Diseases of Gladiolus
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By RAY NELSON

Gladiolus corms, to be eligible for interstate shipment, must not be affected with major diseases in excess of allowable tolerances. Field and storage inspections are mandatory in all states for stocks intended for interstate shipments, and uniform tolerances have been established for the most important diseases. These regulations were adopted to improve the quality of corms and to standardize their certification in all parts of the country. The importance of disease control in gladiolus culture is indicated by the necessity for this joint state action to prevent interstate shipment of corms carrying excessive amounts of diseases and to provide protection to thousands of growers who buy millions of corms each year with the expectation of receiving clean and healthy stock.

Successful commercial producers of corms must grow healthy stocks, and to do so they must be familiar with the major gladiolus diseases and must practice control methods that will prevent them from developing in excess of approved tolerances. Information in this bulletin is the result of 25 years of research by the writer on the important diseases of gladiolus and is intended to aid all classes of growers in identifying these diseases and in practicing effective methods of control.

Research in the pathology of gladiolus was of necessity curtailed during the war years but is now expanded to pre-war levels, and new and improved methods of disease control are continuously being sought. No new fungicides of outstanding superiority, however, have been developed for use on gladiolus, and growers should still rely on those that have proved most consistently safe and effective under a variety of soil and climatic conditions. It is unlikely that miracle fungicides will be developed which will obviate established agricultural practices and the systematic application of proved methods of disease control.

Investigations of new diseases have provided much information that was not available when the last edition of Circular Bulletin 149 of the Michigan Agricultural Experiment Station was issued in 1942. Some diseases, previously undescribed, have attained major importance in a comparatively short time. Two of them are fungous leaf blights, which have only recently become destructive in other areas and which are now appearing in Michigan. They are described, and methods of control, based on preliminary tests, are suggested. They were important in eastern gladiolus plantings in 1946 and 1947 under climatic conditions very similar to those that normally prevail in Michigan. It is likely that they will become important here when seasonal conditions are favorable for their development.

Until recently, virus diseases have not been a serious threat to gladiolus culture in any section of the country, but the increasing prevalence of white-break mosaic is an indication of the potential danger from this group of serious diseases. The low tolerance established for this disease in certified stocks and its observed increase in commercial plantings make it important that all growers be familiar with the common symptoms of white-break and guard against introducing it into their plantings. The symptoms commonly seen in flowers and leaves are illustrated in color so that growers can become acquainted with its various manifestations.

The first description is given of Ink Spot, a blemishing disease of corms. It is one of the newer diseases, for which a comparatively low tolerance has been established in certified stocks.

The commercial production of gladioli is an extensive Michigan industry whose importance is generally underestimated. Growers well-informed about the production of gladioli in this state report that the annual returns to commercial producers of corms and flowers are between 10 and 20 millions of dollars. The number of acres planted exceeds 5,000 and is constantly increasing.

The emphasis in these discussions of gladiolus diseases is on their control in commercial plantings. The commercial producer of corms has an obligation to sell only disease-free stocks, and the new inspection regulations imply official recognition of the fact that the amateur grower cannot be expected to be familiar with the numerous diseases of gladiolus nor to make diseased corms produce healthy plants. He will now have greater assurance of obtaining disease-free stocks when he purchases corms that have been certified by experienced state inspectors.

The natural resources of soil and climate are nowhere more favorable for the production of gladioli than in Michigan. By utilizing the information now available on disease prevention and by practicing approved methods of culture and insect control, the commercial grower can produce corms that will consistently meet the standards of certification and make Michigan-grown gladioli preeminent for freedom from disease.

DISEASES MOST ACTIVE IN THE FIELD

Fungous Diseases

FUSARIUM YELLOWS

(*Fusarium orthoceras* Woll. var. *gladioli* McCull.)

(Fig. 1, page 8)

Fusarium yellows is one of the major field diseases of gladiolus. It is less serious commercially now than it was 10 years ago because of the increased use of resistant varieties, but it remains a destructive disease in susceptible kinds. During a series of drought years, beginning in 1932, Fusarium yellows rapidly became the most important gladiolus disease in Michigan and in the other states where corm production is an important industry. The disease has been responsible, more than any other factor, for the virtual disappearance from the recent catalog lists of many excellent varieties because of their susceptibility to it.

Despite its very serious aspects, Fusarium yellows has had some beneficial effects upon the industry. More than any other disease, it has made growers conscious of the necessity for disease control and has resulted in improved cultural methods. Among breeders, it has stimulated efforts in the production of resistant varieties. As a consequence, more vigorous and more distantly related varieties are now being utilized in the breeding programs of the better hybridizers. Many new, resistant kinds are appearing in the variety lists, and these will increase as hybridizers use the most resistant parents in their breeding.

Effects on Growing Plants — In the field, plants affected with Fusarium yellows display a succession of symptoms that are typical of a systemic disease. Usually these symptoms first become visible with the onset of summer weather. This is because most Fusarium diseases of this type require comparatively high soil temperatures for rapid development. In Michigan, the first symptoms are usually not apparent until July, but if abnormally high temperatures prevail earlier, the first plantings, and especially those from infected corms, may show the effects in June. The disease develops most rapidly in plants produced by cormels or by the smaller sizes of corms, and in them may be seen its most typical and destructive effects.

The first noticeable effect of the disease on the growing plant is a slowing down or cessation of growth or of elongation of the leaves. This is accompanied, or quickly followed, by a localized or general diffuse blanching of the green color from the areas between the veins. Usually this yellowing is first confined to one section of the leaf, such as the tip or one side, but its progress is continuous, and eventually the entire leaf is affected. The yellow color gradually disappears, followed by browning and eventual death of the affected areas. At first only one leaf may show these symptoms, especially in somewhat resistant varieties, but in susceptible varieties the entire plant is finally affected. The rate of blanching depends upon the susceptibility of the variety and the seasonal conditions. In hot weather the disease progresses rapidly, and the most susceptible kinds are quickly killed.

In some varieties, the leaves are naturally thin and are not stiff enough to remain erect when the plant is attacked by the disease. The leaves of such plants eventually droop and finally lie partially or completely prostrate on the ground. Thicker leaves on other varieties usually stay erect even after they are killed. Dead leaves in contact with the soil disintegrate rapidly, and by digging time only vacant areas may mark the site where very susceptible kinds were killed early.

Yellowing leaves, followed by browning and death, are not invariably associated with Fusarium yellows since other diseases may cause similar effects. The symptoms of the disease are sometimes confused with those of Sclerotinia dry rot and Fusarium brown rot. A progressive yellowing of the leaves, however, is very characteristic of plants attacked by Fusarium yellows and is responsible for the name applied to the disease. These symptoms alone are ample cause for suspicion of the presence of this disease, but its effects upon the corm make identification more certain.

Effects on Corms and Roots — The examination of corms from a plant affected with Fusarium yellows will usually dispel uncertainty concerning the identity of the disease. If the corm is sectioned crosswise near the base, a brown discoloration of the core is usually present. In the early stage, this discoloration may extend upward but a short distance, but in more advanced stages the entire core is involved, and dark-colored streaks or arms extend laterally into the flesh. These discolored streaks are the infected fibrovascular bundles and are the channels through which the causal fungus progresses upward from the roots, where the initial infection usually occurs. If infected corms are planted, the initial infection is already established; consequently, the disease develops more rapidly, and the plant is destroyed earlier than are those whose roots become infected from contact with infested soil.

Pockets of decay may occur in the flesh of the corm, extending radially as tentacle-like areas from the infected core or originating as lateral extensions along diseased vascular bundles from the core to the nodes. The corms of very susceptible varieties may decay and disintegrate by digging time, leaving only a spongy or powdery mass of tissue to mark the site where they were planted.

The roots of diseased plants are infected, and the extent of damage varies from a scarcely noticeable browning of the fibrous roots to complete destruction of the root system. In plants killed by the disease, sometimes only brown, dead roots remain. The cortex or sheath of the tractile roots is usually rotted and may be easily sloughed off leaving an apparently sound, central core. Extensive root injury is always followed by conspicuous symptoms in the leaves.

Effect Upon Stored Corms – Corms infected with the Fusarium yellows fungus may continue to decay in storage. This decay can be caused by the Fusarium yellows fungus alone, or associated organisms may contribute to it. In seasons when unfavorable weather conditions prevent the corms from maturing normally and when they cannot be thoroughly cured soon after harvest, they are very susceptible to decay. If Fusarium-infected corms are placed in storage in an immature condition and contain an excessive amount of water, they may be destroyed very quickly. In some varieties, destruction of the core occurs with little or no involvement of the flesh, while in others the decay extends outward from the core and rapidly destroys the whole corm.

The role of secondary fungi in storage decay is not yet fully known. It usually seems that the initial infection is caused by the Fusarium yellows fungus. However, a core rot distinguishable by color and by the spongy texture of the decayed tissue is apparently caused by a fungus or fungi belonging to the blue-mold group. These fungi are usually present in decaying core tissue, but they are commonly sec-

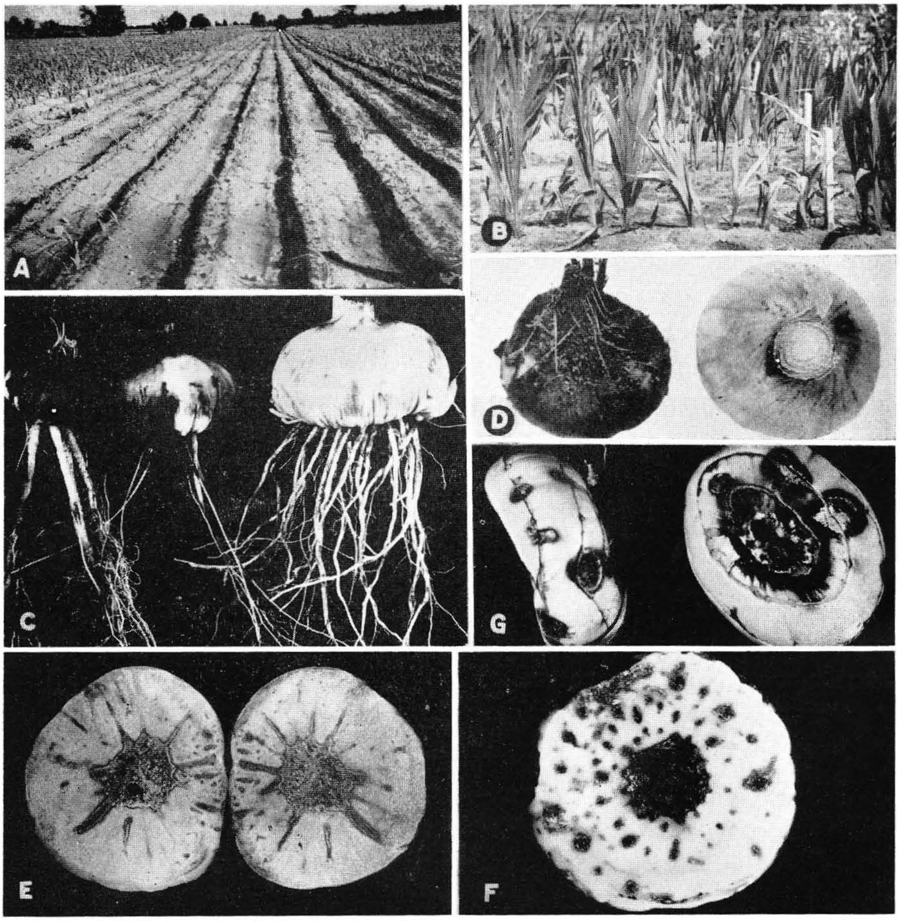


Fig. 1. Fusarium yellows of gladiolus. A—Thin stand and dead plants of a susceptible variety planted in infested soil; resistant varieties on either side. B—Dwarfed and dying plants affected with Fusarium yellows interspersed with normal plants of the same variety. C—Normal roots of variety Dr. F. E. Bennett (right) and diseased roots on plants of the same variety affected with Fusarium yellows. The cortical sheath has sloughed off leaving the central stele intact. D—Dark brown husk (left) on diseased corm of Dr. F. E. Bennett compared with normally light-colored husk on corm of healthy plant. E—Diseased corm of Dr. F. E. Bennett variety cut open to show the brown, rotted core and the diseased vascular bundles extending from the core to the surface. F—A diseased corm sectioned to show discoloration and decay of the vascular bundles. G—Decay visible at the nodes as a result of extension of infection in the core through the vascular bundles to the surface.

ondary invaders. Other forms of core rot result from mercury injury and from the Botrytis disease (see page 26). The various types of fungous core rots have not been clearly distinguished, but observations indicate that the initial infection is often caused by the Fusarium yellows fungus.

The color of the husks on infected corms is much darker than on normal ones, and the silvery luster or sheen characteristic of healthy husk tissue is lacking in those invaded by the Fusarium yellows fungus. Another characteristic of the disease is the firm adherence of the mother and daughter corms and the difficulty of separating them after they are cured. A portion of the mother corm usually remains attached to the core of the new one. After thorough curing, the new corms that fail to separate cleanly from the old ones can be easily sorted out.

Cause of the Disease – Fusarium yellows is caused by a soil-invading fungus belonging to the genus Fusarium. The fungus is a typical vascular parasite, that is, it invades the plant chiefly through the water-conducting tissues of roots, corm, and leaves and induces a generalized or systemic disease. It can subsist as a soil saprophyte for an indefinite time in the absence of the gladiolus plant. This persistence in the soil is a serious aspect of the Fusarium yellows disease because the presence of the fungus renders the soil unsafe for the growing of susceptible varieties.

Predisposing Conditions—Though soil and climatic conditions have a very marked influence upon the development of Fusarium yellows, the most important factor determining occurrence of the disease in infested soil is the relative susceptibility of the variety. Susceptibility ranges from none to complete. High soil temperatures accelerate the development of the disease, and its maximum destructiveness occurs in dry seasons with abnormally high soil temperatures. Conversely, sandy soils are more conducive to the occurrence of Fusarium yellows than are those more retentive of moisture since they are not so well buffered against rapid and extreme temperature changes. Early plantings contract less disease, because they are subjected to a much shorter period of high soil temperature and because root development is completed before soil temperatures reach the optimum for disease development. Nothing is known about the influence of soil reaction on infection, but the disease has been observed in both acid and alkaline soils.

1. **Control by Exclusion**—Gladiolus growers who have clean stocks, and whose fields are still free of the causal fungus, should take all pre-

cautions to exclude infected corms from their fields. Planting stocks should not be purchased indiscriminately, because Fusarium yellows is now established in virtually all sections of the country. Preferably, the fields of growers from whom stock is to be purchased should be visited in August or early September and the varieties inspected before the corms are harvested. Clean stocks of susceptible varieties may still be obtained from some growers, and the only method of maintaining these is to grow them in non-infested soil. Soils safe for the production of susceptible varieties should be maintained in that condition by following the best agricultural practices, including a suitable rotation of crops and annual treatment of all planting stocks with an effective fungicide.

2. **Chemical Control**—The fumigation of infested soil with Chloropicrin (tear gas) has been advocated as a control measure for Fusarium yellows. This treatment, because of its excessive cost and difficulty of application, has no practical value in the commercial control of this disease. It may be of some value in the eradication of the disease in small gardens, but even there it is doubtful if it will prove successful unless the material is applied by experienced workers. There is no practical method of eradicating the disease by chemical treatment of infested soil, and commercial growers should rely on other methods.

3. **Control by Protective Corm Treatments**—Corm treatments alone will not prevent infection by the Fusarium yellows fungus, but if all corms are treated annually with a suitable fungicide, the spread of the disease may be retarded and some protection of the new corms accomplished. It is not recommended that treated corms of susceptible varieties be planted in soils where the causal fungus is present. Some growers, however, who have infected stocks of some susceptible varieties may wish to attempt to clean up these varieties. The planting of infected corms on new soil will result in infestation of that soil with the fungus, but attempts to eradicate the disease from infected stocks must include the use of clean soil if they are to succeed. The method described is recommended as most likely to be effective. Use no corms larger than Number 4 for propagating purposes. Soak these small corms 2 hours in a 1-1000 solution of corrosive sublimate and then dip them for 1 minute in the calomel suspension (page 61). Plant this stock on clean soil and at harvest segregate and save all corms that have formed cormels freely. Repeat this treatment the following year with

the selected corms, using the cormels for planting stock. This method of propagating susceptible varieties is based on the observation that infected plants from corms smaller than Number 4 seldom form cormels. By segregating and using only corms that bear cormels freely, most of the infected ones can be eliminated in two seasons. This is essentially a method of indexing each corm for infection by observing cormel formation at harvest time. Since varieties vary greatly in their normal production of cormels, this should be considered in judging the increase in susceptible varieties treated by this method.

All planting stocks should be treated each season with a recommended fungicide. Calomel is especially suitable because it has a residual protective effect throughout the season.

4. **Biological Control** — See page 58 for discussion of soil management in relation to control of soil-borne disease.

5. **Genetic Control** — Effective control of Fusarium yellows is most practically achieved by the growing of resistant varieties. Early in the investigational work on this disease, it was observed that some varieties were very susceptible to yellows while others appeared to be unharmed. This led to extensive tests in soils infested with very pathogenic strains of the causal fungus. As a result of these tests, many varieties have been indexed for their reaction to the disease. These trials were conducted at East Lansing in cooperation with members of the Michigan Gladiolus Society and other interested growers. The war interrupted this work, but it was resumed in 1947. It is desirable to know the reactions of all important varieties. As soon as the corms of new and approved seedlings have been produced in quantities sufficient for commercial distribution and the variety has been named, it should be tested for resistance to disease. Gladiolus breeders are now much interested in producing disease-resistant seedlings. By selecting resistant parents for hybridization, the probability of obtaining resistant progeny is greatly increased. Breeders interested in the genealogy of the gladiolus should keep records of the parentage of new varieties and help compile a list of those notable for generating strong, resistant progenies.

