb. 17
8. Ice box	10	9.4° C.	Dark	Feb. 20	March 2

The sclerotia of lot 1 were placed in an electric ice box and were subjected to daylight once a day for observation. Lot 2 was placed in the rose range of the greenhouse with diffused sunlight and partial shade from 7:00 to 12:00 A. M. throughout the experiment. Lot 3 was placed in the snapdragon and carnation house under a bench with shaded conditions and diffused light at all times. Lot 4 was placed in the cucumber house in full diffused sunlight during the whole day. Lot 5 was placed in the photographic dark room with no light except when observations were made with the aid of a dim electric bulb. Lot 6 was placed on an east window sill in full morning sunlight outside the Botany Building and subjected to freezing and thawing at day and night temperature varying from 4.1° to 7.2° C. It was brought back into the laboratory when the first signs of germination were observed on February 24. Lot 7 was placed on an east window sill inside the Botany laboratory and subjected to diffused light conditions and constant room temperature. Lot 8 was placed in an ice box in semi-darkness with temperatures varying from 9.4° to 12.7° C. until germination occurred, when it was brought out and kept at room temperature.

The first germination and production of stipes occurred on February 6 in flask number 7. These sclerotia produced from one to four stipes which bore apothecia eleven days later. The second lot to germinate was in the cucumber house at a temperature of 29.4° C. One day later sclerotia began to germinate at 10° C. in the carnation and snapdragon house. Apothecial formation occurred eleven days after first germination signs were observed in the above three cases.

The remaining lots of sclerotia germinated within 25 days after lot 7. The sclerotia in the electric ice box kept approximately at 7.2° C. were the last to germinate but formed apothecia within fourteen days after stipe formation.

Small apothecia in a few cases in four of the lots were produced on multi-branched stipes, this abnormality apparently being due to environmental conditions.

A study of Table II shows that sclerotia will germinate and produce apothecia in a wide range of temperature and light conditions. The sclerotia in lots 1, 6, and 8 were subjected to temperature comparable to those conditions occurring in the compost pile.

Sclerotia in lots 2, 3, 4, 5, and 7 were subjected to temperature fluctuations from 10° C. to 29.4° C., which correspond to conditions in the greenhouse in midsummer and early fall when such plants as chrysanthemums and carnations are benched. It is evident that the development of the fungus through sclerotia germinating in the greenhouse may be in progress throughout the year.

Morphology.

The resting stage of the fungus causing snapdragon wilt is a black tuberiform sclerotium averaging 0.5 - 5 x 0.5 - 9 mm. The sclerotia germinate to form scattered, stipitate, naked, goblet-like apothecia (Plate VI) which vary in color from pale salmon to cinnamon (Ridgway). The apothecial cups are 4 - 8 mm. wide, with a slender sub-flexuose more or less elongated stipe averaging 3 cm. (4). The asci are cylindrical, 115 - 144 x 8.4 - 12 microns, with ascospores arranged in a single row, ellipsoidal and generally guttulate,

7.2 - 12 x 5.2 - 9.6 microns (Plate VI, 1). Paraphyses are few and clavate. The mycelium is pure white and consists of long branching cells, the hyphal threads becoming more septate and branched within the host. When a sufficient amount of food has been taken by the mycelium, the latter begins to form dense masses which ultimately become the sclerotia. No conidia were observed either in culture or on the host.

The characteristics of this fungus identify it as a member of the genus Sclerotinia.

Biometric Studies.

Three hundred and twenty-six sclerotia formed in pure cultures were measured and found to range in size from 0.5 - 5 x 0.5 - 9 mm. with an average size of 2.75 x 2.125 mm.

From fifteen apothecia hand microtome sections were cut and six hundred asci and ascospores were measured. These measurements coincide closely with ascus and ascospore measurements of Sclerotinia sclerotiorum (Table III) by Stevens (6:141-142) and by Dowson (2), although they are a trifle smaller than those usually accepted for the species. The following table gives a comparison of ascus and ascospore measurements by the author and two other workers on this fungus.

Table III.

Comparative Measurements of Asci and Ascospores.

	asci (microns)	ascospores (microns)
Stevens (6)	130 - 135 x 8 - 10	9 - 13 x 4 - 6.5
Dowson (2)	121 - 130 x 6.6 - 8.8	8.8 - 11 x 3.5 - 5
Author	110 - 135 x 7.9 - 11.5	7.2 - 11 x 5.2 - 9.6

In most cases the author's measurements corresponded closely to those by Stevens and Dowson. Dowson working on the fungus from Schizanthus recorded spore measurements of 10 - 13 x 5 - 6 microns in contrast with 8.8 - 11 x 3.5 - 5 on snapdragons. However, the measurements still fell within the limits as defined by Stevens.

