

# THE TWO MOST COMMON DECAYS OF COTTON BOLLS IN THE SOUTHWESTERN STATES<sup>1</sup>

By MICHAEL SHAPOVALOV

*Pathologist, Office of Vegetable and Forage Diseases, Bureau of Plant Industry, United States Department of Agriculture*<sup>2</sup>

## INTRODUCTION

It has been frequently reported from cotton-growing sections of the Southwest that immature cotton bolls are subject to a peculiar form of disease to which the name "smut" has been commonly applied by the growers. The writer has made a survey of cotton fields in California and Arizona and in the section of Mexico immediately adjoining the Imperial Valley and has obtained a considerable number of cultures from affected specimens. These cultures, as well as subsequent inoculation tests, both in the field and in the laboratory, show very clearly that the disease in question is not a smut. Although it is true that in its final phase of development when the boll has dried up it bears a slight resemblance to smut, its initial stages are plainly those of a soft decay.

This soft-decay form either was overlooked by the average observer or, if noticed, was not correlated with subsequent and more pronounced symptoms. Disease symptoms appear limited to bolls that have previously suffered injury by insects or otherwise.

The writer's studies have also revealed the fact that in reality there occur in the field two forms of the boll decay, both of which generally have been known as "smut." One of these is caused by *Aspergillus niger* Van Tiegh. and the other by *Rhizopus nigricans* Ehr. Although on close examination these forms show very distinct peculiarities throughout the entire cycles of their development, they have nevertheless a certain similarity in their general appearance during the fruiting stages of the causal organism. This similarity undoubtedly is responsible for the confusion of the two troubles, particularly since the decay symptoms formerly had not been recognized.

## ASPERGILLUS NIGER

Although very common on all kinds of decaying vegetable matter, the fungus *Aspergillus niger* has heretofore been associated by investigators with only a few diseases of economic plants. Van Pelt (10)<sup>3</sup> considered it to be responsible for a serious black mold of onions in Ohio. Certain laboratory experiments carried on by the writer (7) revealed it to be among important potential parasites of the potato tuber. The same fungus has been definitely shown by Phillips and Smith (6) to be the cause of the so-called smut of white fig varieties in California.

<sup>1</sup> Received for publication April 18, 1927; issued October, 1927.

<sup>2</sup> The writer expresses appreciation to W. B. Camp, of the Office of Cotton, Rubber, and other Tropical Plants, Bureau of Plant Industry, for the great amount of helpful information given him in regard to cotton culture in the San Joaquin Valley and the Southwest in general, and to H. G. McKeever, of the same office, for invaluable assistance in field observations and the collection of specimens.

<sup>3</sup> Reference is made by number (italic) to "Literature cited," p. 312.

The occurrence of *Aspergillus niger* on cotton bolls was briefly reported by the writer (8) in 1925. Aside from the decaying bolls, the fungus was also frequently isolated from young dying squares, from discolored pedicels, and from lesions on the bracts. It was likewise obtained from stem lesions of young seedlings showing symptoms of sore shin. As far as the observations of the last two seasons (1925 and 1926) are concerned, the *Aspergillus* boll decay was more frequently observed in the Southwest than the *Rhizopus* decay and was most prevalent in southern portions of California, though specimens of it were found also in the San Joaquin Valley, in Mexican plantations adjacent to the Imperial Valley, and in Arizona.