In Table 1 are listed the varieties and species that have been tested for resistance. The newer varieties are inadequately represented because originators and growers have been very reluctant to submit corms of the newer and more expensive varieties for testing. Some of the best varieties are in the susceptible group and have practically disappeared from the catalog lists, owing very largely to their susceptibility to Fusarium yellows. Some have been replaced by resistant kinds that are as good as or better than their predecessors. As breeders use more resistant parents for hybridization, the new variety listings will contain increasing numbers of yellows-resistant seedlings.

TABLE 1—*Varieties and species of gladiolus resistant and susceptible to Fusarium yellows, tested at Michigan State College Experiment Station, 1937-47*

RESISTANT VARIETIES

Abe
Adelaide
Adonis
Aida
Albania
Alchemist
Allegro
Amelita Galli Curci
Angelica
Antione
Apricot Glow
Arabella
Baby Decorah
Badger Beauty
Bagdad
Barcarolle
Beacon
Bertha M. Buch
Berty Snow
Betsy Bob-up
Betty Brundage
Betty Nuthall
Bit of Heaven
Black Opal
Blaze
Bloomington Beauty
Bluet
Bonny Scotland
Bright Beauty
Brightside
Buffette
Butter Boy
Cadillac
Capeheart
Cara Mia
Charlemagne
Clarise
Copper Bronze
Coppersheen
Coronation
Creve Coeur
Curlette
C. V. R.
Dainty Queen
Dearborn
Debonair
Del Ray
Desert Dawn
Dream Pink
Dr. Moody
Duna
Early Dawn
Early Peach
Early Rose
Ellen Jacobson
Emile Aubrun
Ethel Cave Cole
Fair Angel
Firefly
Flaming Sword
Fluffy Ruffles
Frances M. Irwin
Francis Cartright
Frost King
Frost Pink Ornatus
Geheimrat Duisberg
Giant Nymph
Gilt Edge
Golden Cup
Golden Dream
Golden Frills
Golden Lancer
Golden Measure
Great Lakes
Helen Wills
Hildred
Honey Dew
Hopedale
Iosco
Irak
Isola Bella
Jalna
Janet
Jean Hoxie
Jeanie
Jewel
Jules Amott
Karl Volkert
King Glick
King Lear
King Tan
King's Ransom
Lady Marie
Lake Placid
La Fiesta
La Paloma
Lavender Ruffles
Leading Lady
Londonderry
Los Angeles
Lotus
Loyalty
Madeline Brown
Magna Blancha
Maid of Orleans
Margaret Beaton
Marion Louise
Marjorie Hatch
Marleen Hatch
Marmora
Marnia
Mauve Magic
Mazie
Mibloom
Milady Imogene
Ming Toy
Minnewashta
Minuet
Mme Von Konynenberg
Miss Bloomington
Miss Elegance
Miss Harriet
Montpelier
Morongo
Morsun
Mother Machree
Mr. W. H. Phipps
Mr. Wm. Cuthbertson
Mrs. Dr. Norton
Mrs. Leon Douglas
Mrs. Lulu Hunt
Nancy Hanks
Nippon
Oberon
Ogemaw
Olive Marie Brown
Orange Beauty
Orange Butterfly
Orange Delight
Orange Princess
Orange Queen
Oriental Pearl
Our Selection
Pastorale
Paul Grampel
Picardy
Prairie Gold
Primate
Primrose Princess
Primrose Queen
Princess Maria
Purple Supreme
Raquel
Red Phipps
Reflection
Reverie
Rewi Fallu
Rideau
Robert Shippie
Robert the First
Sandra
Seafoam
Senorita
Seventh Heaven
Silverado
Silver Wings
Smiling Maestro
Snow Baby
Snow Princess
So Big
Southern Cross
Souvenir
Spirit of St. Louis
Spotlight
Sunshine Girl
Surfside
Takina
Tangerine
The Moor
Tip Top
Treasure Gold
Tyrian Princess
Wampum
Wasaga
White Butterfly
White Gold
Yakima Apricot
Yellow Gold
Yellowstone

RESISTANT SPECIES

Gladiolus dracocephalus
Gladiolus primulinus
Gladiolus psittacinus
Gladiolus psittacinus var Hookeri

SUSCEPTIBLE VARIETIES

Airy Dream
Albatross
Allemania
Amador
America
Anna Eberius
Au-Gres
Ave Maria
Beauty Wave
Ben
Benedict
Betty Coed
Bill Sowden
Black Jack
Bleeding Heart
Blue Admiral
Blue Beauty
Blue Bizarre
Blue Domina
Blue Moon
Blue Wonder
Bob White
Cactus Rose
Cadence
Canberra
Captain Boynton
Charles Dickens
Chicago White
Christabel
Commander Koehl
Crimson Glow
Del Rosa
Dr. F. E. Bennett
Dr. Hoeg
Dream
Dream of Beauty
Early Dune
El Nathan
Ethylyn
Flame Nymph
Flor Rico
Frascati
Gold Eagle
Golden Chimes
Golden Goddess
Halley
Harvest Moon
Heavenly Blue
Helga
Henets Favorite
Highland Laddie
Honey
Jenny Lind
Jersey Cream
Joerg's White
Jonkheer Van Tets
Joyful
Kalamazoo
Kewpie
King Arthur
King George
Lansing
Lavender Delight
Le Marechal Foch
Lilac Glory
Lindsay
Louise
Mahogany
Major Edw. Bowes
Mammoth White
Margaret Fulton
Margaret Peter
Martha Dean
Mary Ansteen
Mary Elizabeth
Mary Shary
Maunga
Mildred Louise
Milford
Miss Alameda
Miss New Zealand
Moondara
Mrs. H. E. Bothin
Mrs. E. J. Heaton
Mrs. F. C. Hornberger
Mrs. Francis King
Mrs. T. J. Knudson
Mrs. Frank Pendleton
Mrs. F. C. Peters
Mrs. P. W. Sisson
Mrs. M. G. Wade
Mystic
Odin
Peace
Peggy Lou
Pelegrina
Pensacola
Pfitzer's Triumph
Phyllis McQuiston
Pinnacle
Polar Ice
Precious
Pride of Wanakah
Prince of Orange
Puck
Purple Classic
Purple Glory
Queen Louise
Queen of Bremen
Raysheen
Recovery
Red Cannon
Red Lory
Robert Burns
Roi d'Albert
Rosemaid
Rosemarie Pfitzer
Rudolph Serkin
Ruffled Gold
Rusty
Scarlano
Scarlet Wonder
Schwaben
Schwaben Girl
Sequoia Blue
Sheila
Shirley Temple
Sonny Boy
Sovereign
Splendorra
Star of Bethlehem
Star Prince
Streak of Butter
Sunrise
Sweetheart
Tasman
Tidbit
Tiffany
Trevonian
Unusual
Vagabond Prince
Vaughn's White
Virginia
War
White Spire
White Triumphator
Will Scarlet
Wurtembergia
Yellow Emperor
Yvonne

SUSCEPTIBLE SPECIES

Gladiolus alatus
Gladiolus callistus
Gladiolus cardinalis
Gladiolus carmineus
Gladiolus hirsutus
Gladiolus namaquensis
Gladiolus tristis
Gladiolus Watermeyeri

SCLEROTINIA DRY ROT

(*Sclerotinia gladioli* Drayt.)

(Fig. 2, page 15)

Sclerotinia dry rot is one of the major corm-borne diseases of gladiolus. It is present to some extent in practically all plantings and may become very destructive if ignored. It is markedly influenced by soil conditions, and as a result it increases rapidly in some seasons and decreases in others. Soil moisture is very important in its development, and in wet seasons it may increase to serious proportions. It is both a field and storage disease; plants may be killed in the field, or they may escape infection there and the corms become seriously infected in storage.

Field Effects—Young plants and those grown from cormels and the smaller sizes of corms are the most susceptible to dry rot. Infected plants, especially from small corms or cormels, show a progressive yellowing and dying of the leaves by midsummer somewhat similar to that caused by Fusarium yellows. A single plant or groups of young plants may yellow and die in the row, and all stages of yellowing and browning of the leaves can best be seen in plantings grown from the smaller corms. The causal fungus infects the leaves and stem at, or below, the soil line and causes a dry rot. It also attacks the roots, causing them to decay. There is no effect on the corm, however, comparable to that produced by the fungus of Fusarium yellows. The central core and the fibrovascular bundles that radiate from it in freshly dug corms usually show no discoloration such as that found in corms attacked by Fusarium yellows. In severely affected corms, some discoloration of the vascular bundles may develop in late stages of the disease.

Effects on Corms—In the early stages, small dry-rot lesions cannot be easily distinguished from those caused by scab but become more characteristic as they enlarge. At first the lesions are mere reddish-brown specks in the flesh, with a slightly elevated, darker border. As the spots enlarge, the centers become sunken and dark brown to black in color, but the edges are then slightly raised and a lighter color. The individual spots are usually round, but they may unite to form much larger, irregular lesions. The center of some lesions is covered with a gray, scab-like membrane. However, there is never any

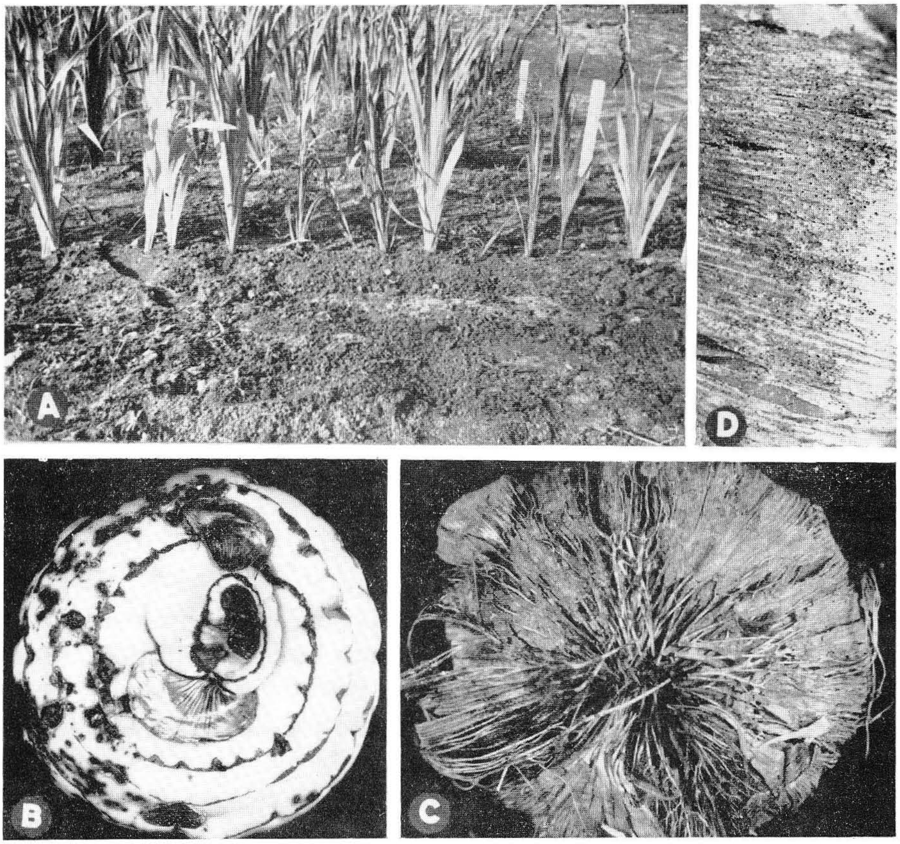


Fig. 2. Sclerotinia dry rot. A—Plants of variety Margaret Beaton killed by dry rot interspersed with healthy plants in the row. The disease was corm-borne and the attacked plants died at an early stage of growth. B—Small, reddish-brown dry-rot lesions with darker borders. They are not visible until the husks are removed and often are most numerous on the upper portion of the corm. C—Dry and shredded husks on a corm as a result of infection with the dry-rot fungus. D—A portion of infected husk (enlarged) to show the very small, numerous, black sclerotia of the dry-rot fungus (Sclerotinia gladioli).

shiny, varnish-like material associated with the lesions at any stage, and this character aids in distinguishing the disease from scab.

Effects on Husks – Dry-rot lesions are often apparent on the dried leaf bases or husks as tobacco-brown areas. Only isolated spots may show this discoloration, or the infection may be so general that the entire husk is much darker than normal. Infected husks are usually brittle and shred easily when handled. They also lack the silvery sheen characteristic of healthy husk tissue. The husk infections may be apparent at digging time although the flesh appears normal. Later, during the curing process or in storage, if the corms have not been thoroughly pre-cured, the infection extends to the flesh beneath. Removal of the husks frequently is necessary to reveal the lesions in the flesh. A lusterless appearance or the occurrence of brown stains on the husks may be signs of the presence of dry-rot lesions in the flesh beneath.

Very small, black, pimple-like bodies (sclerotia) are frequently formed in large numbers on the infected husks, on the corm lesions, and on the dead leaves and stems of plants attacked by dry rot. They are usually most numerous on the husks, just above their point of attachment to the corm, and on dead stems below the soil line. The sclerotia are resting bodies of the causal fungus, and they can withstand long periods of unfavorable conditions. They enable the fungus to live several years in the soil in the absence of the host plant. Their presence definitely identifies the disease as Sclerotinia dry rot.

Development in Storage — Corms may appear normal when dug and yet show heavy infection after they have been in storage for some time. Those harvested from soils infested with the dry-rot fungus and stored under moist conditions are likely to be seriously damaged and may be reduced to hard, dry mummies by spring. Browning of vascular tissue and small pockets of decay may develop in storage. It is especially hazardous to store corms that have not been thoroughly cured. An apparently sound crop at harvest may become badly diseased as a result of the subsequent development of the fungus during the storage period.

Predisposing Conditions — Dry rot is usually more prevalent in heavy soils and in those that are poorly drained. Excessive fall rains and warm soils result in increased amounts of dry rot. Failure to practice crop rotation leads to excessive amounts of the disease, since the causal fungus builds up rapidly in soil used continually for growing gladioli.

Control — Short rotations are not effective in freeing infested soil of the dry-rot fungus. The length of time it will persist in the soil in the absence of the host plant has not been definitely determined. The production of sclerotia on infected husks, leaves, and flowering stems provides the fungus with resistant, long-lived structures that assure survival in the soil when the host plant is absent. One instance has been observed of the fungus remaining in the soil for 10 years during which no gladioli were grown. Crop rotations to stimulate the germination of sclerotia and their subsequent disappearance have not been worked out, but such rotations are a possible method of freeing the soil of the fungus. Research of this type is needed, and the new field of biological control of plant disease is now receiving attention. (See page 58.)

Good soil drainage is very essential, and the utilization of sandy loam soils with a porous subsoil will give the best results in the production of corms free of dry rot. Rapid and thorough curing of the corms immediately after harvest will prevent the development of dry rot in storage. The use of artificial heat is recommended, especially in seasons when conditions are unfavorable for natural curing.

Corms treated with either calomel or yellow oxide of mercury and planted in well-drained, sandy soils will produce progeny free of dry rot, even though the parent corms are infected. No other fungicides yet tested have been as effective. All planting stock should be treated (see page 61 for details) with one of these materials and planted in soils free of the causal fungus. The liquid treatment is recommended, but cormels and the smallest corms can be dusted with the powder by shaking them in a paper sack containing just enough of the fungicide to coat them. The liquid treatment, however, is less costly.

BASAL DRY ROT

(*Fusarium* sp.)

(Fig. 3, page 18)

Basal dry rot is a comparatively new disease of gladiolus. It was first observed in Michigan in 1931 on corms of the variety Souvenir shipped from the Pacific coast. It has since been observed in other varieties.

Only the corms are affected, and the main effects of the disease are usually restricted to the first and second internodes. The lesions are visible when the corms are dug, and under favorable curing conditions they do not enlarge after harvest. They are irregular in outline and vary greatly in size. They rarely, if ever, extend deeper than 2 to 4 mm. into the flesh. The diseased tissue is hard, rough, usually somewhat scaly after the corms are dry, and is dark brown to black in color.

The affected area is sunken, and there is a sharp line of demarcation between the diseased and healthy tissues. Only a small portion of the first internode may be affected, or the diseased area may include all or portions of the first and second internodes with small lesions occurring occasionally on the third.