The hyphae varied in width from 10 to 24 microns (Plate VI, 2). The smallest hyphae observed were those formed on Coon's synthetic agar and on malt dextrose agar. The largest hyphae were found on potato dextrose agar, showing a possible correlation of growth with the carbohydrate content of the medium.

Taxonomy.

According to the spore measurements and other characters, the fungus causing the wilt disease of snapdragons in Michigan is Sclerotinia sclerotiorum (Libert) Massee (=Sclerotinia libertiana Fuckel). Madame Libert in 1837 first gave this organism the name of Peziza sclerotiorum. In 1870 Fuckel transferred this to his genus Sclerotinia and changed the name to S. libertiana. Later in 1895 Massee, following the recognized rules of nomenclature, used the name

Sclerotinia sclerotiorum. The question as to the correct name for this species is discussed fully by Miss Wakefield*.

Comparison With Other Wilt Diseases.

Several other diseases which cause wilting affect the snapdragon in America, the most important and troublesome being anthracnose (5 and 7:109-110), Phyllosticta antirrhini Stew., which affects the leaves, stems, and shoots. This disease, however, can be distinguished from Sclerotinia wilt by the characteristic spots that occur on the stems and leaves. The spots when numerous cause the affected foliage to shrivel, cling to the stem, and die. All parts above ground are attacked by the parasite, but there is no sudden wilting of the foliage such as characterized the sclerotinial disease.

Another disease of snapdragon causing a wilt and drooping of the foliage is Verticillium wilt (1), caused by the fungus Verticillium albo-atrum Rein. and Bert. This is a soil inhabiting parasite and causes a typical wilt of the whole plant. It is distinguished from sclerotinial wilt by a number of characteristics, viz. (1) the wilt is not sudden; (2) the vascular tissues of the plant are discolored; (3) no cankers are formed on the stems; (4) no sclerotia are formed; (5) Verticillium albo-atrum produces conidia; and (6) affected stems do not have the characteristic color seen in plants attacked by S. sclerotiorum.

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*Wakefield, E. M. Phytopath. 14:126-127. 1924.

Control

Since snapdragon wilt occurs in the greenhouse in late winter and early spring, the control measures advised by Pethybridge (3) to combat diseases of other plants caused by the same organism in the field cannot be used.

The plants are attacked by two forms of the fungus, (1) mycelium in the soil, and (2) by ascospores.

Since infection in the greenhouse results from these two sources, the most effective method is to exclude the parasite from the soil.

Exclusion.

Soil in benches, pots, ground, and seed beds, as well as pots and flats, should be thoroughly sterilized by steam. If steam is not available, formaldehyde or Semesan may be used to free the soil of mycelium.

A large grower of snapdragons in Michigan experienced a severe loss in 1929 due to an epiphytatic of this disease in his greenhouse. In 1930 the soil in the benches was sterilized, but the disease was not completely controlled. In 1931 not only the bench soil but the pots, flats, benches, and seed were sterilized, and as a result not a single plant was attacked by the disease.

Sclerotia in the soil of the snapdragon bench are carried out to the compost pile at the end of the growing season where they freeze and thaw from one to three years before being brought back into the house with the soil for use in snapdragon benches or for other susceptible crops. S. sclerotiorum being an omnivorous parasite and sapro-

phyte is in all probability often present in the soil used primarily for preparing greenhouse compost either in the form of growing mycelium or of sclerotia. This makes it imperative to sterilize every bit of soil before attempting to grow this crop. If the parasite gains entrance, other measures must be taken to eradicate the disease before it has progressed very far.

Eradication.

Plants found in the greenhouse infected high up on the stems can be saved by excision of the diseased branch two or three inches below the darkened area. As a diseased plant bears no spores, it is innocuous to the neighboring plant if its diseased leaves or stems do not come in contact with parts of the other.

If dead or diseased plants are allowed to remain on the surface of the bench soil or are thrown out on the refuse pile, there is an excellent opportunity for sclerotia to form and be freed by decomposing stems. All diseased stems and plants should be destroyed by burning immediately after they are collected.

When the disease has been observed and all infected plants eradicated, steps should be taken to protect the crop from further infection.

Protection.

Care in watering, temperature, ventilation, and spacing may protect the plants from being attacked by the parasite. Spores and mycelium on the surface of the soil are easily splashed by water to freshly cut or injured stems. A layer of sterilized sand or gravel

spread over the surface of the soil in the bench will prevent distribution of the fungus by water.