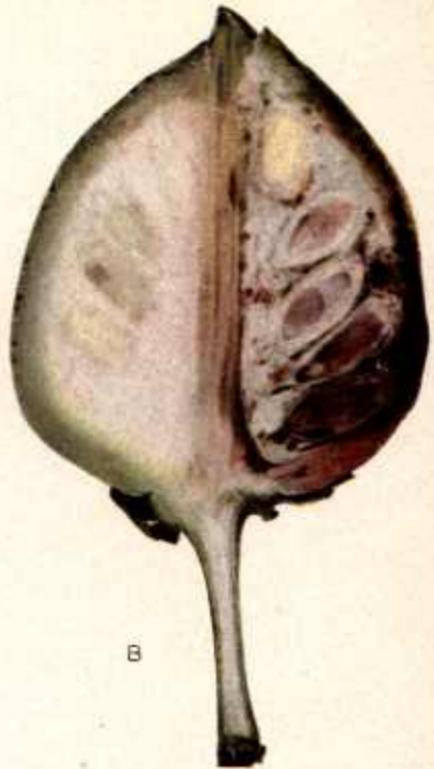
The rot begins as a soft pinkish spot either on the side of the boll or somewhere near its base. The hue and the extent of the pink discoloration vary more or less, but the discoloration is always present and is characteristic of this sort of decay (pl. 1, A). As the lesion increases in size, the color of the older decayed area turns from pink to brown and the original discoloration remains only in the freshly decaying regions—that is, on the border of healthy and diseased tissues. If such a boll is cut open through the affected area the same pink to purplish and red-brown shades of the invaded tissues will be seen (pl. 1, B). The fructification of the fungus begins in relatively early stages of decay, but the spores are white or light gray at first, darken very rapidly, and in a short time give the diseased bolls a “smutty” appearance (pl. 2, B). The fungus is capable of destroying all parts of the boll—the capsule, the lint, and the seeds. Cultures of the organism have been obtained from all such affected tissues. When it is destroyed by the parasite, the entire boll dries up and remains closed (pl. 2, A). Frequently, however, the progress of the decay is checked, either by unfavorable environmental conditions not yet understood, or by the natural development of the boll if it is affected when nearly mature. In such cases the bolls open only partially, the affected portions remaining closed. The black masses of the *Aspergillus* spores may be seen in abundance both on the inside and the outside of the bolls (pl. 2, C and D).

Artificial inoculations with pure cultures of *Aspergillus niger* were made on growing bolls in the field and in the greenhouse, and on picked bolls incubated in moist chambers in the laboratory. The percentage of infection was greatest when picked bolls were used fresh—as soon as they were brought to the laboratory. Bolls which remained in the room for several days before inoculation gave only a small percentage of infection, showing that a certain degree of succulency of the tissues is necessary for the most destructive results. Atmospheric humidity likewise appears to be essential for the best activity of the parasite. This is shown by the fact that the bolls growing in the greenhouse were affected more readily than those growing in the field. The inoculum was introduced partly by applying it to wounds made either with a scalpel or with a needle, and partly by smearing it on the surface of bolls not injured artificially.

With but one exception—namely, in the case of a group of uninjured inoculated bolls placed in a moist chamber (see Table 1)—positive results were obtained only in those cases in which injured bolls were inoculated. One of the bolls placed in the chamber became infected, but proof was lacking that this boll had been brought from the field entirely uninjured. This seems to indicate that the