When diseased corms are planted, they may produce normal-

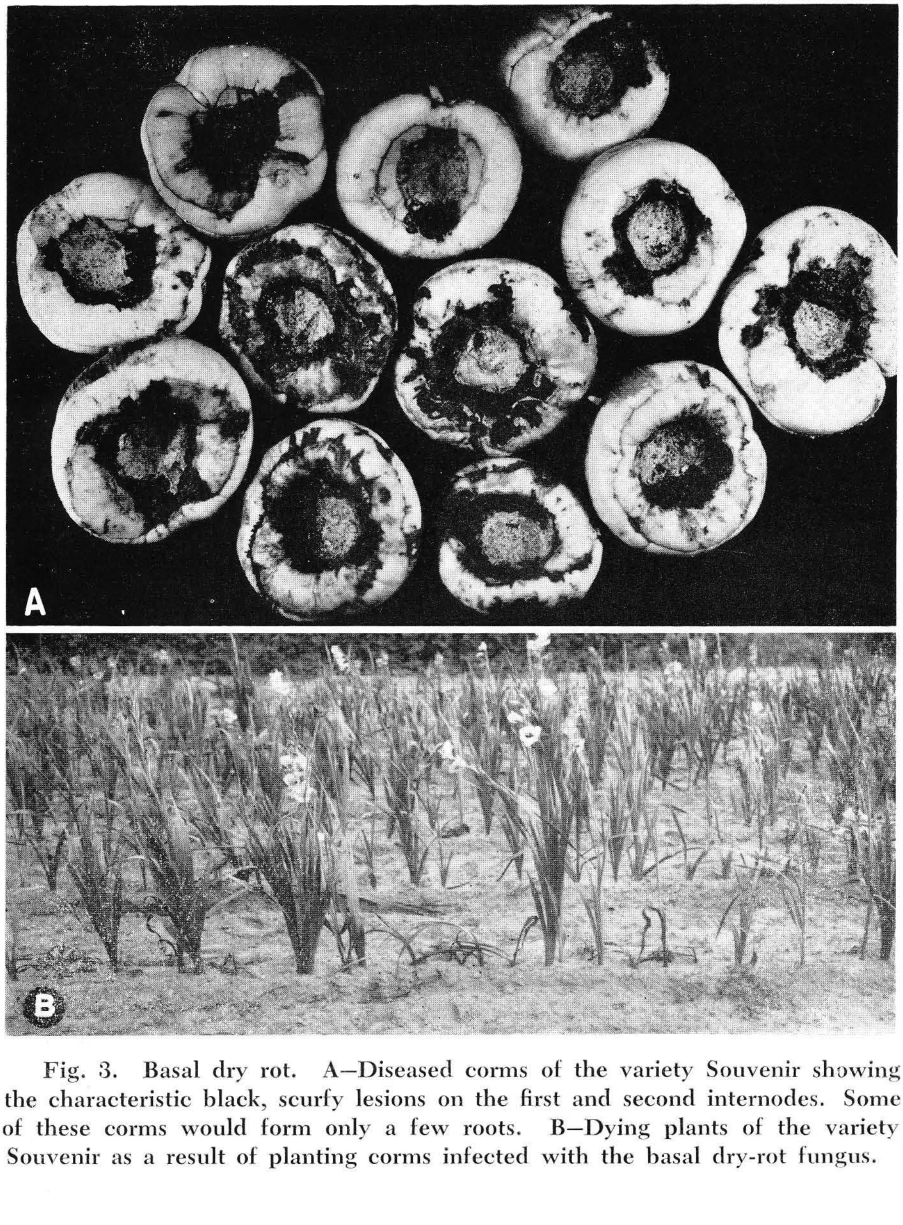


Fig. 3. Basal dry rot. A—Diseased corms of the variety Souvenir showing the characteristic black, scurfy lesions on the first and second internodes. Some of these corms would form only a few roots. B—Dying plants of the variety Souvenir as a result of planting corms infected with the basal dry-rot fungus.

appearing plants unless the root-forming tissues are largely or completely destroyed. If this has occurred, the shoots emerge and die from lack of root support. Poor stands follow the planting of badly infected stocks. Weak, slow-growing plants may arise from infected corms because the roots are too few to support normal growth. On the other hand, the effects of the disease on the growing plant may be so inconspicuous that its presence is unsuspected until the corms are harvested.

Control — The basal dry-rot fungus can persist for some time in the soil in the absence of gladioli, and it may be difficult to eliminate by short rotations. Precautions should be taken to prevent the introduction of the fungus into the soil from infected corms. Planting stocks should be scrutinized carefully, and if there is evidence that they are infected, they should be destroyed or treated either with calomel or yellow oxide of mercury (see page 61). These materials are highly effective in the control of this disease, and even badly diseased corms will produce clean progeny if treated. It should be remembered, however, that the planting of treated, diseased corms may result in the infestation of clean soil with the basal dry-rot fungus, and thus ultimately prove to be a very expensive practice. It is better to destroy visibly diseased corms and treat the others as a precautionary measure against the spread of the disease.

SEPTORIA LEAF SPOT AND CORM ROT (HARD ROT)

(*Septoria gladioli* Passer)

(Fig. 4, page 20)

As originally described, hard rot is a disease that attacks both leaves and corms of gladiolus. At one time it was reported as a major cause of loss in the eastern states. It has been observed in Michigan only on leaves, mainly on those produced by cormels or the smaller sizes of corms. The corm-rot phase, known as hard rot, is apparently not easily distinguished from the decay caused by the Sclerotinia dry-rot fungus, and this has led to considerable confusion. Although many corms suspected of infection with *Septoria gladioli* have been received for confirmation, none has been found infected with this fungus. Apparently the corm-rot stage of the disease does not occur frequently in Michigan.

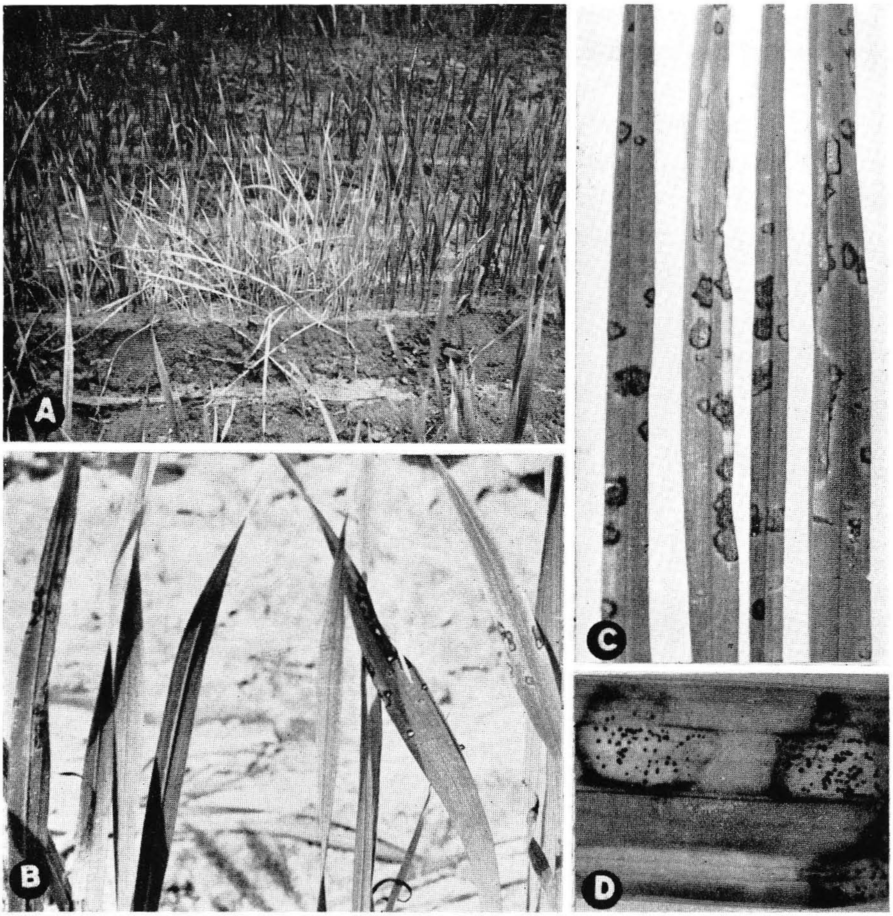


Fig. 4. Septoria leaf spot. A—A group of young plants grown from cormels and dying from infection with Septoria gladioli. B—Leaves of individual plants photographed at close range to show the characteristic type of Septoria lesion. C—Characteristic reddish-brown lesions with lighter centers with the pycnidial spore cases of the causal fungus visible in the centers of some spots. D—Septoria lesions enlarged to show the typical, black, spore cases. They contain thousands of spores which ooze out when the leaves are wet and are splashed to surrounding plants.

Effect on Leaves—On the leaves, the first symptoms of Septoria infection are small, brown or purple-brown spots that are almost circular in outline. They may be numerous, covering the entire leaf blade, or few and scattered. As the spots enlarge, the affected leaf tissue becomes darker and is finally dark brown with a lighter center. In the centers of the older, more mature spots, the lighter-colored area is dotted with small, black, pimple-like structures, the fruiting bodies of the causal fungus. They are specific for this disease and are a distinct aid in identifying this leaf spot. These structures contain thousands of spores of the fungus. During rains, they ooze to the surface and are splashed to surrounding plants, which thus become infected.

The mature Septoria lesions vary in shape. A single infection results in a circular spot, but infected areas of leaf tissue in close proximity merge and form larger and more irregularly shaped spots. The majority of the spots are elongated, because the leaf veins tend to restrict the extension of growth of the diseased area in a plane parallel to the long axis of the leaf.

Young plants in densely populated rows or beds are sometimes so extensively infected with Septoria that large numbers may be killed. Cormels and the smaller sizes of planting stock are sown thickly in the row, and the dense stands of the young plants make it easy for the fungus to spread rapidly in the row. The disease is more destructive in young plants because of this crowding and perhaps also because of greater susceptibility of the smaller leaves.

Effect on Corms — *Septoria gladioli* is reputed to cause a hard rot of the corm with characteristic sunken, irregularly-shaped, shallow, dark brown to black areas of decay. This phase of the disease has not been observed in Michigan, but it may occur and be confused with Sclerotinia dry rot. The Sclerotinia lesions on the corm frequently contain small, black, pimple-like bodies somewhat similar to those in the Septoria disease. They are microsclerotia with an entirely different function, but they can easily be mistaken for the spore cases of *Septoria gladioli* and thus be the cause for confusion of the two diseases.

Predisposing Conditions — Septoria leaf spot is primarily a wet-weather disease, since the causal fungus is disseminated by splashing water. It is of little importance in dry seasons. Conversely, it is likely to be most destructive in the wetter soils and may become very damaging to plantings watered with overhead sprinklers. It usually develops most rapidly in early summer in fast-growing leaves of young plants, especially when rainfall is above normal and temperatures are abnormally low. It is not checked, however, by higher temperatures if rainfall is abundant.

Control — A 2- to 3-year rotation is recommended to free the soil of the causal organism. It is unlikely that *Septoria gladioli* can maintain itself in the soil for very long without contact with the gladiolus plant. A 2-year rotation would probably eliminate it from sandy and sandy loam soils.

In the original experiments on control of this disease in New York State, corm treatments were of little value. Calomel and yellow oxide of mercury were not tested, however, and they may provide considerable protection to the new corm. These treatments are recommended in preference to others.

Fungicidal sprays and dusts have not been tested extensively for control of the leaf-spot phase but should afford good protection. The tolerance of gladiolus foliage for various fungicides has not been established, but bordeaux mixture has been injurious in some localities. For spraying, Dithane is recommended for trial, and for dusting, either Dithane Z-78 dust or the Cuprocide-sulfur combination.

STEMPHYLIUM LEAF BLIGHT (RED SPOT)

(*Stemphyllium* sp.)

(Color Plate I, centerspread insert)

Stemphylium leaf blight is one of the newer diseases of gladiolus. It has rapidly increased in importance and is rated in some sections as the chief disease of this plant. While it is not yet as widely distributed as some other major diseases of gladiolus, it has already caused serious damage in commercial and garden plantings in southern and eastern sections of the country. It has appeared in Michigan plantings but has not been destructive. Its rapid spread and destructiveness under favorable conditions makes it potentially one of the most serious of all gladiolus diseases.

This leaf blight was observed in Florida plantings as early as 1940 and has become increasingly destructive in that state and in fields in other southern states. It caused serious damage in New York and New Jersey in 1946 and again in 1947. Though observed earlier in those sections, it apparently had not caused much loss in commercial plantings since the first reports of serious injury followed the outbreaks in 1946. Affected plants were observed in Michigan in 1946 and 1947, but both seasons were unfavorable for the development and spread of the disease and there were no reports of serious damage in any fields. It seems probable, from our knowledge of similar diseases in other plants, that Stemphylium leaf blight will spread to most of the important gladiolus-producing sections of the country and that it will soon be a major leaf disease. Its appearance may be anticipated in all sections where climatic conditions are favorable for its development.

As its name implies, Stemphylium leaf blight is primarily a leaf disease, and it causes a very destructive blighting of the foliage. In the beginning, the typical lesions are merely round, yellow dots with a lighter-colored border. Because the leaf veins limit the expansion of the spot more in the horizontal plane than in the vertical, it tends to become elliptical in shape. The smallest spots are hardly more than 1 mm. in diameter and may occur in very large numbers. Two or more may merge to form much larger lesions, but the average size of the spot remains small in comparison with the lesions of some other leaf diseases of gladiolus. At a very early stage of development, a distinguishing character appears that makes identification of this leaf disease comparatively easy. *A crimson-colored dot or spot appears in the center of the lesion*, and its presence has given rise to the name "Red Spot". It is specific for this disease, and the occurrence of crimson dots in the centers of the small spots definitely distinguishes this leaf blight from all others. Though not all the spots on a leaf will show the crimson centers, they invariably occur where there are several or many lesions to be observed. Some spots are pale green with very small red centers, others are yellow or light brown and may attain a diameter of ½ inch where several spots merge. They normally occur in great numbers on the leaf blade, the flower stalks, and the bracts.

The development of numerous lesions on the leaves is followed by a progressive yellowing and withering of the foliage. The leaves usually begin to die back from the tips or along the margins, and this change envelops the leaf continuously until it is destroyed. The extent of the damage depends upon the number of spots that develop on a leaf Under epidemic conditions, unprotected plants are killed quickly by mass development of infections over the entire leaf area. Later, the dead leaves show blackened spots over their surfaces, they break over, and when in contact with the moist soil, they develop dark, olivaceous or brown, felty masses of the causal fungus bearing many spores. These spore masses are continually spreading the disease to adjacent or more distant plantings.

The most destructive outbreaks of Stemphylium leaf blight develop just preceding or at flowering time, although they may be delayed until after the flower spikes are cut. The crop may be completely ruined within a short time by rapid development under favorable conditions.

Conditions Favoring an Epidemic — Stemphylium leaf blight is most prevalent in moist weather, and dews and fogs are especially favorable for its rapid and destructive development. Summer showers are not likely to favor leaf infection as the gladiolus leaf is not easily wet by rain. Periods of high atmospheric humidity with warm days and cool nights favor its rapid development.

Control — No definite information is available on the effectiveness of spraying or dusting for the control of leaf blight. Where spraying has been tried, the initial applications were delayed until the disease was well established and consequently were less effective than earlier, preventive applications would be. It is likely that copper sprays will not be effective for control of this disease, since similar diseases on other plants have not been satisfactorily checked by copper fungicides. Laboratory screen tests indicate that some of the newer fungicides are more likely to prevent foliage infection by this leaf spot and the following are suggested for trial:

1) Puratized Agricultural Spray. Use 1 pint of 5-percent solution to 50 gallons of water, adding Triton 1956-B (½ pint to 100 gallons) or some other detergent to make the solution wet the leaves.

2) Dithane Z-78 or Spergon, 2 pounds to 100 gallons of water. A detergent must be added to facilitate wetting of the leaves.

3) Cuprocide-Sulfur-Talc Dust. This is an effective copper-sulfur dust combination for the control of many leaf diseases and is superior to other fungicidal dusts containing only copper and an inert filler. For best results, the finished dust should contain the following:

7 pounds yellow Cuprocide
30 pounds fine dusting sulfur
63 pounds alkaline talc (Loomkill)

Neutral or acid fillers are unsatisfactory, and alkaline talcs have been found essential for the most effective preservation and fungicidal efficiency of the dust. DDT may be added for the control of thrips and a proportion of 3 to 5 percent is effective.

4) Dithane Z-78; 6-percent dust.

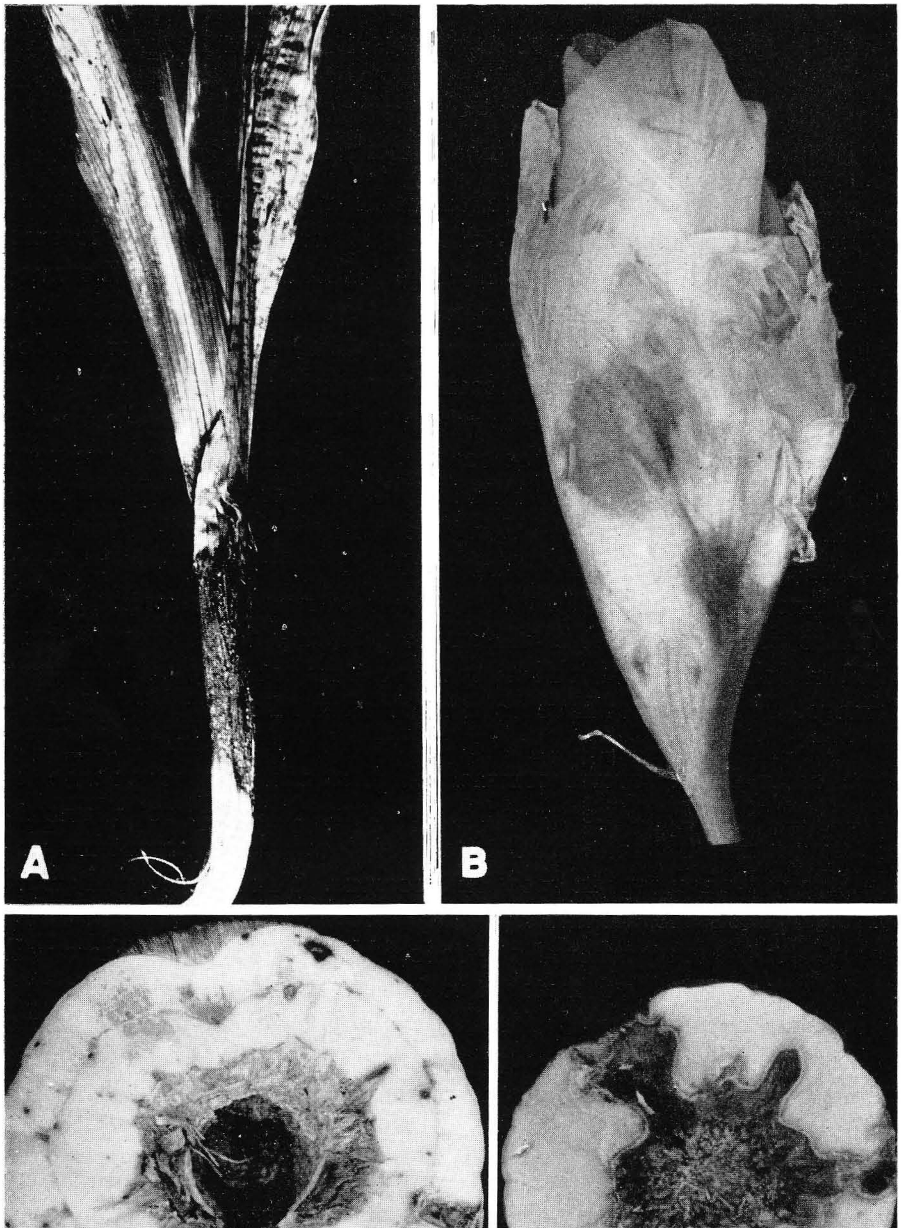
BOTRYTIS LEAF SPOT, STEM AND CORM ROT

(*Botrytis gladioli* Kleb.)