Wind blown ascospores may be a source of infection on freshly cut stems. As a protective measure, cut flower stubs may be daubed with a Bordeaux mixture paste.

In cloudy weather water should be withheld and the plants given an abundance of ventilation in order to keep the foliage as dry as possible at all times. Snapdragon wilt is favored by high humidity, overwatering, poorly drained benches, and insufficient ventilation. Spacing the plants about one foot apart will facilitate ventilation and assure quick drying. In view of the thermal requirements of the plant and the fungus, a night temperature of 10° C. should be maintained.

Resistance.

Since all varieties and colors of snapdragons used in the experiment were susceptible, there is no indication that resistant varieties are now available among the important commercial kinds. However, in view of the results obtained in control of disease in other plants, there is a possibility that if large numbers of varieties were studied, less susceptible ones might be found, particularly in view of the fact that older plants with harder tissues were much more resistant. If certain varieties are characterized by harder tissues or by earlier maturity of cortical tissues, they would be less susceptible.

Discussion

The pathogen S. sclerotiorum is a very common fungus attacking a great variety of plants, especially in rainy seasons in the field or in humid conditions under glass. Because of the various symptoms on a large number of host plants, diseases caused by the fungus have become known under various names, such as "drop", "wilt", "Sclerotinia rot", "stem rot", and "soft rot".

Whether or not this organism is distributed by propagators cannot be said; although, if the greenhouse man has had a previous epidemic of wilt, sclerotia or mycelium could easily be transported through the soil adhering to the seedling roots or in pots and flats. This is possibly not the case, but it behooves the grower of plants for sale to supply strong and vigorous plants grown in sterilized soil, and the buyer should select and accept only good healthy stock.

The practice of using old composted soil without sterilization is not recommended, and satisfactory control of this disease must depend upon the use of sterilized soil with attention to the temperature and humidity relationships of the plant and the fungus.

Summary

1. A wilt disease of the cultivated snapdragon occurs throughout central and southern Michigan causing great losses in the crop each year in the greenhouses. The host range of the parasite on the snapdragon is not known, but it is logical to assume, because of the omnivorous nature of the parasite, that it is present wherever the snapdragon is grown under glass.

2. Diseased plants were obtained from Lansing, East Lansing, Mount Clemens, and elsewhere, and the fungus was isolated and proved to be pathogenic to snapdragons, hyacinth, gladiolus, Delphinium, stock, Schizanthus, tomato, chrysanthemum, gourd, lettuce, and many other greenhouse crops.
3. Plants are usually attacked by mycelium or by ascospores through cut and wounded stems, and the fungus causing the disease works with great rapidity causing the loss of the entire plant.
4. The progress of the disease was most rapid between the temperatures of 17° - 21° C. It was most destructive under conditions of high humidity.
5. Evidence is presented of the fungous nature of the disease and the causal organism identified as Sclerotinia sclerotiorum.
6. A technical description of the parasite is given.
7. Recommendations for control are: (1) Sterilization of soil, pots, and all material with which the plants come in contact, (2) Care in watering, (3) Regulation of temperature and humidity, (4) Air circulation by spacing of plants, (5) Covering the soil with sterilized sand, (6) Excision of diseased stems and eradication of diseased plants, and (7) Destruction of refuse.

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Legends

Plate I. Snapdragon plant affected with wilt (natural infection). The wilting is due to canker formation which completely girdled the stem near the soil level.

Plate II. Snapdragon plant attacked by Sclerotinia sclerotiorum. The blossom spikes and young succulent shoots were first attacked by the fungus which gradually spread and affected the entire upper portion of the plant.

Plate III. A mature snapdragon plant girdled just above the soil level by a canker formed by the fungus S. sclerotiorum. Infection occurred at the cut end of the flower spike a few inches above the soil level.

Plate IV. Large roughened canker formed by S. sclerotiorum at the crown of a flowering plant. Infection occurred through the stub of the cut flower stem.

Plate V. A. Snapdragon plant inoculated through the stub of the excised flower stem with a pure culture of S. sclerotiorum. The fungus progressed rapidly downward until it girdled a lateral stem following which a rapid wilting occurred.

B. Snapdragon plants inoculated in the tops through wounds with a pure culture of S. sclerotiorum.

Plate VI. A. Asci, ascospores, and paraphyses of S. sclerotiorum (camera lucida drawings x 600).

B. Hyphae of S. sclerotiorum showing characteristic habit of branching (x 600).

C-E. Germinating sclerotia from pure cultures of S. sclerotiorum (x 8).

Plate I

Plate II

Plate III

Plate IV

Plate V

B

A

Plate VI