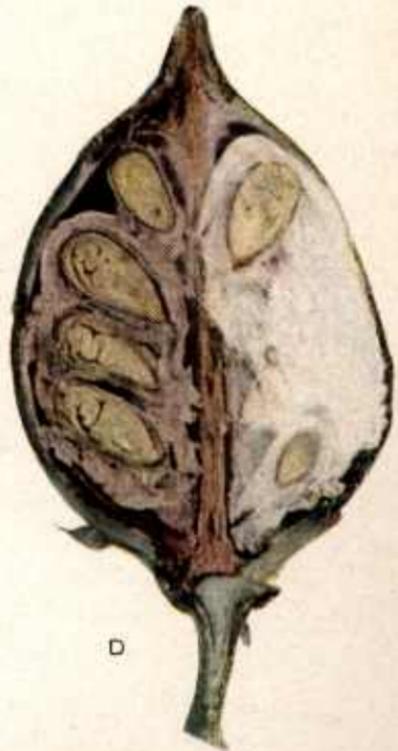
A



B



C



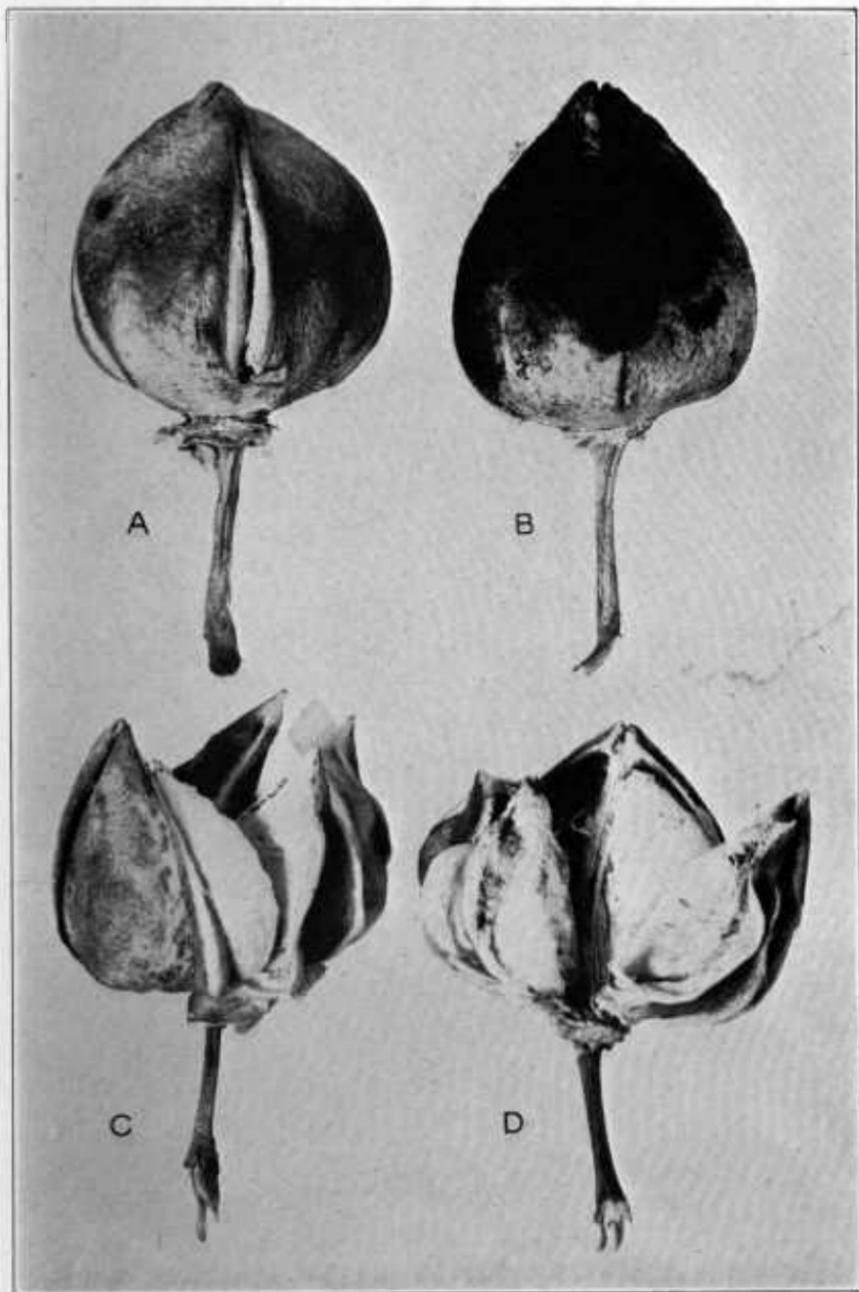
D

### TWO FORMS OF COTTON-BOLL DECAY

A and B, caused by *Aspergillus niger* Van Tiegh.; C and D, caused by *Rhizopus nigricans* Ehr.