(Color Plate I, centerspread insert; Fig. 5, page 26)

Though the Botrytis disease of gladiolus was apparently under observation in England as early as 1927, it has only recently become important enough to command investigation in this country. Destructive outbreaks of the leaf-blight phase have occurred in southern and western states, where conditions are especially favorable for its development and where it has become a serious menace to gladiolus culture and especially to flower production. It occurs in the Pacific Northwest, especially along the coast, and in Florida it has been very destructive in many plantings. In 1945 the writer observed plantings ruined by the leaf-spot phase along the southern California coast, and at Christmas and through February flower spikes for sale in florist shops throughout the Los Angeles area were stripped of spotted leaves to make the spikes salable. Extensive plantings were seen in April 1947, in California in which leaf spot and stem rot were causing great damage. Isolated cases have been reported in Michigan, and, despite very unfavorable weather for its occurrence in 1947, infected plants were observed in several commercial plantings. Its occurrence in Michigan is likely to be sporadic, however, since the requirements of temperature and moisture for its widespread development are unlikely to prevail except in occasional seasons. Since large numbers of infected plants are continually being sent into Michigan and other states from the areas where Botrytis leaf blight is epidemic, there will be no lack of infectious material to initiate outbreaks when climatic conditions become favorable for the development of the disease. There are several phases of the Botrytis disease, including a leaf blight, a stem rot, and a corm rot, and each phase of the attack may be exceedingly destructive.

Effects on Growing Plants — When infected corms are planted, they may decay in the soil or produce shoots that yellow and die at an early stage. In this stage, the disease may be confused with Fusarium yellows. The planting of disease-free corms in Botrytis-infested soil may also be followed by decay and failure of shoots to appear, by emergence of the shoots and subsequent attack by the stem-rot phase, or even by normal development of the plant. The sequential develop-


A
B
C
D

ment following such a planting is dependent upon soil and weather conditions. If the shoots emerge and begin normal development, they are frequently attacked by stem rot and show the most conspicuous symptoms as they approach the flowering stage. Girdling cankers develop at or near the soil line and sometimes at the point of separation of the leaves. If the rot begins at or below the soil line, it progresses inward and finally rots the entire stem, with the result that the plant yellows and dies. If infection starts higher on the stem where the sheathing leaves separate, the rot progresses outward and downward, enveloping successive layers of leaves which turn yellow at the tip, then progressively downward to the point of activity of the fungus. The stem and leaves below the point of attack may remain green and normal in appearance.

Under moist, cool conditions, a gray mold develops over the surface of the diseased portions of the leaf and stem, and countless thousands of spores are matured to spread the disease to surrounding plants. In the rotted stem tissue, black or purplish-black sclerotia develop if moisture is adequate. At a late stage of development, the rotted stem tissue becomes fibrous and stringy, with all the tissue disintegrated except the more resistant fibers. Sclerotia are often intermingled with the mass of disintegrated tissue.

Effects on Leaves — The leaf-spot phase is the most conspicuous and destructive form of the Botrytis disease. The most ruinous outbreaks have occurred in plantings for cut flowers, where spotting of the leaves is objectionable because of the unsightly effect upon the entire spike. Clean foliage is a necessary attribute of a salable spike.

The leaves of attacked plants usually bear large numbers of small, brown, rounded spots, paler brown in the center and with a well-defined, darker margin. Merging of two or more spots results in larger, elongated, irregularly shaped lesions which are typically lighter in color at the center. There is usually a zone of pale-yellow tissue

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← Fig. 5. Botrytis blight. A—Stem-rot phase of the Botrytis disease, showing the typical dark-brown-to-black canker at or near the soil line. The stem is completely girdled. B—Botrytis infection on the petals of a white-flowered variety. The petal spotting developed in transit and was favored by the "sweating" that often occurs in unventilated packages. C—Core rot caused by Botrytis gladioli. The central core of the corm has been destroyed by a dry rot extending to the upper surface. The flesh is not involved. D—A brown, spongy, corm rot extending from the central core to the surrounding flesh. Such a rot eventually destroys the entire corm. It develops rapidly in immature or incompletely cured corms.

around the larger lesions, and, where infections are numerous and a large proportion of the leaf tissue is attacked, the leaf, or a portion of it, gradually turns yellow or brown and eventually dies. Botrytis leaf-blight lesions are distinguished by the light brown centers with darker margins in contrast with those of Stemphylium leaf blight, which are easily recognized by the presence of a red zone in the center. Neither should be confused with the Septoria leaf spot, where the lesions are brown with numerous black pimples visible in the gray or lighter brown centers.

Effects on Flowers — A serious phase of the Botrytis disease and one which sometimes develops in the field on open flowers, is the occurrence of brown, water-soaked spots on the petals. They are especially conspicuous on white and light-colored petals and buds. During the winter of 1947, certain light-colored varieties were boycotted on the Chicago market for a time while Botrytis blight was ruining those sent to market. The spotting developed in transit as a result of "sweating," which produced sufficient moisture for germination of the spores present on the buds and bracts when the flower spikes were packed for shipment. In the field, under very moist conditions, especially those resulting from dew or fog, the buds and petals may be attacked and quickly ruined by numerous infections. Infected petals fall to the soil where, in contact with moist earth, they continue to produce enormous numbers of spores which disseminate the fungus to surrounding plantings and also to distant fields. Gray masses of spores are also produced on petal, bud, and leaf lesions, and the appearance of spots covered with the spore masses and moldy surface growth of the fungus is responsible for the name "gray mold disease."

The Corm-Rot Phase—There are two or more distinguishable forms of Botrytis corm rot which are apparently caused by the same species of Botrytis responsible for the spotting of leaves and flowers. One form observed in Michigan on corms produced in the Pacific Northwest consists of sunken, rounded, straw-colored lesions with a darker margin which are not easily seen because they are hidden by the dried leaf bases. If arrested by rapid drying under warm conditions, this type of decay may be unseen until the husks are removed.

A second form of corm rot, which may be only a more advanced stage of the type just described, consists of a tan-colored, spongy decay in the flesh which finally may involve the entire corm in a soft, dark-brown rot. This type of rot may originate in the central core from which it spreads to the surrounding flesh. Typical "nests" or masses of gray mold with accompanying spores as well as sclerotia may be present. The sclerotia may be found as coralloid masses on top of the corm. This type of rot progresses very rapidly under moist storage or in transit where temperatures are likely to be most favorable for it.

The most commonly observed form of corm injury by Botrytis is a dry rot in which only the central core of the corm is involved. The surrounding flesh is usually unaffected. This type of core rot may originate from a rotting stem, in which case the progress of core destruction is downward. In other corms, the infection apparently begins at the base and progresses upward.

The dry type of core rot may be accompanied by destruction of the surrounding flesh with a spongy type of decay. Arms of decay extend outward from the core in a manner similar to those that develop in corms attacked by the Fusarium yellows disease. These varied forms of corm rot are apparently varietal responses to infection or, in some instances, they may be determined by the site where infection occurs. The course of the disease is noticeably influenced by moisture, and under very favorable conditions it progresses with great rapidity and reduces the corm to a spongy mass of rotted tissue. The rotted tissue becomes powdery on drying and sclerotia are often present in the more resistant portions of fibrous tissue that remain.

Conditions Favoring the Botrytis Disease — Excessively moist atmospheric conditions, accompanied by temperatures between 60° and 70° F., are ideal for the development of Botrytis. That is why the disease is so destructive during the winter and early spring months along the Pacific coast and in Florida. Temperature conditions are also most favorable at that time. Fogs or dews, which deposit fine droplets of water on the leaves, provide the ideal form of moisture for leaf infections. In the northern states, conditions in late spring and early summer may be the most favorable for the leaf-spot phase, since lower temperatures are likely to prevail then when the plants are especially susceptible.

The stem-rot phase also requires abundant moisture for development of infections on the stem. Excessive rainfall and water-logged soils are conditions favoring stem infections at the soil line, while moisture retained in the crotch where the sheathing leaves separate is required for the type of stem rot that develops at that point.

In storage, Botrytis corm decay will continue at temperatures too low for progression of other types of corm rots. Storage of corms at recommended temperatures will not completely check the growth of Botrytis in the moist flesh, and the storing of improperly cured corms is likely to be followed by heavy losses in those sections where this disease occurs. In transit, conditions are especially favorable for Botrytis rot because corms are frequently packed in unventilated cars with no provision for air movement around the packing containers. The shipping of corms in burlap bags and solid stowing in the cars have led to much decay both from Botrytis and Penicillium rots.

Control in the Field — 1) It is desirable to destroy all plant debris to remove as much infectious material as possible. This may be done by deep plowing immediately following harvest of flowers or corms. If Botrytis is active in the field while spikes are being cut, florets should not be allowed to mature and fall to the soil. Uncut flowers should be destroyed.

2) Protection of the plant can be accomplished with fungicidal sprays or dust. Preliminary laboratory tests have indicated that the following materials may be effective in areas where Botrytis is destructive to leaves and flowers:

a) Puratized Agricultural Spray, as for the Red Spot disease.

b) Fermate, 2 pounds to 100 gallons of water.

c) Dithane Z-78 or Parzate, zinc fungicides, at strengths recommended by the manufacturers, usually 2 pounds to 100 gallons.

d) Cuprocide-sulfur-talc or Dithane Z-78 dusts where dusting is preferred to spraying. Dusting may be as effective as spraying, since the dust will adhere readily to the foliage while sprays tend to run off or collect in large drops.

Supplementary Materials — It will be necessary to use an effective wetting agent with the sprays. Triton 1956-B or similar, commercial wetting agents are satisfactory. The gladiolus leaf is difficult to wet because of its waxy surface, and sprays tend to run off because of the upright position of the leaf. Only enough Triton or other wetting agents should be used to break the surface tension of the water since larger amounts will cause excessive runoff. The amounts to use will be determined by the condition of local water supplies. Excessively alkaline waters will require larger quantities of the wetting agent. Usually from ¼ to ½ pint per 100 gallons is sufficient, but larger quantities may be needed to obtain effective wetting of the leaf surfaces. Timely and thorough applications will be required to control both the Botrytis and Stemphylium leaf blights. Spraying should be begun before infections are evident and applications must be repeated at intervals sufficiently short to keep all growing parts of the plant covered. Usually applications at 7- to 8-day intervals are sufficient, but under very favorable conditions for the development of Botrytis and Stemphylium, closer spacing may be necessary. Prevention should be stressed in any program of control.

3) Corm Treatments – Infected corms should never be planted. To destroy surface-borne fungi like Botrytis, treat the corms as recommended for control of other corm-borne organisms.

Control in Storage – To prevent development of Botrytis rot in storage, all corms should be well cured. Removal of excess moisture by artificial heating is advisable. Thoroughly cured corms are unlikely to decay in storage at the usual temperatures, but immature or partially cured corms will be especially susceptible to attack by Botrytis.

BACTERIAL DISEASES

SCAB

(*Bacterium marginatum* McCull.)

(Fig. 6, page 32)

To growers, both amateur and commercial, scab in probably the most familiar of all gladiolus diseases because of its wide distribution and common occurrence in both garden and commercial plantings. It is chiefly a nuisance disease to the commercial grower, as it must be controlled because of its disfiguring effect which renders the corms unsuitable for sale. However, it causes little actual damage, and infected corms usually produce plants that flower as well as those that are scab-free. Though this disease is usually not difficult to control, commercial stocks are more commonly infected with it than with any other.

Effect on the Plant – Under wet conditions, and especially in heavy soils, the plant may be affected with a stem or neck rot that begins near the surface of the soil. This form of the disease occurs on the leaves as numerous, very small spots which enlarge and coalesce to

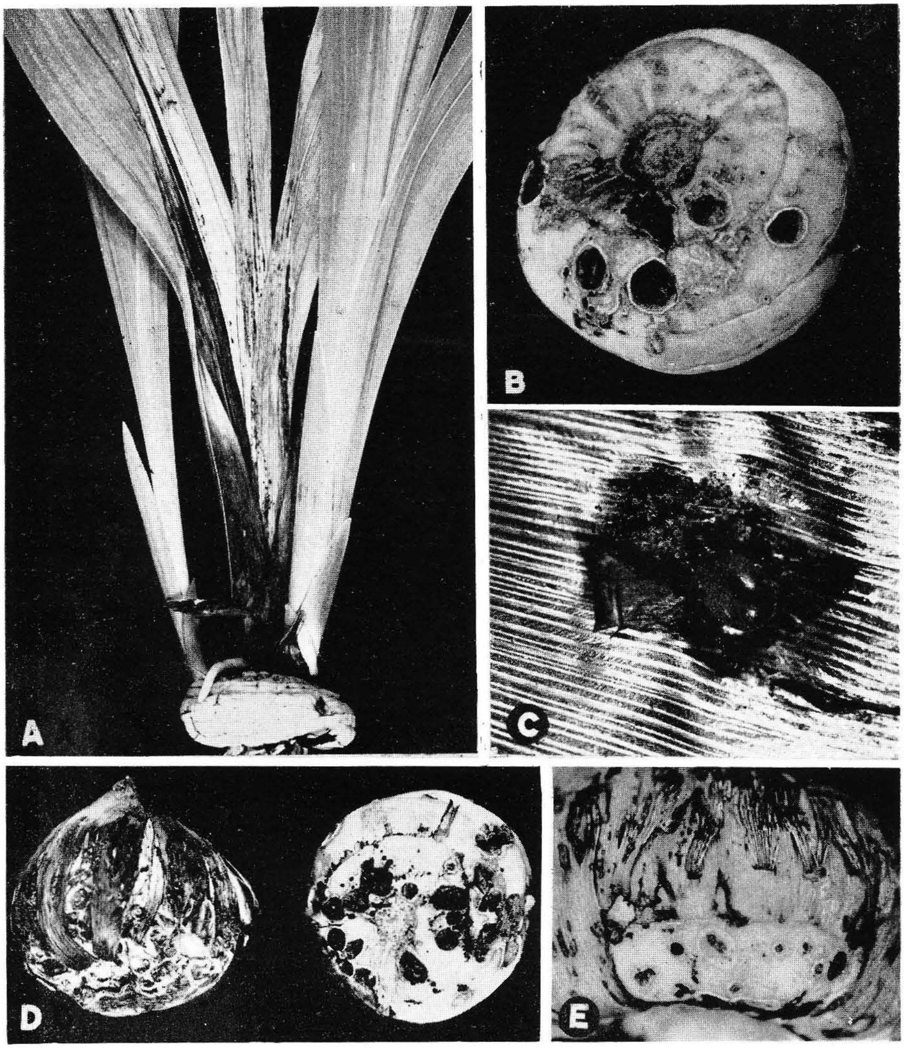
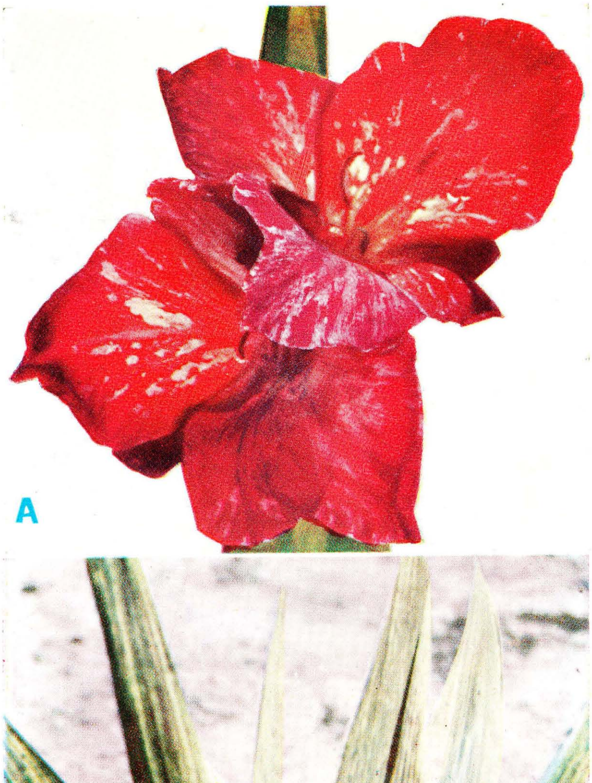


Fig. 6. Gladiolus scab. A—The neck-rot form of scab which sometimes develops under excessively wet soil conditions. B—Large, crater-like lesions, usually most numerous at the base of the corm. They are covered with a shiny, varnish-like ooze from the diseased tissue. C—A drop of bacterial ooze on the surface of a scab lesion. Note that the husk tissue is destroyed. D—The corm at the left shows the dark, shredded, diseased husk tissue and the one at the right the characteristically sunken effect of scab in the flesh. The lesions are elongated and carbonaceous and have eroded the husk tissue. E—Eroded husks and crater-like lesions in the flesh.

