

TEXAS AGRICULTURAL EXPERIMENT STATION
AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
W. B. BIZZELL, President

BULLETIN NO. 273

JANUARY, 1921

DIVISION OF PLANT PATHOLOGY AND PHYSIOLOGY

**PINK ROOT DISEASE OF ONIONS
AND ITS CONTROL IN TEXAS**



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PINK ROOT DISEASE OF ONIONS AND ITS CONTROL IN TEXAS

BY J. J. TAUBENHAUS AND FREDERICK W. MALLY*

INTRODUCTION

Onions are considered an important economic crop in Texas. Bermuda onions are grown especially in the Rio Grande Valley and in Webb, Dimmit, Zavala, La Salle, and Frio Counties. During the last fifteen years a disease, popularly known as pink root, has caused considerable damage, and it seriously threatens the profitable culture of onions on diseased lands. The acuteness of the situation in 1915 made the junior writer call on the Texas Agricultural Experiment Station for assistance in solving this problem. An arrangement was accordingly made, whereby the Division of Plant Pathology and Physiology of the Texas Agricultural Experiment Station, in cooperation with the growers and the county agent of Webb County, agreed to undertake the work with the hope of determining the cause of the pink root disease, and, if possible, to devise practical methods of control. With the exception of all the laboratory experiments, the junior author has wholeheartedly cooperated in all the field work for which he shares equal responsibility.

There is no doubt but that pink root has existed a long time in the onion district of Texas, and probably in other states of the Union. Its economic importance was recognized when the Texas acreage of Bermuda onions had expanded, and the Texas Bermuda onion was recognized among the northern markets as a very desirable early crop. Dr. O. M. Ball, Professor of Biology of the Texas A. and M. College, claims that he saw this disease some fifteen or twenty years ago. There seems no doubt but that he then observed the same trouble which is described in the present bulletin. A careful search through the literature, however, shows no mention whatsoever of any description before of an onion trouble that would correspond to the pink root disease now under discussion. It seems that at an early date Mr. W. M. Gilbert of the United States Department of Agriculture had at one time worked on this disease. In answer to our inquiry, under date of May 15, 1918, as to whether or not he ever published anything on it, Mr. Gilbert stated, "So far as I know, there are no publications on this disease." The senior author† in 1917 and later in 1918† was first to call attention to it in literature.

*County Agent, Webb County, Laredo, Texas.

†Taubenhaus, J. J. Pink root, a new disease of onions in Texas, *Phytopath.* 7:59, 1917 (Abstract).

†Diseases of Truck Crops, 1918. (E. P. Dutton Co., New York.)

ECONOMIC IMPORTANCE

It is not possible to state definitely the money loss incurred from pink root in Texas during the last fifteen years. Our studies date back only four years, and our estimates necessarily apply to that time. In general, the conservative estimator may easily place the losses from pink root, in badly diseased fields, from 35 or 43 per cent. to an occasional total failure. Assuming a normal yield on a healthy field to average about 400 crates per acre, one may see that the losses from pink root, all things being equal, will vary according to the following conditions: (1) The yields will be reduced when slightly or badly infected sets are planted in a healthy soil. Specific instances in many cases have shown a decided decrease in yield from 25 to 75 crates per acre or a direct loss of 6 to 18 per cent. Similar losses will occur when healthy sets are planted in a soil which is infected with pink root. (2) Heavy loss will occur when badly diseased sets are planted on badly infected pink root land, in which case there will be a decrease of from 100 to 200 crates per acre or a direct loss of 25 to 50 per cent. Assuming that the average normal price to the onion growers the past few years to be \$2.00 per crate in the April market and \$1.50 per crate in the May market, one can readily see that a loss of 100 to 200 crates per acre will represent a total net waste to the Texas grower of from \$200 to \$400 per acre for April, and \$150 to \$300 for May. These estimates are given as a basis so that every grower will be able to figure his annual losses from pink root, relatively and according to current annual prices. As a result of our investigations, it can be definitely stated that pink root of onions is primarily a field disease, and its effect is to reduce directly the yields of marketable onions.