A and C, external appearance of the bolls affected by the two types of decay;

B and D, interior views of the same bolls



Later stages of cotton-boll decay caused by *Aspergillus niger* Van Tiegh.  
A.—Rapidly decayed and dried-up boll with a very scanty fructification of the fungus.  
B.—Boll destroyed by a slower decay with abundant fructification.  
C. and D.—Partially decayed and partially opened bolls (braets removed to show larger surface of the bolls).

fungus is mainly if not exclusively a wound parasite. The decay as it naturally occurs in the field often is associated with visible insect wounds, particularly with those made by the bollworm, although in many instances such injuries are not apparent. It is possible, however, that the infection in these cases is associated with some minute punctures caused by smaller insects. In the case of the wound inoculations, the decay did not always appear on the surface at the point of the inoculation, but sometimes developed first within the boll and then broke through at a point more or less removed from the wound. The time necessary for the appearance of the first external signs of the decomposition varied from three to eight days.

A more detailed account of the inoculation tests and their results is given in Table 1.

TABLE 1.—Results of inoculating cotton bolls with *Aspergillus niger*

Group and kind of material used	Time between inoculation and final examination (days)	Inoculated				Controls				Remarks
		Injured		Uninjured		Injured		Uninjured		
		Total number	Number affected							
Group 1: Green picked bolls in moist chambers.	8	11	3	10	0	10	1	10	0	{Discoloration characteristic only with a few larger lesions. One boll decayed completely; three bolls decayed mostly in the interior. Most injured inoculations showed decay on the third day, the largest involving three-fourths of the boll and the interior.
	9	14	14	13	0	10	0	-----	-----	
	15	57	55	11	1	12	0	-----	-----	
	Total in group	82	72	34	1	32	1	10	0	
Group 2: Growing bolls in the greenhouse.	16	4	4	-----	-----	(a)	(a)	(b)	(b)	{Typical decay, but not involving more than half the boll; part visible on the third day and the remainder on the eighth day; unaffected portions split and the fungus fruiting appeared on the surface.
	3	4	4	-----	-----	-----	-----	-----	-----	
	Total in group	8	8	-----	-----	-----	-----	-----	-----	
Group 3: Growing bolls in the field.	14	25	19	25	0	25	0	25	0	{Spots from a fraction of 1 to 2¼ cm. The extent of decay varied from a small spot to more than half the boll.
	13	36	32	5	0	17	0	-----	-----	
	9	13	12	-----	-----	6	0	-----	-----	
	Total in group	74	63	30	0	48	0	25	0	
Total in three groups.	-----	164	143	64	1	80	1	35	0	Average infection with wound inoculations, 87.2 per cent.

<sup>a</sup> No injured checks were used.

<sup>b</sup> A number of uninjured bolls growing at the same time remained healthy.

All of the inoculations included in Table 1 were carried on with cultures of *Aspergillus niger* isolated from decaying cotton bolls. In addition, six growing bolls were inoculated with culture No. 1001, previously isolated by the writer (7) from a potato tuber, in order to ascertain the pathogenicity of this culture to cotton and the character of symptoms produced. The inoculations were made with

one of the series included in Group 3. All of the six bolls became infected and the symptoms were identical with those produced by the strains isolated from cotton. The decay developed to the extent of one-half of the boll, the fungus fruiting on the diseased part. The unaffected portions split open in a typical manner.

It has been noted that under natural conditions in the field earlier sets of the bolls show the largest percentage of infection. Inasmuch as the beginning of the decay is often associated with bollworm injuries, the heavier infection in the earlier bolls may readily be explained by the fact that the bollworm, which is subject to many natural enemies, diminishes in numbers as the season progresses.