Color Plate I. Botrytis and Stemphylium leaf blights. A—Dark brown lesions with light brown centers which are characteristic of Botrytis leaf spot. Note that there are no black pimples in the lighter centers of the lesions like those that occur in the Septoria leaf-spot disease. B—Typical lesions of Stemphylium leaf blight showing the characteristic red centers which are responsible for the name "Red Spot".

Color Plate II. White-Break mosaic. A—Color transformation in the florets of variety Debonair as a result of infection with white-break virus. A normal flower is shown at the left for comparison. B—Color breaking in a spike of Picardy, normal spike at the right for comparison. The virus of white-break mosaic causes various effects in the flowers. Here streaking is evident in the unopened buds and there is hooding of the petals.



Color Plate III. White-Break mosaic. A—Color breaking in florets of variety Dr. Moody. This is the most commonly observed effect of white-break, and infected plants can be identified by these symptoms. B—White-break plant symptoms in the variety Picardy. A yellow-green specking or mottling is common in some varieties the season following infection with the white-break virus. In other varieties, foliage symptoms consist of gray specking, spotting, or mottling, or no leaf symptoms may be detectable.

form elongated lesions that become soft and watery in wet weather. These lesions occur most frequently near the bases of the leaves and may spread upward for several inches. Following this, the lesions turn yellow, then gradually brown, and the plant dies. This form of the disease, however, is of infrequent occurrence in well-drained soils.

Effect on Corms — On the corms, scab can easily be identified by the form of the characteristic lesions. These are usually circular, sunken spots with raised margins and are commonly most numerous at the base of the corm. They may be few or very numerous. If few, they are sometimes quite large and crater-like, forming deep holes in the flesh. The most characteristic feature of the corm lesion is the occurrence of a shiny, hard, varnish-like material over the surface, the result of an exudation of viscous material that hardens in contact with air. Its presence definitely proves the disease is scab. On some varieties, the scab lesions are somewhat corky, and if they are numerous, the surface of the corm is scaly or cork-like in texture and black in color. In such lesions the varnish-like exudate is often lacking, but some lesions can always be found in which the distinguishing hard and shiny exudate can be seen to make identification positive. Masses of soil may be glued to the corm as a result of contact with the sticky exudate.

On the dried leaf bases (husks), scab forms very characteristic spots. These lesions are dark brown to coal black, usually elongated in shape, and are erosive, that is, they eat out the husk tissue, leaving holes with a rough, carbonaceous margin. Infected husks are brittle and are easily broken in handling.

Predisposing Factors — Soil and climatic conditions have a very marked effect upon the occurrence of scab each season. Like most bacterial diseases, it is dependent upon water for dispersal and on suitable environmental conditions in the soil for corm or stem infection. The disease is more prevalent in wet seasons and in heavily watered soils; consequently, it is likely to be more troublesome in poorly-drained, heavy soils. There is no definite experimental evidence that it is more prevalent in alkaline soils, although heavy applications of stable manure seem to cause an increase of the disease and make treatments less effective. It is markedly influenced by some soil factor that is not yet understood, since, in our experiments, control has been easy in one locality, while in another, with apparently very similar soils, all treatments have failed to reduce the disease and, in fact, have increased it. This phenomenon is probably attributable to some biological cause, as well as to chemical differences in soils. The scab organism survives at least 1 year in the soil, and cultural practices which do not include suitable rotations will usually be followed by increasing amounts of the disease.

Control – Corm treatments, in conjunction with crop rotation, usually provide effective control of scab. Corm treatments alone are not always effective. Well-drained soils, preferably sandy loams, are most suitable for the culture of gladiolus in Michigan. It is most important that the subsurface drainage be adequate to facilitate rapid removal of surface water. Water should never accumulate or stagnate around the corms. Gravelly subsoils provide the best type of drainage. In well-drained soils, the planting of untreated, scabby corms is often followed by a harvest of scab-free progeny, while the most effective corm treatments may not reduce the disease in soils highly retentive of water.

Though corm treatments alone cannot be relied upon to control scab, they are an indispensable part of the program for the production of disease-free stocks. No fungicidal treatment will be effective in destroying organisms that have penetrated the flesh of the corm, but surface disinfestation may be accomplished by soaking and dipping treatments with various fungicides.

Mercury compounds have been the most effective materials for the control of scab, and maximum protection is obtained by their use. Corrosive sublimate in a 1-1,000 concentration is the most widely used corm-treating solution. The unhusked corms are soaked for 2 hours in this solution just before planting. Longer soaking is likely to cause injury, especially to early-flowering varieties which have sprouted slightly before treatment (see page 60 for details of treatment).

Some growers prefer to treat with calomel instead of with corrosive sublimate, since the treatment time is much shorter. It is employed as a 1-minute dip just before planting and has the advantage of uniformity because it does not lose strength as does the corrosive-sublimate solution (for directions on preparation and use, see page 60).

In some soils, mercury compounds are ineffective in reducing the amount of scab and, in fact, seem to increase it. The cause of this is unknown, but it may be due to the effect of such compounds upon the microbiological balance in the soil. Mercury is selective in its effect upon soil organisms, and it may inactivate or destroy those that are antagonistic to the scab organism in soils where the mercury compounds are ineffectual. Such effects are probably not uncommon and, in fact, may be of greater importance than heretofore realized.

If animal manures are used, they should be applied to a crop preceding gladioli, since corm treatments are less effective in freshly manured soils.

BACTERIAL BLIGHT

(*Bacterium gummisudans* McCull.)

(Fig. 7, page 36)

This bacterial leaf blight is sometimes important in commercial plantings. It was described in 1924 from observations on its occurrence in Michigan in 1922 and 1923. It has not subsequently been reported as the cause of serious damage in this state, but it makes sporadic appearances in favorable seasons. It was observed in more than usual amounts in 1939 and 1940, and it is not unusual to find infected plants in commercial plantings in seasons of normal or excessive rainfall. It produces very conspicuous effects upon the leaves and may be destructive to the foliage in irrigated fields or in abnormally wet seasons.

Bacterial blight is most important in planting stocks because the close spacing of the plants results in a more rapid spread of the disease. Plants from larger corms are also susceptible, but the disease is observed less frequently in plantings for flower production.

In early stages of the disease, the spots are small, elongated and water-soaked, which makes them dark green in color. They usually are in the form of squares or rectangles between the veins. Single spots unite to form larger ones, and when rain is abundant the whole leaf may be covered with the lesions. Later they turn various shades of brown or purple, and when the leaf tissue is dead the foliage of the plant appears to have been scorched. When the infections are numerous, the leaf may be partially or completely killed by midsummer.

A gummy exudate flows freely from the lesions and accumulates over them in the form of cream-colored drops which are firm when dry. The exudate consists of masses of the causal bacteria mixed with disintegration products of the diseased leaf tissue. It dissolves readily in water, and splashing rain or irrigation water carries the bacteria to

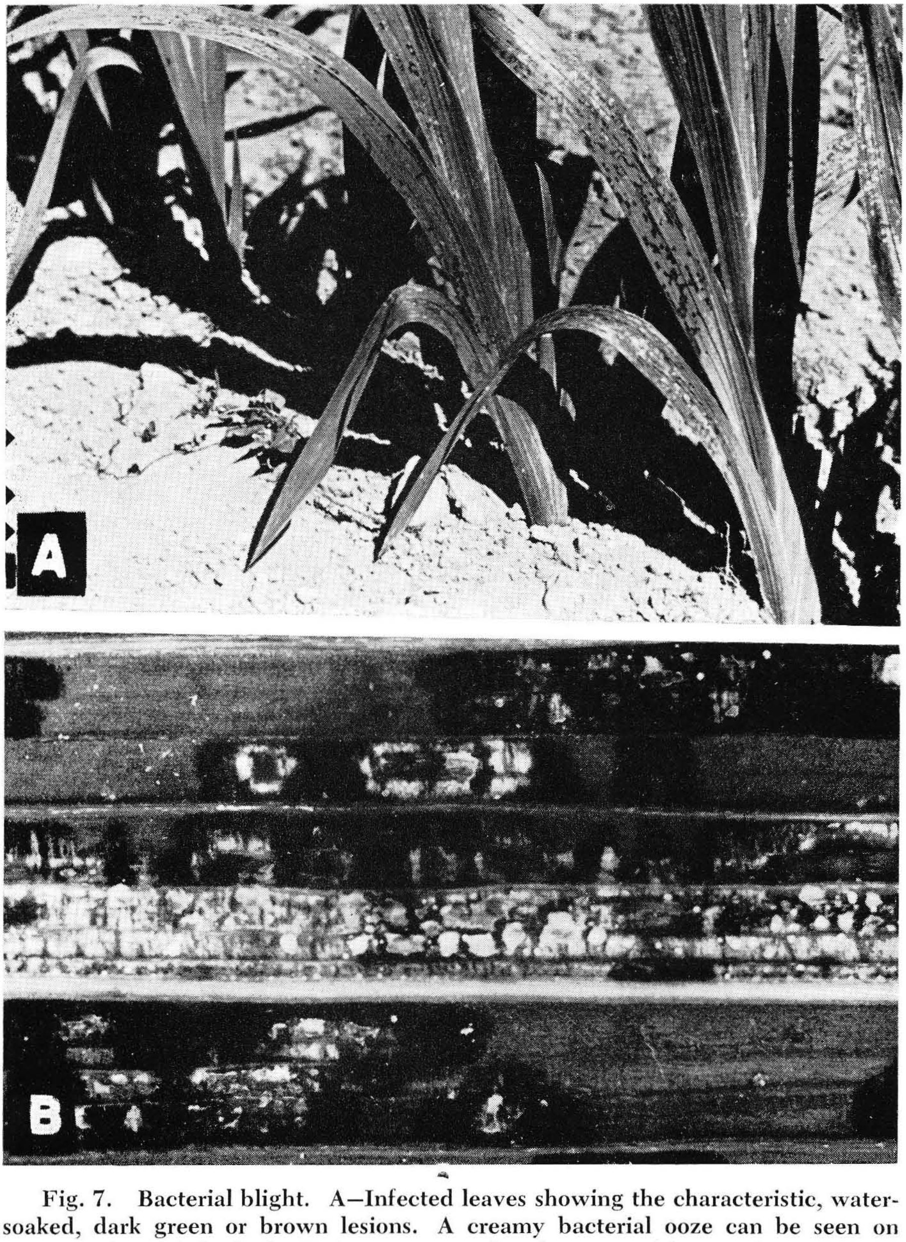


Fig. 7. Bacterial blight. A—Infected leaves showing the characteristic, water-soaked, dark green or brown lesions. A creamy bacterial ooze can be seen on some portions of the leaf. B—Dry, cream-colored masses of bacterial ooze on the lesions of bacterial blight (enlarged).

other leaves, where they enter the stomata and establish new infections. Water is the most important local disseminating agent, but insects may carry the bacteria to distant plants.

The disease is corm-borne from infections in the husks and flesh. This has been proved by planting untreated corms in soils where previously no gladioli have been grown. Small, dark-brown lesions, superficially resembling those of scab, have been observed on the corms of affected plants.

Predisposing Factors — Since water is the chief disseminating agent of the bacteria, wet weather, or water applied from overhead sprinkling lines, provides the most favorable conditions for the disease. Poorly drained or heavy soils are most likely to be suitable sites for outbreaks of bacterial blight.

Control — Corm treatments, as recommended for the control of scab, crop rotations, and selection of suitable planting sites, including well-drained soils, are the most effective measures for the prevention of leaf blight.

VIRUS DISEASES

The virus diseases of gladiolus have not yet been clearly differentiated. Two diseases of the mosaic type have been identified, but much more information concerning them is needed. No virus disease comparable in importance to some that occur on other economic plants has been observed in gladiolus, and this is rather remarkable in a plant that is propagated by vegetative methods. It is not to be anticipated that a plant so widely and intensively cultivated as the gladiolus will indefinitely remain free from serious virus diseases. Already there is an apparent increase in the incidence of white-break mosaic in commercial stocks, and this may mark the beginning of a new phase of culture when virus diseases will be of major concern to commercial growers. Growers should now be familiar with the two types of mosaic disease in gladiolus so that there will be less confusion concerning their differentiation and so that the regulations governing the certification of stocks infected with them will be enforced.

TYPE I – MILD MOSAIC

(Fig. 8, page 39)

This disease is now believed to be present in most of the older varieties of gladiolus and to cause comparatively little injury. Symptoms are visible in young plants of many varieties, especially early in the spring when temperatures are favorable for their expression. In the leaves, there is a mottling or striping with alternating lighter and darker shades of green which gives a mosaic appearance to the tissue in which it occurs. It may be more conspicuous on the flower stem of some varieties and is also visible on the buds and expanded bracts. By midsummer, the foliage symptoms may have disappeared, since high temperatures cause a masking of the most noticeable effects in the leaves. The mosaic mottling is most conspicuous on plants grown under glass where temperatures can be maintained at levels most effective for development of the typical mosaic effects.

The effect of mild mosaic in the flowers is detectable as a light striping or penciling of color on the petals. This is so general in most varieties of gladiolus that growers commonly regard it as a non-pathological, heritable trait. Seedlings free from mosaic infection do not display this color pattern, but they develop it after they are grown in proximity to established varieties. The effect of mild mosaic on the flowers is not especially objectionable, and it is doubtful that it detracts from the beauty of the variety.

Mild mosaic causes no pronounced dwarfing of the plant, although in some varieties where the leaf symptoms are especially prominent it is reasonable to believe that the infection is the cause of some reduction in the size of the plant. In most varieties, however, the general effect of the disease is not debilitating, and they do not seem to deteriorate from year to year. This is in marked contrast to the reaction of plants infected with the virus of white-break mosaic.

The mild mosaic virus is insect-borne and is carried from plant to plant by various species of aphids. The same virus causes a destructive yellow-mosaic disease in beans and also a similar disease in clover and other legumes. Plantings of gladiolus adjacent to bean or clover fields may be subjected to heavy inoculation with the virus as a result of insect migrations. Disease-free seedlings may readily acquire the virus if planted close to bean or clover fields, and, in fact, may contract the disease by insect inoculation when far removed from cultivated

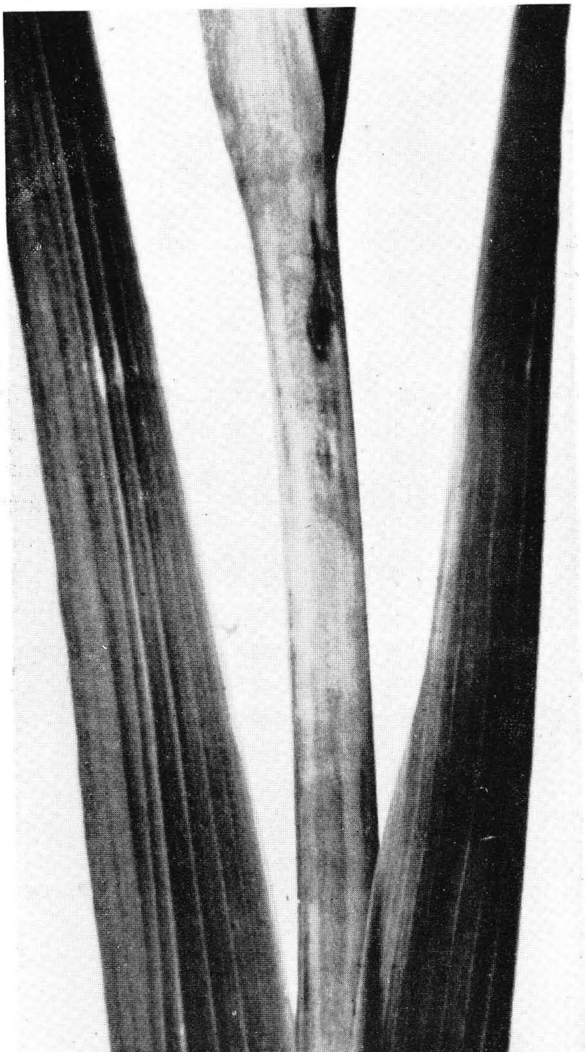


Fig. 8. Mild mosaic. A greenish-yellow mosaic mottling is visible in the flower stem, mostly as elongated stripes. It occurs commonly in the leaves also and is most readily detected in early summer when rapid growth is occurring and before air temperatures become high enough to cause symptoms to disappear.

crops. It has been suggested that plantings of gladiolus be kept away from bean and other legume fields. The emphasis is probably in the wrong place because the virus is a greater menace to beans than to gladioli, as it causes a very destructive disease in the former. Since most, if not all, the common varieties of gladiolus are infected with the mild mosaic virus, the planting of beans in close proximity to gladiolus fields is a procedure likely to result in considerable injury to the bean crop, especially if the season is favorable for the multiplication of aphids.

The virus of mild mosaic is corm-borne, and once a plant becomes infected it carries the virus in the corm each season. No method of eradication is known, and a seedling once infected remains a carrier throughout its existence. However, the virus is not transmitted through seed, and seeds from infected bean plants give rise to normal, healthy plants. Usually, however, the bean plant is so seriously affected by the presence of the virus that seed production is strongly inhibited.

Whether the presence of the mild mosaic virus in a variety is essential for the expression of white-break mosaic symptoms is not known. Infection with two viruses is a requirement for color breaking in some other plants, and future investigations may demonstrate that the mild mosaic virus in gladiolus is only one entity of a complex that requires another virus for manifestation of white-break symptoms. This can only be determined when methods have been developed for transmitting the white-break disease from plant to plant. If the mild mosaic virus is one of an association of viruses that cause the white-break disease, its importance would be much greater than is now postulated.