Although pink root is only a field trouble, evidences tend to show that it is of economic importance as a transit disease. No extended investigations have as yet been carried out to determine definitely whether or not onions infected with the disease and coming from pink root land, have poorer carrying qualities in transit than those which are free from the disease and are grown on healthy soil. Recent observations, however, tend to indicate that onions from pink root soil are more subject to attacks of black mold decay, *Aspergillus niger*, and soft rot, *Bacillus caratovorvus*, than those which were grown on healthy land. This is especially true when the onions are dug during a wet spell, or when shipped under improper conditions of ventilation. In 1917 two crates of onions affected with pink root and two crates of healthy onions were secured from Laredo and shipped to Bryan, Texas. These were stored in crates under the living-house of the senior writer, and they were well protected from the sun. Within a period of four weeks the onions from pink root land decayed to the extent of 80 per cent. The nature of the decay was that of black mold, *A. niger*, and later it was followed by soft rot, *B. caratovorvus*. There were no indications whatsoever that the pink root organism was the cause of any decay of the bulb itself. The onions from the healthy land kept four weeks longer, but finally rotted from the same cause as above. Further studies are now in progress to determine the effect of pink root on storage qualities of onions. For the present, it is safe to suggest that

onions grown on pink-root infected land have somewhat poorer carrying qualities, and they rot earlier under storage conditions.

GEOGRAPHIC DISTRIBUTION OF PINK ROOT

Pink root is widely distributed, although its economic importance has not as yet become generally recognized in other states. The writer has had typical specimens of pink root sent to him by Professor Elizabeth Smith of California. Likewise, Dr. J. C. Walker, in a letter dated September 11, 1919, states that he found pink root of onions near Stockton, California, in a 2500-acre onion field, of which thirty acres were badly affected with pink root. Yields on that area were reduced 50 per cent. He further states that pink root is common on matured bulbs on old onion soil in the Wisconsin onion section, but apparently the disease has done little damage as the roots only turn pink near harvesting time. In 1917 the junior writer personally collected typical specimens of pink root of onions in Des Moines, Iowa. The disease, which was apparently doing but slight damage, was found on matured onions. Pink root of onions is prevalent in the Bermuda Islands, the original home of the Bermuda onion. Typical specimens of pink root of onions were collected by Professor Whetzel in the muck lands of New York and in the Bermuda Islands. Typical specimens of onions affected with pink root were received from Professor Leonard M. Outerbudge of the Department of Agriculture, East Bermuda. Cultures made from these specimens yielded a species of *Fusarium* which morphologically and physiologically seems to be identical with *F. mali*, the cause of pink root of onions in Texas. The writers have collected specimens of pink root of onions from practically every place visited in Texas where onions are grown, either commercially, or on a small scale. Table 1 indicates the present definite recorded distribution of the pink root disease of onions.

Table 1.—Distribution of Pink Root.