#### RHIZOPUS NIGRICANS

Unlike *Aspergillus niger*, *Rhizopus nigricans*<sup>4</sup> is a well-known parasite of many cultivated crops (4), though the cotton plant has not been on the list of its hosts until comparatively recently. Its association with the sore-shin lesions in Egypt was suspected by Balls (1, p. 19) to be more than accidental, although in rather extensive inoculation experiments by Briton-Jones (3, p. 6-18) positive results on young seedlings were obtained only with *Rhizoctonia solani*, whereas *Rhizopus nigricans* failed to cause any damage. The same author (2), however, definitely established the fact that the latter fungus causes a decay of bolls in Egypt, gaining entrance through insect wounds. A few years later Kirkpatrick (5) published a detailed account of his studies of this decay, showing the nature of the damage caused and the resulting losses to the growers.

In the United States this disease may be found in the same localities of the Southwest in which the *Aspergillus* rot occurs. However, during the seasons of 1925 and 1926 the former appeared to be less prevalent than the latter, and could be found in greater abundance in the San Joaquin Valley than in sections farther south.

As far as cotton bolls are concerned *Rhizopus nigricans*, like *Aspergillus niger*, appears to be principally, if not exclusively, a wound parasite. In most cases it was found to be associated clearly with the circular holes made by the bollworm. Kirkpatrick (5) from his studies of this disease in Egypt arrived at the definite conclusion that *R. nigricans* is strictly a wound parasite, and he described several insect agencies responsible for bringing about the infection.

The *Rhizopus* decay, as it occurs in the Southwest, is quite distinct through all its stages of development. It lacks entirely the pink discoloration characteristic of the *Aspergillus* decay. The affected portions of the capsule are olive green in color and retain this uniform discoloration until the decayed parts dry up, at which time they become darker. The colored plate accompanying the Briton-Jones paper shows a very dark-brown color of the affected portions of the capsule, which may be observed in this country only at the time when the bolls begin to dry up.

In the earlier stages of the disease the specimens observed by the writer in the United States showed merely a dark-green color of the lesions (pl. 1, C), and little, if any, of the brown or reddish shades. The discoloration of the interior tissues of a freshly decaying boll

<sup>4</sup> L. L. Harter, of the Office of Vegetable and Forage Diseases, Bureau of Plant Industry, examined the writer's culture and confirmed its identification.

is not so uniform and homogeneous and varies from steel gray to slightly purple, with shades of pink and yellow, the latter shades occurring particularly in the seeds (pl. 1, D).

The fruiting stage of the fungus can also be readily distinguished from that of *Aspergillus niger*. The spore masses are not quite so dense as those of the latter organism, and they form a dark-gray or blue-gray rather than a sooty-black powdery film over the boll (compare pl. 1, A, with pl. 1, C, and pl. 2, B). The progress of the decay is somewhat more rapid than that observed in the case of *Aspergillus*, as for example under humid greenhouse conditions.

With respect to other characteristics, the two diseases are very similar. The *Rhizopus* decay may break through at points other than the infection wound and may affect either the entire boll or only a part of it. In the latter case the unaffected part may open up and the fungus fructification be seen on the inside, much in the manner shown for the *Aspergillus* decay. Moreover, it affects not only the capsule but also the immature lint and the seeds, as is clearly evident from the illustrations in Plate 1.

*Rhizopus nigricans* was isolated by the writer also from discolored pedicels, dying small squares, and spots on bracts. It frequently occurs on stem lesions of young cotton seedlings showing symptoms of sore shin, either alone or in association with other fungi. These lesions may be reproduced by means of artificial inoculations with pure cultures of the fungus (9), although not so readily as with *Rhizoctonia solani*.

The results obtained by inoculating cotton bolls with *Rhizopus nigricans* are given in Table 2.