TYPE II – WHITE-BREAK MOSAIC

(Color plates II, III, centerspread insert; Fig. 9, page 41)

This virus disease has been recorded in Australia, England, Canada, and the United States. It undoubtedly occurs wherever the gladiolus is grown and is the only serious virus disease reported in this plant. Though conclusive proof of the virus nature of the disease is still lacking because of the difficulties encountered in transmission studies, there is little doubt that it belongs in the group of mosaic diseases of the color-breaking type. It has recently been increasing in commercial plantings and has caused serious damage to some varieties. As a corm-

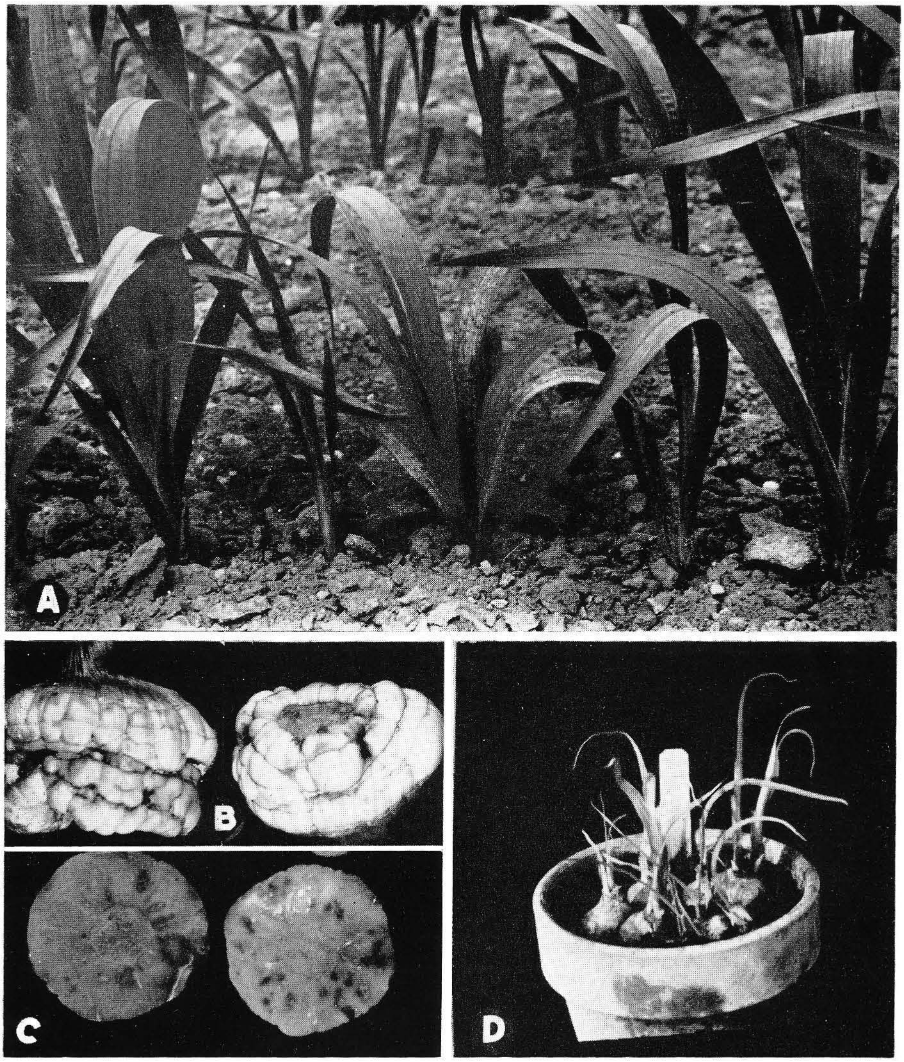


Fig. 9. White-Break mosaic. A—Three dwarfed plants between two healthy plants of the variety Debonair. The dwarfing is the result of infection with the white-break virus. The central plant shows a conspicuous gray spotting in the leaves which is characteristic of the white-break mosaic disease. It is rarely seen in first-year infections. B—Warty corms from Debonair plants infected with white-break. The corms may be variously misshapen or malformed. C—A warty corm sectioned to show internal necrosis as small pockets of degenerating tissue. D—Weak, spindly shoots arising from warty corms of the variety Debonair. This is the final stage of the disease, since no corms are formed to perpetuate the plant.

borne disease, white-break is being widely disseminated in uncertified planting stocks.

Effect on Leaves — White-break symptoms cannot always be detected in the leaves of affected plants, especially during the season when the plants become infected. When present, the leaf symptoms consist of a definite gray or yellowish-green streaking, spotting, or specking, which in some varieties may easily be confused with thrips injury. The mottling is unlike that caused by the mild mosaic virus; it is much more definite and conspicuous and is less affected by temperature. In most varieties in which plant symptoms have been observed, the usual effect is a gray spotting that is also unlike typical mosaic symptoms in other plants. The individual gray or yellowish-green spots are small and very numerous, often involving the entire blade. In other varieties, a distinct yellow streaking occurs, and the green color may disappear entirely from portions of the leaf.

Plants that contract white-break seldom show the effects in the leaves until the season following infection, and not always then. Usually, however, they can be detected in the row by their smaller size and by other symptoms. Some varieties quickly run out because of the rapid debilitating effects of the disease, the plants becoming progressively smaller until they no longer produce viable corms. Some varieties, however, have been observed to show little reduction in vigor for 2 or 3 years following infection. The dwarfing effects of the disease appear to be related to the intensity of foliage symptoms, and, in plants that show such symptoms, the reduction in vigor of the plant is proportional to the extent of the leaf injury. Where no foliage symptoms are evident, white-break can be diagnosed by its effects on the flowers.

Effects on Flowers — The most striking and characteristic effects of white-break mosaic can be seen in the flowers. The symptoms are not uniform, since varieties react differently to the infection. Three types of change in the floret color have been observed and others may be detected when a wider range of varieties is studied. Those observed appear to be fundamental and can be seen in most collections of varieties where the disease is active.

1. **Color Breaking** — Color breaking in the florets is the most constant symptom of white-break mosaic and is displayed by more varieties than are the other types of floret change. The intensity of the

color break varies. This may possibly be due to infection with different strains of the virus, since this variable intensity has been observed in different plants of the same variety. There is other evidence for the existence of strains of the virus, such as qualitatively different symptoms in plants of the same variety. Color breaking of the most common type consists of spotting or streaking of the florets with a design of gray or yellowish-green spots dispersed without any seeming pattern of regularity in the ground petal color. This is shown clearly in the reaction of the variety Dr. Moody illustrated in color plate III—A. The broken color is always lighter than the normal color and is usually white, light gray, or a light shade of green or yellow-green.

2. **Color Transformation** — A very striking change in color of the florets occurs in some varieties when they are infected with the white-break mosaic virus. The reaction of the variety Debonair, illustrated in color plate II—A, is typical of this change. Normally, Debonair is pink, but this color is replaced by a dull, indeterminate shade of purple in the florets of infected plants. In this variety, the color transformation is accompanied by changes in petal texture — they become thicker, coarser, and somewhat ruffled, with a tendency toward hoodiness. The florets open only partially and are often twisted or otherwise deformed. They are also greatly reduced in size. The writer once saw an entire planting of Debonair in which every plant displayed symptoms of this nature. It is not surprising that some growers who note the sudden appearance of such a remarkable color change in a variety should suspect that it is due to hereditary influence. The suggestion has been made that some varieties whose origin has been attributed to a mutational change were in reality plants that became infected with the white-break virus. There is no proof of this, but certainly one unfamiliar with the symptoms of white-break in the flower could be excused for mistaking color change in a variety like Debonair for an example of a mutation.

3. **Color Degradation** — A third floret change that occurs in other varieties affected with white-break is a degrading of the normal petal color to a lighter hue. This is illustrated by the variety Picardy shown in color plate II—B. It is true that the color normally fades quickly in the florets of some varieties but fading occurs more rapidly in plants attacked by mosaic, and even the opening buds on plants infected with mosaic are lighter than those on mosaic-free plants. This indicates that a fundamental degrading of color results from this virus infection,

though normal fading may accentuate the lightness of the hue after floration is complete. That color degradation is not a uniform effect is shown by the reaction of many varieties in which there is no evidence of change in the intensity of the floret color even though it shows strong color breaking.

4. **Other Flower Effects** — Florets on plants affected by mosaic are usually considerably reduced in size and may be ruffled, twisted, warted, or deformed in other ways. They often open more slowly and less completely and show the effects of aging much more rapidly than florets on mosaic-free plants of the same variety.

Effect on Corms — In some varieties, the corms from plants infected with mosaic show a peculiar, warty condition that makes them asymmetrical and also causes malformation. Such corms may be deeply constricted at the nodes, especially the lower ones, and this divides the corm into unequal segments. Sometimes the enlargement of the corm is impeded more in one section than in another, as though the effects of virus infection were more intense in one portion of the corm, and this results in marked asymmetry. Corms from such plants may be abnormally elongated.

The development of warty corms is apparently uncommon since they are seldom observed. It is suggested that different strains of the white-break virus may cause different reactions, or still another explanation is that different associations of viruses may be responsible for the various types of changes observed. Settlement of these questions awaits development of methods for transmitting the virus from plant to plant.

When planted, the warty corms produce weak, spindly or grassy shoots that usually fail to form progeny, and the plant dies. The shoots from such corms are often curled or twisted and sometimes display typical spotting that is characteristic of white-break leaf symptoms.

Insect Relationships — Definite evidence concerning spread of white-break mosaic in the field has been obtained in experimental plantings. The disease has been observed to spread rapidly from diseased to healthy plants in some seasons. The rate of increase of white-break in a variety with a low initial percentage of infected corms is faster than can be accounted for by normal vegetative propagation. Plantings have been observed in which the disease increased so rapidly that some varieties were ruined in two seasons. Though no definite proof of insect transmission has been obtained in controlled experiments, all the circumstantial evidence indicates that they are the active carriers of the virus. In other bulbous plants, aphids have been shown to be the vectors of some mosaic viruses, but no success has been obtained in transmission tests with several species collected from gladiolus plants naturally infested in the field. Neither has the virus been transmitted by the gladiolus thrips.

Control of White-Break — All plants displaying foliage symptoms of white-break should be removed and destroyed as soon as they can be detected. Newly infected plants displaying only flower symptoms sometimes, though not always, show foliage symptoms the following year. Inspection at flowering time is the surest method of detecting diseased plants. In fields intended for certification, where only one inspection can be made, it should be done while the plants are flowering.

The writer's experience with this disease has demonstrated that thorough roguing for two or three seasons will reduce white-break infections to low levels. Persistent removal of all diseased plants is the only method now known that will keep white-break below the level required for certification. Failure to rogue out infected plants will soon lead to excessive amounts of disease in susceptible varieties. Little is yet known about the comparative susceptibility of varieties, but the disease has been observed in many of the commercial varieties in a wide range of colors.

DISEASES OF UNDETERMINED CAUSE

INK SPOT

(Fig. 10, page 46)

Ink spot is a blemish disease that apparently affects only the corm. Dark gray to black stained areas occur on the dried leaf bases, sometimes accompanied by a superficial decay in the flesh at the point of attachment of the stained section of the leaf base to the corm. The discolored areas are usually circular in outline and vary in size from a few millimeters in diameter to spots more than an inch wide. They occur most commonly on the upper half of the corm but are not restricted to any portion. All sizes are affected, from the smallest cormels to the largest corms. The stained portion of the husk is brittle and on some varieties is almost carbonaceous. When the flesh is

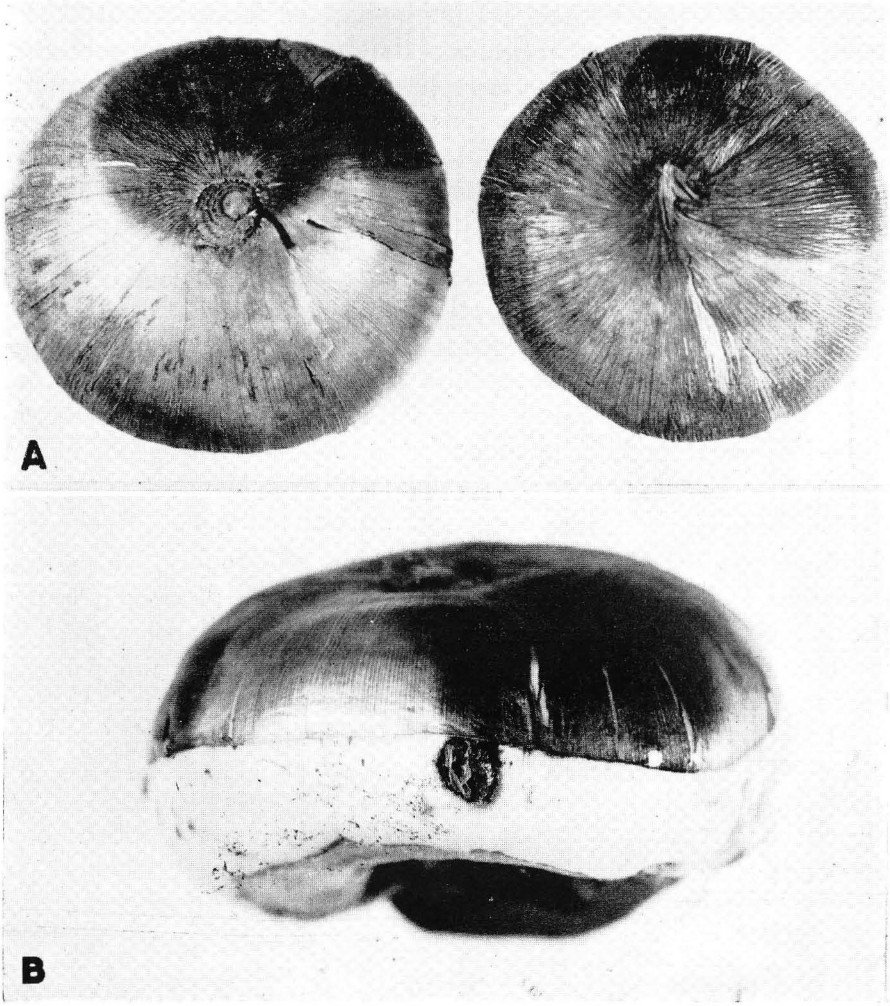


Fig. 10. Ink spot. A—Large, black lesions on the husks of a corm affected with Ink spot. The husk lesions may extend through one or more dried leaf bases. The affected tissue is dry, brittle, and carbonaceous. B—A flesh lesion at a node where blackened tissue of an inky spot on the husk joins the corm. The cause of this disease is undetermined.

affected, it is always at a node where a stained section of the husk is attached. The result is a black, superficial, dry rot which develops very slowly and seldom involves an area more than ½ inch in diameter. It is apparently quickly checked by rapid curing of the corm.

The disease can be found in some varieties in most commercial collections of corms. Sometimes it has caused considerable damage in commercial plantings, and varieties showing excessive amounts of stain have been disqualified for interstate shipment. Its occurrence is much more widespread in some seasons than it is in others. In small-scale experimental plantings of affected corms, on well-drained sandy soils, the disease has not reappeared in the progenies. It has persisted, however, in some commercial fields for several seasons, and some growers have reported increased amounts of stain each succeeding season.

The cause of the disease is unknown. Fungi isolated from the stained scales and from the flesh lesions have not reproduced the disease in experimental trials. Nevertheless, it appears probable that the disease is of fungous origin. A somewhat similar infection in bulbous iris is caused by a fungus, and the gladiolus disease may be either related to it or similar in nature. Growers report that the staining increases with continuous culture on the same site; this indicates that it is a parasitic disease.

Control — Since the occurrence of more than 2 percent stained corms in a variety will disqualify it for certification, it is necessary to control ink spot in commercial plantings by corm treatments and rotations. Where standard treatments are used each year and corms are planted in well-drained, sandy loam soils, the disease can be kept below tolerance levels if suitable crop rotations are practiced.