State.	County or City.	Collector.	Identified by.	Date.
Iowa....	Des Moines.....	F. W. Mally.....	J. J. Taubenhause.....	Aug. 9, 1917
Bermuda	Paget East.....	L. M. Outerbudge....	J. J. Taubenhause.....	April 14, 1920
				June 16, 1920
Texas....	Valley Wells.....	I. A. Hiatt.....	J. J. Taubenhause.....	Dec. 11, 1920
California	San Francisco.....	R. Watsuoka.....	J. J. Taubenhause.....	Feb. 7, 1920
California	Berkeley.....	E. H. Smith.....	J. J. Taubenhause.....	Sept. 1919
Texas....	Webb, Laredo.....	B. Richardson.....	R. H. Pond.....	Mar. 22, 1911
Texas....	Big Wells.....	McFadyen.....	J. J. Taubenhause.....	April 10, 1916
Texas....	Pearsall.....	Ira Durrenberger....	Ira Durrenberger....	April 25, 1915
Texas....	Mission.....	J. C. Walker.....	J. C. Walker.....	April 3, 1918
Texas....	Webb, Laredo.....	F. W. Mally.....	J. J. Taubenhause.....	Repeatedly
Louisiana	New Orleans.....	F. W. Mally.....	F. W. Mally.....	Mar. 22, 1918
Texas....	Webb and vicinity.	Taubenhause and Mally	Taubenhause and Mally	1915
Texas....	Webb and vicinity.	Taubenhause and Mally	Taubenhause and Mally	1916
Texas....	Webb and vicinity.	Taubenhause and Mally	Taubenhause and Mally	1917
Texas....	Webb and vicinity.	Taubenhause and Mally	Taubenhause and Mally	1918
Texas....	Webb and vicinity.	Taubenhause and Mally	Taubenhause and Mally	1919
Texas....	Webb and vicinity.	Taubenhause and Mally	Taubenhause and Mally	1920
New York	H. H. Whetzel.....	H. H. Whetzel.....	1920

It is, of course, speculative at this time to try to determine the place from which pink root was first introduced in Texas. Mention has already been made of the presence of pink root of onions in Bermuda,

the home of the Bermuda onion. It is possible, or even probable that the disease has been brought in from there to Texas with dry sets. Nowadays only onion seeds, and no dry sets, are purchased from the Bermuda Islands for seed-bed purposes in Texas. Texas growers do not plant dry sets extensively because of the fact that these produce an uneven crop with too many "splits" and "doubles." It seems quite certain that in the early history of the onion culture in Texas, pink root, with imported dry sets, was introduced from Bermuda. It is likely that pink root has been introduced in the same manner from Bermuda to the other states indicated in Table 1.

RANGE OF HOSTS SUSCEPTIBLE TO PINK ROOT.

Mention has been made of the fact that practically all varieties of onions and garlic are susceptible to pink root. In order to determine definitely how many of the genera and species of Liliaceous plants are susceptible to pink root, various varieties were secured and planted as indicated in Table 2. From Table 2, it is seen that neither the Narcissus, Tulip, Funkia, Iris, Fresia, Lillium, nor the Callas are subject to pink root. However, the onion, the shallot, the multipliers, and garlic, are all susceptible to the disease.

In order to determine the susceptibility of various varieties of onions to pink root, tests were made in a field which was badly infected with pink root. The varieties tested were: The Yellow Dutch, Strasburg, the Yellow Denvers, Australian Brown, Large Red Globe, Large Red Wethersfield, Large White Globe, White Portugal (Philadelphia), White Silverskin, and Extra Early Red. With the exception of the last, all of the others showed a very high percentage of pink root, ranging from 21 to 36 per cent. in the seed bed, up to 100 per cent. in the field. The Extra Early Red variety of onions showed a very small percentage of pink root, and it is probable that the seed under this name may have been the same, or similar to the Red Bermuda variety, which is fairly resistant to pink root. All the others tested were strictly northern varieties. Numerous other field trials and observations have shown beyond doubt that the Denia onion, a Spanish variety, is especially susceptible to pink root when transplanted in an infected pink root soil. It is safe to state that on badly infected soil, neither the Denia nor any other of the Spanish varieties should be planted. It is fortunate for the onion growers in Texas that the true Bermuda Crystal White Wax and the White (Yellow) Bermuda are decidedly more resistant to pink root than any other group or class of onion is. Practically all of the "multiplier" varieties of onions, as well as shallots, are all highly susceptible. Of the varieties of garlic, it appears that several strains of the Mexican and Italian are more susceptible to pink root than the large growing varieties known as the Chinese. Hence on a pink root-infected soil the latter should be preferred. Of the Mexican and Italian varieties, the pink type of garlic seems to be more susceptible than the white. The Mexican or Italian Whites are not so resistant as the large Chinese white types previously mentioned. Like the onion, the pink root of garlic is carried with the bulbs that are used for seed, and for planting purposes. Hence all the methods of

controlling pink root of garlic are practically the same as those which apply to onions.