TABLE 2.—Results of inoculating cotton bolls with *Rhizopus nigricans*

Group and kind of material used	Time between inoculation and final examination (days)	Inoculated				Controls				Remarks
		Injured		Uninjured		Injured		Uninjured		
		Total number	Number affected							
Group 1: Green-picked bolls in moist chambers.	5	12	11	-----	12	0	-----	-----	91.7 per cent infection in Group 1; the outer capsule was destroyed first, then the hard membranes were attacked, but the fiber seemed to remain unaffected.	
Group 2: Growing bolls in the greenhouse.	4	3	3	-----	(a)	(a)	(b)	(b)	Four inoculated bolls decayed completely, the remainder from one-third to one-half. Decay affected from one-third to one-half of the boll, breaking out on the side opposite the wound.	
	3	3	3	-----	(a)	(a)	(b)	(b)		
	4	6	6	-----	3	0	-----	-----		
Total in group...	-----	12	12	-----	3	0	-----	-----	100 per cent infection in Group 2.	
Group 3: Growing bolls in the field.	13	34	18	5	0	17	0	-----	Typical <i>Rhizopus</i> decay affecting from a portion to entire boll.	
	9	12	7	-----	6	0	-----	-----		
Total in group...	-----	46	25	5	0	23	0	-----	54.4 per cent of infection in Group 3.	
Total in three groups.	-----	70	48	5	0	38	0	-----	Average infection with wound inoculations, 68.6 per cent.	

<sup>a</sup> No injured checks were used in these cases.

<sup>b</sup> A number of uninjured bolls growing at the same time remained healthy.

## SUMMARY

Two forms of decay of cotton bolls, frequently referred to as "smut" in their later stages, have been found to occur commonly in southwestern United States.

These diseases are not true smuts and have only a superficial resemblance to the smuts.

One of these forms of decay is caused by *Aspergillus niger* Van Tiegh. and the other by *Rhizopus nigricans* Ehr.

The two diseases may be readily distinguished by the discoloration of the affected tissues as well as by the character of the fruiting stages of the parasites.

Both organisms readily produced rot of artificially wounded and inoculated cotton bolls, but failed to affect uninjured bolls.

The infection in the field apparently depends on injuries caused by various insects, the most noticeable of which are those caused by the bollworm. Control measures, therefore, will have to be directed chiefly against these insect enemies.

## LITERATURE CITED

- (1) BALLS, W. L.  
1912. THE COTTON PLANT IN EGYPT: STUDIES IN PHYSIOLOGY AND GENETICS. 202 p., illus. London.
- (2) BRITON-JONES, H. R.  
1923. A WOUND PARASITE OF COTTON BOLLS. Egypt Min. Agr., Tech. and Sci. Serv. Bul. 19, 8 p., illus.
- (3) ———  
1925. MYCOLOGICAL WORK IN EGYPT DURING THE PERIOD 1920-1922. Egypt Min. Agr., Tech. and Sci. Serv. Bul. 49, 129 p., illus.
- (4) HEALD, F. D.  
1926. MANUAL OF PLANT DISEASES. 891 p., illus. New York and London.
- (5) KIRKPATRICK, T. W.  
1925. NOTES ON THE FUNGUS RHIZOPUS NIGRICANS EHR., IN RELATION TO INSECT PESTS OF THE COTTON PLANT IN EGYPT. Egypt Min. Agr., Tech. and Sci. Serv. Bul. 54, 28 p., illus.
- (6) PHILLIPS, E. H., SMITH, E. H., and SMITH, R. E.  
1925. FIG SMUT. Calif. Agr. Expt. Sta. Bul. 387, 38 p., illus.
- (7) SHAPOVALOV, M.  
1919. SOME POTENTIAL PARASITES OF THE POTATO TUBER. Phytopathology 9: 36-42, illus.
- (8) ———  
1926. ASPERGILLUS DECAY OF COTTON BOLLS. (Abstract) Phytopathology 16: 75.
- (9) ———  
1926. WHAT IS "SORE-SHIN"? (Abstract) Phytopathology 16: 761.
- (10) VAN PELT, W.  
1917. BLACK MOLD OF ONIONS. Ohio Agr. Expt. Sta. Mo. Bul. 2: 152-156, illus.