CHEMICAL INJURIES

(Fig. 11, page 48)

Serious injury to gladiolus has followed the use of Ceresan and other mercury compounds under some conditions. The damage is manifested early by poor stands or later in the season by a yellowing and dying of the plants. Injured corms may fail to grow, and some varieties may be ruined by this type of injury. Plants are most likely to be harmed in soils deficient in moisture, but damage has also been observed in soils containing adequate moisture. The variety Dr. F. E. Bennett has been cited as one especially sensitive to mercury injury, but there are others equally susceptible. Results with Ceresan are erratic, usually more so than with other mercury compounds, and the nature of the injury is not understood. It may occur in some soils and not in others, and a similar response has been noted for many years

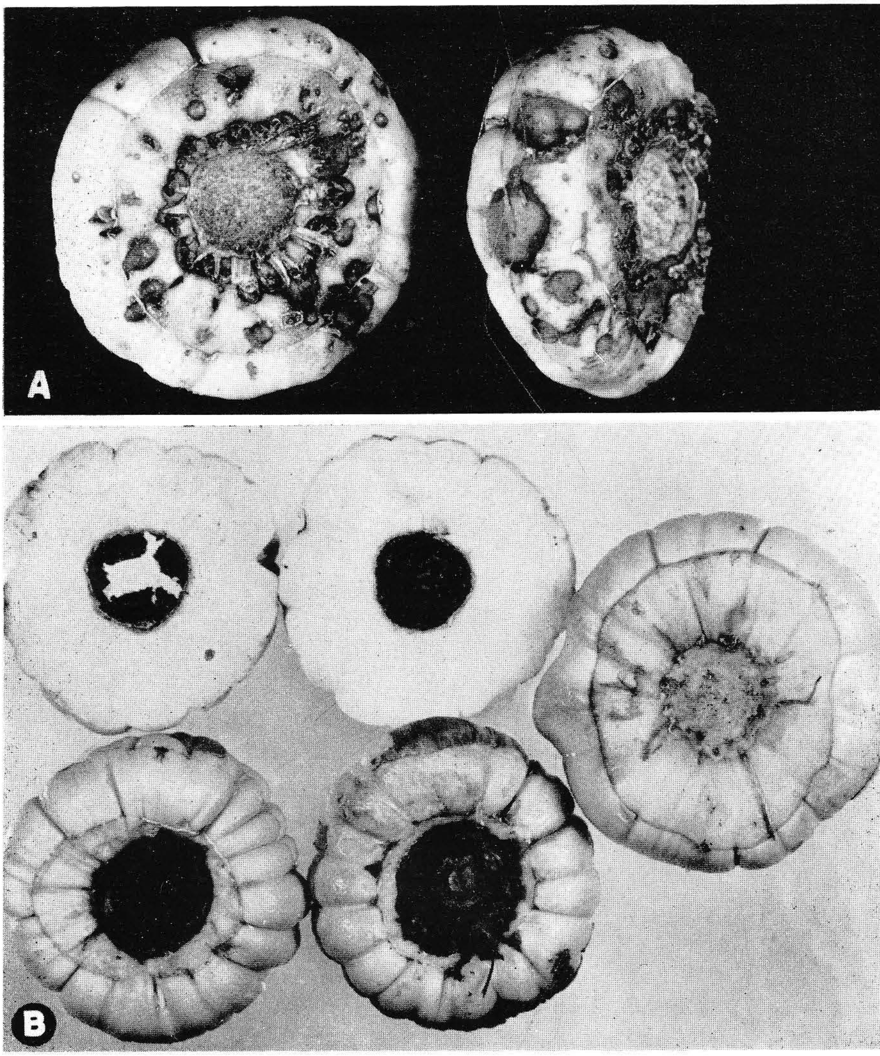


Fig. 11. Chemical injury. A—Primary (direct) injury from treating corms with corrosive sublimate. This type of injury may result from using a concentration greater than 1-1000, or from excessively prolonged treatment, or from delay in planting treated corms. B—Secondary injury on daughter corms as a result of treating the mother corms with calomel. The concentration was 1 pound to 2½ gallons, with a commercial spreader-sticker added. Treatment time was 1 minute. The plants died soon after flowering. Variety Dr. F. E. Bennett, normal corm at right.

in corms treated with corrosive sublimate. Corms affected with diseases like scab, Sclerotinia dry rot and basal dry rot are likely to be damaged in some soils and some seasons. It has been observed frequently that mercury treatments are effective in controlling scab in some soils and in others of apparently the same type they are not. Though this response may be due to direct chemical effects such as soil binding of the mercury, it is more likely biological in nature, for mercury is selective in its action upon soil organisms and may suppress groups of organisms that are normally antagonistic to the scab pathogen.

Where mercury injury is delayed in appearing until late in the season, the leaves turn yellow, the plants die, and there is a hard, brown rot of the central tissue of the corm. There is normally no decay in the flesh of the corm. Blue-mold fungi, apparently as secondary invaders, are active in the rotting tissue. The primary cause seems to be a toxic effect of the mercury. The type of injury and the appearance of the plants in the field is suggestive of Fusarium yellows, since that disease causes a yellowing of the leaves and a typical core rot. The chemical injury can be distinguished, however, by the sharply restricted nature of the dry core rot, which normally does not extend into the adjacent flesh. Severe chemical injury may involve fleshy areas surrounding the central core, especially at the base of the corm where the mother corm is in close contact with the base of the daughter corm.

Delay in planting corms treated with mercury compounds is sometimes followed by surface injury visible as sunken, discolored areas in the flesh. Excessively prolonged soaking in corrosive sublimate and other mercury materials is likely to cause this type of damage.

In using mercury compounds, especially Ceresan, directions should be followed explicitly, and the treated corms should be planted without delay. There should never be as much as a 24-hour delay between treatment and planting. Though Ceresan is less reliable than some other mercury compounds, injury has been observed in corms treated with corrosive sublimate and with calomel, especially where a detergent is added. In some instances, one variety has been treated with several kinds of mercury compounds without injury, and another variety treated similarly and planted in adjacent rows has displayed serious effects. In soils containing adequate amounts of moisture, the hazards of mercury injury are less than in those deficient in water, and sandy soils are apparently more favorable for the occurrence of this trouble than those having a high organic content. Sprouting corms should not be treated with mercury compounds if early flowering is desired, since a retardation in flower formation usually follows such treatments.

DISEASES MOST ACTIVE IN STORAGE

Fungous Diseases

FUSARIUM DRY ROT (BROWN ROT)

(*Fusarium oxysporum* Schlecht, var. *gladioli* Massey)

(Fig. 12, page 51)

Fusarium dry rot is one of the major diseases of gladiolus in some sections of the United States and is apparently increasing in Michigan. It is really a field disease, since the majority of infections take place before the corms are dug, but because the subsequent decay develops after harvest it has been classed as a storage disease. Freshly dug corms usually seem to be free of infections, but under some conditions the characteristic brown, water-soaked lesions are visible when the corms are dug.

Brown rot has caused serious damage to the gladiolus cut-flower industry in Florida, and when it was described from New York in 1924, it was a major disease in that state. It is now an important disease in Illinois and other sections, notably Texas and California. Occasionally it has caused severe damage to some varieties in Michigan. The loss of 100,000 corms of the variety Peggy Lou in one planting was reported in 1945. It is apparently becoming more widely disseminated in Michigan and elsewhere and must be treated as a major disease in the production of both corms and flowers.

In the reports on the occurrence of this disease, it has sometimes been confused with Fusarium yellows, an entirely different malady. The chief resemblance between the diseases is that both cause a brown, dry rot of the corm. The best evidence of dissimilarity is demonstrated by the high resistance of the variety Picardy to Fusarium yellows and its equally great susceptibility to Fusarium dry rot. The frequently reported breakdown of resistance of Picardy to Fusarium yellows has, whenever investigated, proved unfounded and is

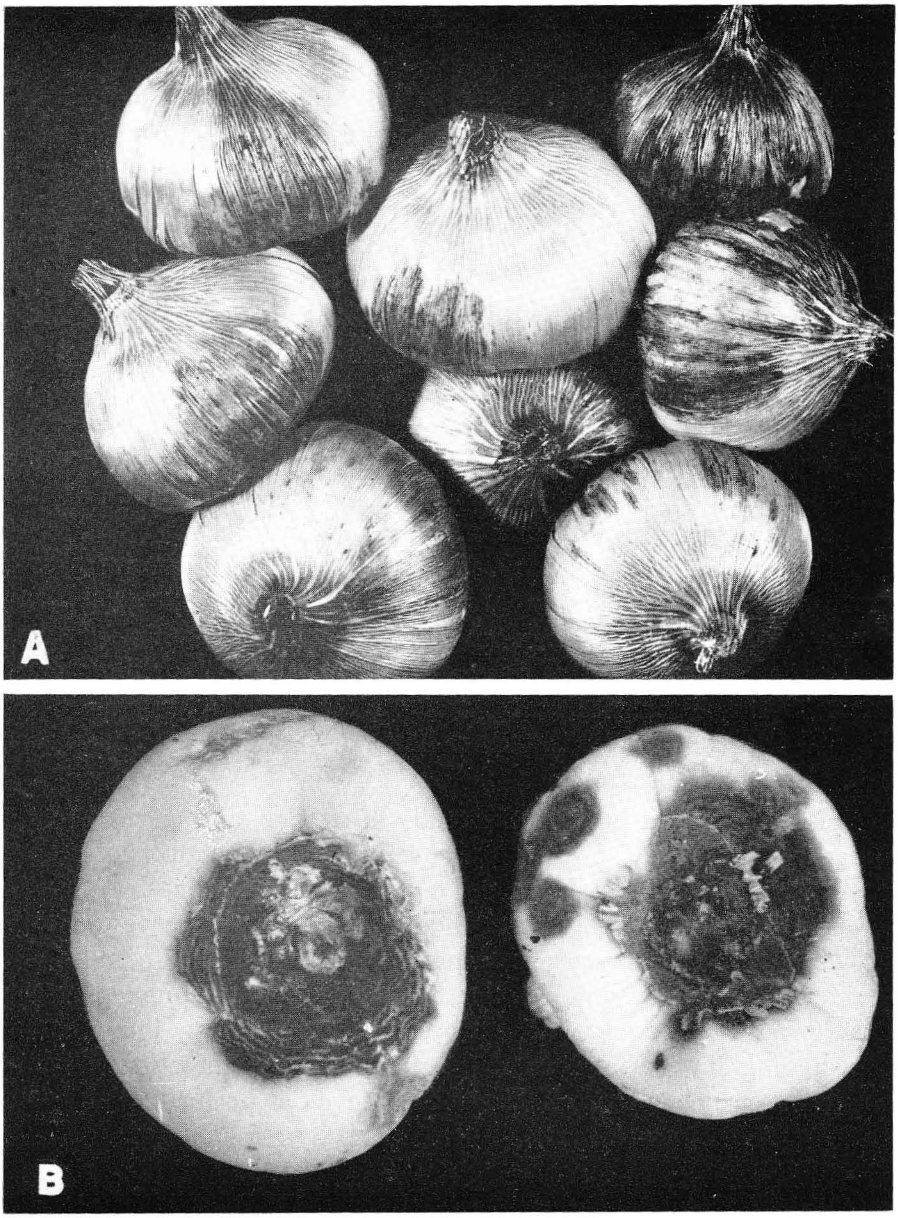


Fig. 12. Fusarium dry rot. A—Corms affected with Fusarium dry rot, showing the discolored husk tissue over the corm lesion. Similar husk discolorations occur over lesions of Sclerotinia dry rot. B—Typical Fusarium dry-rot lesions on corms. They are usually most numerous at the base, and the diseased flesh quickly becomes wrinkled to form a series of concentric rings. Infected corms are soon reduced to hard, black mummies unless the decay is checked by rapid and thorough drying.

based on the undifferentiated, destructive effects of dry rot in this variety.

The typical lesions of Fusarium dry rot are somewhat sunken, and the flesh of the corm is tan-colored and firm. The lesions occur most commonly near the base of the corm, where they are easily seen. Lesions on other parts of the corm are not always readily detected since they are covered by the husks. Dark, stained areas on the husk, however, may cover typical flesh lesions directly beneath. As the corm becomes drier, the diseased tissue shrinks somewhat, becoming leathery, and the surface wrinkles to form a series of characteristic concentric rings. These rings were formerly considered of diagnostic value, since they were thought to be specific for this disease. However, they also occur in the lesions of Penicillium dry rot and are therefore not of specific diagnostic importance. The lesions of Fusarium dry rot can be distinguished from those of the Penicillium rot by the absence of the green, water-soaked border typical of the Penicillium infections. Small, round, gray sclerotia, about the size of mustard seeds, frequently develop in the rotting flesh attacked by the Penicillium disease, but these never occur with Fusarium dry rot. Another distinguishing feature is the occurrence, under moist conditions, of blue masses of spores that cover the lesions of Penicillium dry rot. These do not occur in the Fusarium disease.

Fusarium dry rot progresses rapidly in storage, and corms of very susceptible varieties are often destroyed early in the storage season. Susceptible varieties may be ruined even before the corms are cleaned because of the rapid progress of the disease in corms harvested during wet weather or in seasons when they do not mature completely. Infected corms can be quickly reduced to hard, black mummies. If the corm is well ripened and is cured rapidly and completely immediately after digging, it does not become infected in storage, infections already established are checked, and the disease develops no further until the corm is planted in moist soil.

Conditions Favoring Dry Rot—Continuous use of one site for growing gladioli results in a rapid increase in the amount of brown rot and subsequent destructive attacks of the disease. It is favored by warm and moist soils in the fall preceding harvest, and fall rains are often followed by heavy infection and destructive losses in storage. Late planting with consequent immaturity of harvested corms is a predisposing condition of rapid decay in storage.

Control—A pre-planting dip in Ceresan has been reported effective in the control of Fusarium dry rot. (See page 62.) Together with crop rotations, selection of good planting sites, and the growing of the more resistant varieties, this treatment should be helpful in preventing excessive losses. In addition, facilities should be provided for rapid and thorough curing of the corms immediately after harvest. They should be placed in ventilated trays and exposed for 2 or 3 weeks to temperatures near 80 degrees F. The consequent reduction in water content of the flesh will make cured corms more resistant to decay by all rot fungi. This artificial curing will be especially beneficial in seasons when unfavorable conditions at harvest make natural curing difficult or impossible. Well-matured corms are naturally more resistant to decay, but in seasons when climatic conditions prevent complete maturation, the use of artificial heat will provide an effective compensation. Some varieties produce corms that are considered "softer" than others. Those in the Primulinus group appear to decay much more rapidly and should be dried with artificial heat. The purpose of artificial curing is to reduce the moisture content of the corm to a level where fungi cannot grow in the flesh. This level is not so low as to cause shrivelling or a noticeable change in the appearance of the corm.

Differences in varietal reactions have been observed, but no attempt has yet been made to classify resistant varieties as has been done with Fusarium yellows. Picardy is one of the most susceptible varieties and consequently has lost favor in areas where the disease is prevalent. The testing and classification of the most important commercial varieties should be done so that the hybridizers may select the best ones for the production of resistant seedlings. It is interesting to note that in the original report on this disease in 1924, all varieties tested were found susceptible. This is apparently not true today, since different degrees of susceptibility have been observed in the varieties now grown.

PENICILLIUM ROT (BLUE MOLD)

(*Penicillium gladioli* McCull. and Thom.)

(Fig. 13, page 54)

This is primarily a storage disease, and the causal fungus is dependent upon wounds in the corm for an avenue of entrance. It seldom attacks uninjured corms or those that are cured rapidly immediately

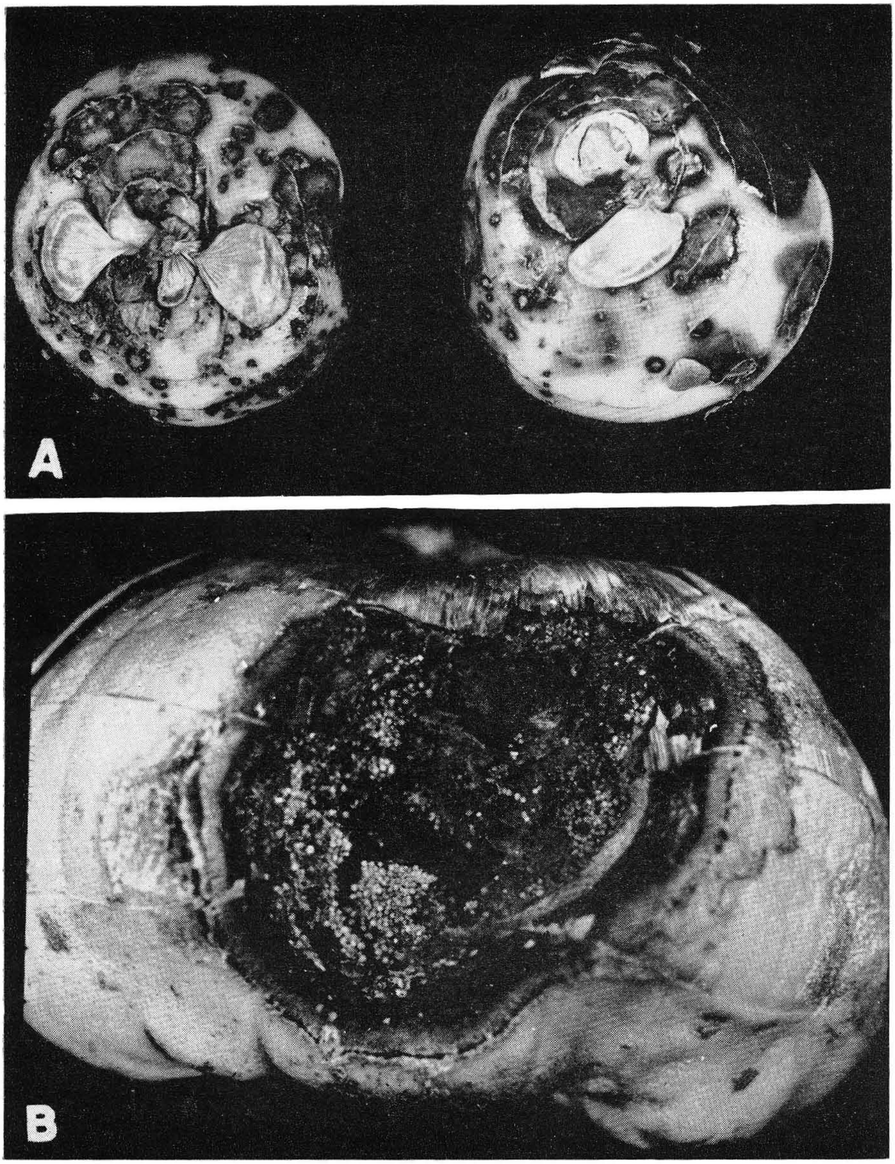


Fig. 13. Penicillium rot (Blue-Mold rot). A—Numerous lesions of Penicillium rot developing on corms stored before they were thoroughly cured. The disease may develop very rapidly in "green corms." B—A large lesion of Penicillium rot enlarged to show the numerous, small, round, gray sclerotia of Penicillium gladioli. Blue spore masses of the fungus develop on the lesions under moist conditions.

after harvest. Effective control, therefore, depends largely on methods of handling corms during and after harvest.

The lesions of blue-mold rot are somewhat similar to those of the Fusarium dry rot disease. They are light to dark brown, are sunken, and occur any place in the flesh of the corm. Under moist conditions, they enlarge rapidly, especially in corms that are not thoroughly cured. *The border of the decaying area is water-soaked and is a greenish color,* which aids in distinguishing this rot from the Fusarium disease. Under moist storage conditions, the rotting tissue is usually soft or spongy, but in well-cured corms it is firm and leathery. Under some conditions, small, gray sclerotial bodies, about the size of mustard seeds, are formed in large numbers in the rotting tissue, especially near the surface of the lesion, and their presence gives a granular consistency to the rotting flesh. When the corms are moist, blue spore masses of the fungus form on the surface of the lesion. It is from the blue color of these spore masses that the name "blue mold disease" has arisen. The spores disseminate the fungus throughout the storage house and contaminate trays and other containers used in handling the corms.