Table 2.—Range of Liliaceous Hosts Susceptible to Pink Root.*

Host Used.	Date of Planting.	Date and Per Cent Pink Root.
Healthy dry Egyptian onion sets.....	Mar. 10, 1917	July 28, 71 per cent
15 Denia, healthy green sets.....	Mar. 10, 1917	July 28, 72 per cent
15 healthy shallots.....	Mar. 10, 1917	July 28, 48 per cent
15 healthy garlic bulbs.....	Mar. 10, 1917	July 28, 78 per cent
15 healthy onion sets, "multipliers".....	Mar. 10, 1917	July 28, 70 per cent
15 healthy bulbs, Narcissus Beauty.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Narcissus, Glory of Leiden.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Narcissus, Double Campenell.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Narcissus, Queen of Holland.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Narcissus, Victoria.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Narcissus, Empress.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Narcissus, Emperor.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Tulip, Mon Tresor.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Tulip, Dream.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Tulip, Faust.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Tulip, Psyche.....	Mar. 10, 1917	July 28, no pink root
15 healthy rhizomes, Funkia Subcordata.....	Mar. 10, 1917	July 28, no pink root
15 healthy rhizomes, Funkia Undulata Variagata.....	Mar. 10, 1917	July 28, no pink root
15 healthy rhizomes, German Iris, mixed.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Fnesia, var. Purity.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Lillium Trifolium.....	Mar. 10, 1917	July 28, no pink root
15 healthy bulbs, Calla Lily.....	Mar. 10, 1917	July 28, no pink root

*Greenhouse tests in pink root-infected soil.

SYMPTOMS OF THE DISEASE

The symptoms of pink root disease of onions are very striking. The trouble is confined only to the growing roots, bulb plate and crown, but not to the onion or garlic bulb itself. Affected root crowns frequently have yellowish roots. These may later turn pink or they may remain yellow indefinitely. The yellow, however, does not seem to be a stage of the pink root disease, but merely indicates an unhealthy condition. Yellow root invariably opens the way to later infections of the pink root disease.

The name pink root best describes the symptoms of the malady. Affected roots are dry, dead, and possess a distinct pink color which fades slightly as the roots are exposed to the sun. The disease may appear at an early stage in the seed bed. It is found in the field during all the stages of the development of the plant, but it checks growth more severely as the plants begin bulbing or the bulbs approach maturity. In light stages of infection, only a few roots may show the pink color, whereas in advanced stages, every root of the bulb may be affected. In severe cases, the roots become pink as fast as new ones are formed. Such plants, at the end of the season, have spent all their energy in producing new roots. Thus they become permanently stunted, and fail to produce a marketable sized bulb (Fig. 1, a and b). In this case, a projecting nipple is formed at the bottom plate of the bulb (Fig. 1, c to f), the nipple merely indicating the area in which the old roots were produced and died, and the outer demarcation where new roots were continually being formed.

In the seed bed, the disease is seldom severe enough to stunt the green sets. Hence, outwardly, there is little to indicate the presence of