In some corms, the drying of the affected tissue results in the formation of concentric rings similar to those typical of the lesions of Fusarium dry rot. This may lead to confusion in diagnosis, but the color of the edges of the blue-mold lesions is a distinctive character and is helpful in distinguishing the two diseases. Corms showing blue-mold lesions usually decay when planted, but corm treatments may provide considerable protection. Standard treatments at planting time may save infected corms of rare or exceptionally valuable varieties.

Control — Penicillium dry rot is not difficult to control in stored corms if they are prepared carefully for winter storage. The most important treatment to make them resistant to decay is the prompt reduction of moisture content immediately after they are dug. In handling the corms during and after harvest, some wounding and bruising is unavoidable. Through these surface wounds the fungus penetrates the flesh, and the rot progresses rapidly if the cells are high in water content. Curing the corms immediately after harvest by exposing them to artificial heat at 80 degrees F. for 2 to 3 weeks will make them very resistant to decay. Freshly dug corms should not be piled deeply in crates or in other containers until after drying has removed moisture to a level where they are resistant to decay.

Storage temperatures most favorable for keeping the corms dry and cool should be maintained without sharp departures. Sudden temperature changes result in the deposition of moisture on the corms, and this produces more favorable conditions for infection by decay fungi. Ventilation should be adequate to keep atmospheric humidity at medium levels, and slatted trays or other suitable receptacles that will permit free circulation of air around the individual corms should be used.

NON-PARASITIC DISEASES

STORAGE BREAKDOWN

(Fig. 14, page 57)

In some seasons, numerous specimens of corms affected with diseases peculiar to the storage house and not of parasitic origin are received for diagnosis. The affected corms show various kinds of stains and discolorations, especially at the nodes, and slight or extensively pitted areas at the base of the corm or at the nodes. The pitted areas at first are colorless, but they gradually develop various shades of brown. Picardy and Maid of Orleans at times have been seriously affected by this type of breakdown. Other varieties are also susceptible.

These storage troubles are apparently various manifestations of the same type of disease, a non-parasitic storage breakdown. They are the result, in most instances, of storage under unfavorable conditions. They may develop also as the result of unusual seasonal conditions that prevent normal maturing of the corms so that they go into storage in an abnormally active physiological condition. When sufficient ventilation is not provided in storage, especially around the individual corm, excessive cellular activity may result in injury to the cells because of their failure to obtain sufficient oxygen for normal physiological functions. A similar effect may occur as a consequence of storing immature corms at abnormally low temperatures, where again the basic cause of the breakdown is suboxidation, which results in an accumulation of poisonous products in the cells. Similar diseases affect fruits and vegetables under comparable conditions in storage and transportation.

Control — To prevent these storage troubles, provision should be made for constant circulation of fresh air around the storage containers. Storage in deep bins, or in containers where air cannot constantly

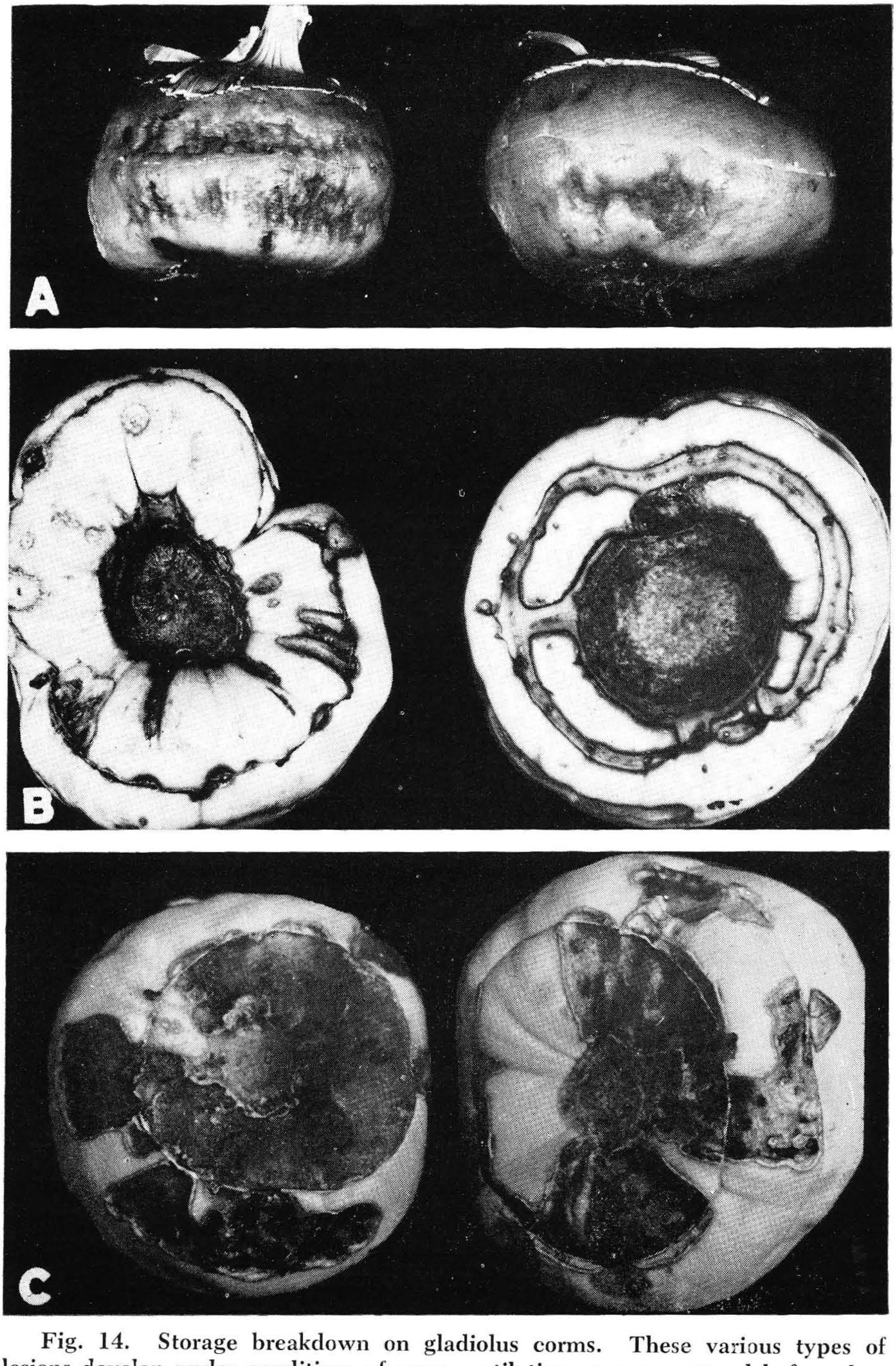


Fig. 14. Storage breakdown on gladiolus corms. These various types of lesions develop under conditions of poor ventilation on corms stored before they are well cured. A characteristic form of breakdown on Picardy is illustrated in C.

reach the corms, will establish conditions very favorable for this type of breakdown. Some varieties are much more sensitive to such unfavorable conditions than others and will develop injury much more quickly. A well-matured and thoroughly cured corm of any variety is unlikely to be adversely affected by normal storage conditions. However, even such corms may develop pitted and stained areas if subjected to prolonged storage under conditions of poor ventilation, and partially cured corms may be injured very quickly. It is significant that this type of breakdown always develops early in the storage season and that as curing proceeds the corms apparently become more resistant. Curing with artificial heat immediately after harvest will be the most effective preventative of this type of disease in storage.

SOIL MANAGEMENT AND THE CONTROL OF SOIL-BORNE DISEASE

Some of the most important diseases of gladiolus are soil borne. These include Fusarium yellows, Fusarium dry rot, Fusarium basal rot, Sclerotinia dry rot, scab, and bacterial leaf blight. Undoubtedly the leaf-blight fungi survive in the soil on the diseased plant refuse that is plowed under. The Fusarium diseases, however, are the most destructive of the soil-borne infections, since the causal fungi may persist for several years in the soil in the absence of the host plant. The maximum periods of survival for these diseases are unknown, but the writer has evidence of the persistence of the Sclerotinia dry-rot fungus in sandy loam soil for 10 years during which no gladioli were grown. The bacterial parasites are much shorter lived under comparable conditions.

The gladiolus is an intensively grown crop, and the tendency of many growers is to plant on one site as long as it can be profitably used for the production of corms. Unremittent use of such sites is followed by increasing amounts of soil-borne disease until finally culture on a new site is required to prevent excessive injury from these diseases. The fungi that cause the soil-borne diseases of gladiolus are not normal constituents of the soil microflora but are soil-invading organisms introduced in or on infected corms. Following introduction, their increase is dependent upon soil conditions, continuity of culture, and the susceptibility of the varieties grown. Continuity of culture is an especially important factor. Concurrently with their increase in the soil through parasitic activity, certain associative saprophytic fungi and other micro-organisms multiply more rapidly than other normally competing forms. As a result, the soil microflora, which originally was in a state of equilibrium, becomes unbalanced and consists predominantly of the pathogen and its associated predatory micro-organisms. Microbiological competition is thereby reduced, and the harmful organisms increase while the activities of the friendly saprophytes are suppressed. Thereby the soil becomes biologically fortified for an attack upon the gladiolus, and it is no longer a suitable site for the growing of healthy plants. Removal to new soil becomes necessary unless resistant varieties or effective control measures are available.

In any modern system of gladiolus culture, control of soil-borne disease is imperative, and crop rotations and the growing of soil-building crops are effective supplementary measures. Soil fertility is increased and a better balanced microflora is maintained if variable crop residues are returned to the soil. Under natural conditions, no one plant species grows continually on the same site. A weed does not flourish indefinitely in uncropped soil; it is gradually displaced by other plants as soil conditions change and become more favorable for other species. The site is occupied by a continuing succession of plants, and this rotation of species returns a variety of plant residues to the soil which increase soil fertility and maintain a microbiological balance that prevents harmful organisms from becoming dominant. By this method, the soil microflora is maintained in a state of basic equilibrium and is a favorable medium for the growing of a cultivated species. This favorable balance can be upset by a one-crop system of utilization of the site.

The gladiolus grower should imitate this natural method of maintaining the soil in a fertile and biologically favorable condition for the culture of a crop. To encourage maximum competition among soil organisms, a variety of crop residues should regularly be returned to the soil. If this is not done and the gladiolus is grown continually on the same site, the soil will become colonized by the harmful organisms introduced in planting stocks and will soon become unsuitable for the growing of disease-free corms.

Some useful soil-building crops to employ in rotations with gladiolus are soybeans, clovers, rape, buckwheat, sudan grass, and rye. By wise planning, large organic residues can be returned to the soil in 1 year. As an example, soybeans can be planted about May 15 and the plants plowed under deeply about August 10, when they will have attained maximum vegetative development. Rape can then be broadcast and the soil rolled lightly. By September, the rape will have produced maximum vegetative growth and can be rolled and disked under. If rye is then sown and plowed down in the spring, just preceding the planting of a cultivated crop, a maximum of organic material will have been incorporated in the soil. The crop immediately following the rye preferably should not be gladiolus. There is little experimental information on the crop sequences most effective in the control of disease, but very beneficial results have been obtained in the control of Fusarium yellows following a crop of soybeans and rye. It cannot be anticipated, however, that effective control can be achieved with such short rotations.

The reduction of injury from root disease in cotton, strawberries, and other crops by the growing of soil-building plants in the rotation is proof of the value of this new approach to the control of soil-borne disease. For the gladiolus grower with limited space, the method of biological control may be a useful supplement to standard control practices and may assist in minimizing injury from the most serious of the soil-borne diseases.

FUNGICIDAL SOLUTIONS AND SUSPENSIONS FOR CORM TREATMENTS

Standard Corrosive Sublimate Solution

The standard solution for treatment of gladiolus corms is prepared by dissolving 1 ounce of corrosive sublimate in 7½ gallons of water. For greater or lesser volumes, the same proportions should be used. The solution must be prepared in stone or wooden vessels because it attacks metals. For large quantities of corms, especially constructed, wooden vats are desirable, and for smaller numbers, wooden barrels are satisfactory.

Corrosive sublimate dissolves slowly in cold water. Its solubility is 20 times greater in hot water. Where no method of heating water is available, dissolution of the chemical in cold water can be hastened by the addition of 1 part of table salt to 3 parts of corrosive sublimate. For each ounce of corrosive sublimate use ⅓ ounce of salt.

The corrosive-sublimate solution loses strength with use, and its effectiveness is reduced after contact with corms. It is essential also that a proper balance between volume of solution and quantity of corms be maintained. If too many corms are soaked in a comparatively small volume of solution, the disinfecting power of the chemical will be unsatisfactory. The volume of solution should be two to three times that of the corms. For example, for the 2-hour treatment, 15-20 gallons of solution should be used for each bushel of corms. After the first treatment, the strength of the solution must be restored by the addition of about ⅓ ounce of corrosive sublimate to each 7½ gallons. Before treating the third lot, an additional ⅓ ounce of the chemical must be added for each 7½ gallons. The solution should then be discarded and a new one prepared.

Mercury is removed from solution by the corms, especially by the husks, and the amount removed is proportional to the surface area; thus, a bushel of corms of the smaller sizes removes proportionately larger amounts of mercury than a bushel of the larger ones because the total surface area of the small corms is greater. The unsatisfactory results sometimes obtained in using this treatment under commercial conditions are partly due to failure to maintain the solution at full strength and to keep the ratio constant between the volume of solution and the quantity of corms.

Prolonged soaking in this solution is not recommended and may cause injury in some varieties. The 2-hour soaking period is long enough for safe and effective fungicidal activity.

Calomel and Yellow Oxide of Mercury for Basal and Sclerotinia Dry Rots

One pound of calomel or of yellow oxide of mercury mixed with 5 gallons of water makes an excellent fungicidal suspension, especially for the control of either Sclerotinia dry rot or basal dry rot. In preparing these suspensions for the control of either of these diseases, the chemical should be first mixed with a small amount of water to form a smooth paste. Some Dreft or a wetting agent like Triton 1956-B should be added to the water, since these detergents will make it easier to wet the powder. After the powder is thoroughly wet and forms a paste free of lumps, it is added to the full volume of water. Additional quantities of Dreft or Triton should be added to the suspension so that it will wet the corms, but an excess may cause too much runoff of the chemical. The suspensions must be kept well stirred, as these mercury materials precipitate very quickly.

The corms should be treated in a porous container, such as an onion sack, and kept in the suspension until they are well coated with the particles of mercury. If the sack is raised and lowered several times, 1 minute is sufficient time for treating each lot of corms. After wetting the corms, the excess liquid should be drained back into the container. It can be conserved by using a slatted rack above the treating container or some other device for allowing the liquid to drain into the vessel. If this is done, 5 gallons of the suspension will treat several bushels of corms. It can be used as long as there is sufficient liquid to wet the corms, since the concentration does not change if the liquid is kept well stirred.

New Improved Ceresan

New Improved Ceresan is being used in some sections for the control of Fusarium dry rot, and it has been reported effective in the prevention of the corm decay in storage and in the field. It has not been extensively used in Michigan, because this disease has not yet become generally important in commercial fields. New Improved Ceresan, however, is not always a safe fungicide to use, since the corms may be injured if soil conditions are not favorable at the time of planting. It often causes injury in dry soils, and moisture must be adequate to stimulate rapid corm germination. The corms should be planted immediately after treating, as delay increases likelihood of injury. Some varieties are much more susceptible to mercury injury than others, but there is little information available as a guide.

The recommended strength of Ceresan is 1 ounce in 3 gallons of water or 1 pound in 50 gallons. Ceresan is difficult to wet, and a detergent like Dreft, Triton 1956-B, or some similar commercial wetting agent should be used in preparing the treating solution. Add a tablespoonful of Dreft to about 1 quart of water and stir well. Wet the Ceresan with a small amount of this liquid and stir it until it forms a very smooth paste, then dilute with the rest of the water containing the detergent. Pour the Ceresan suspension into the full volume of water and add enough Dreft or Triton to make the liquid wet the corms, but do not use excessive amounts. The insoluble, inert filler in the Ceresan will settle out, but this does not decrease the strength of the active material.

The corms should be left in the solution for *15 minutes only*, removed, drained, and planted immediately, for if left overnight out of the soil they are likely to be injured. The strength of the solution does not materially decrease with use, and it can be used for treating several lots of corms.

Lysol Solution

One pint of Lysol in 25 gallons of water has been recommended as an effective fungicide for the control of corm-borne diseases. Our experience with this material has been unsatisfactory, and it is not recommended for commercial use. Several reports of severe injury from its use came from growers who used it in Michigan in 1946 and 1947. As with Ceresan, results are too erratic to warrant its general use in commercial plantings, and the commercial grower will profit more by continuing the use of safer materials until more effective ones are developed and thoroughly tested.

Fumigation of Storage Houses

To destroy rot fungi in storage houses, especially those that cause rots of the blue-mold type, fumigation will be helpful after all corms are removed from storage in spring. This is most effectively accomplished by burning sulfur in a free flame. All cracks should first be sealed, and 3 pounds of sulfur for each 1,000 cubic feet should be burned in a flame. Charcoal soaked in kerosene and burned in metal containers will provide a good flame for igniting the sulfur. Fumes from burning sulfur are deadly to insects and fungi, and this method is effective for ridding the storage house of these pests. The fumes cause a blackening of lead paint, and sulfur should not be burned in newly painted houses. The fumes are also very irritating to the nose and throat and should not be inhaled.