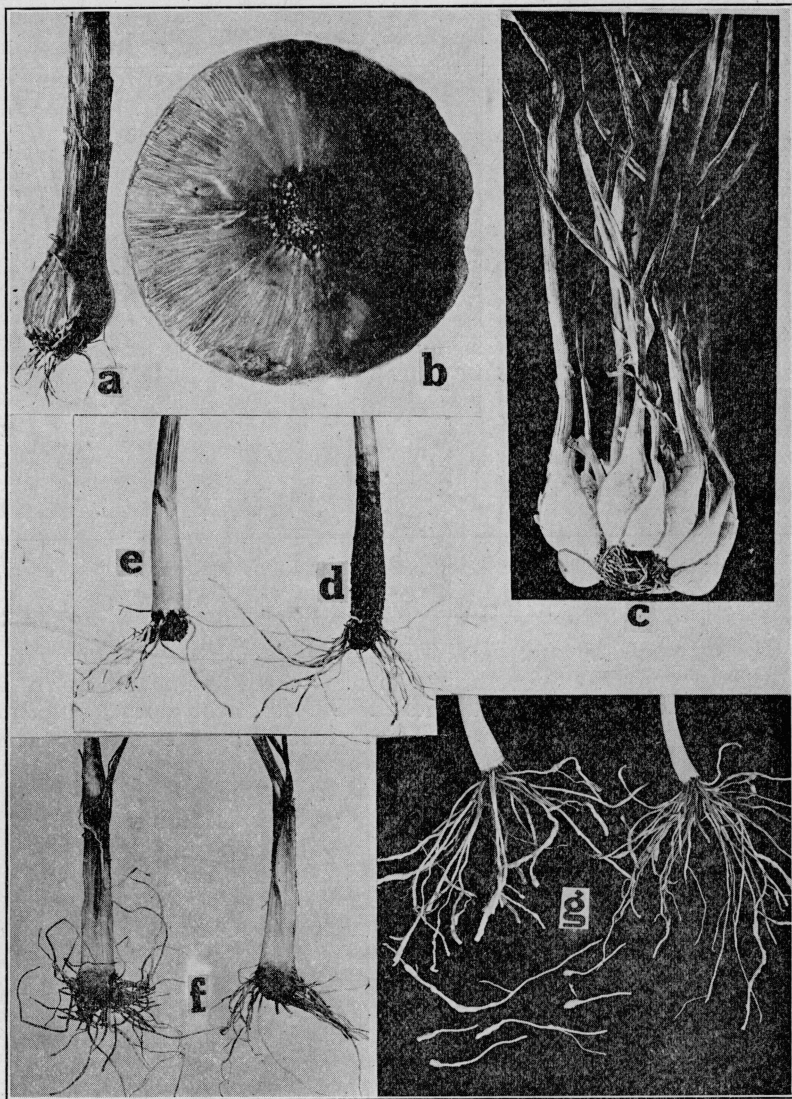


Figure 1.

- (a) Extreme case of onion plant infected with pink root. This plant is of the same age as the onion shown in (b).
 (b) Healthy, mature onion bulb for comparison.
 (c) "Multiplier" onion affected by pink root, showing the typical nipple formation.
 (d) and (e) Two young green onion sets badly infected with pink root and showing the nipple formation.
 (f) The same plants as (d) and (e) cut longitudinally to show the nipple and the diseased bulb plate.
 (g) Onion sets, the roots of which are affected by root knot.

pink root until the green sets are pulled and the roots examined. Diseased plants are quickly and easily recognized, and hence the extra expense in culling out and discarding them will be money well invested. In the main field, too, there are few outward symptoms to indicate the presence of pink root. In severe infections, however, the plants are stunted and seem to make little or no headway. It is during harvesting that the serious result is noticed. Diseased bulbs are slightly to severely undersized. The roots are either few or all pink and dry with the characteristic nipple present. After the bulbs have been exposed to the sun for drying, the pink color on the diseased roots, although slightly faded, contrasts strongly with the white of the healthy ones. Frequently, and due largely to favorable cultural conditions, the growth of the onion plant in a pink-root infected soil is faster than the disease can destroy the roots. In that case, the bulb matures, producing an average fair sized onion, with only a portion of its roots showing the disease. It is cases like these which tend to mislead the grower into believing that pink root is not a serious disease in reducing materially the final yields.

CAUSE OF THE DISEASE

For a long time, onion growers in Texas have maintained that pink root was not a disease; but that it was brought about through alkali in the soil, through the attack of thrips, or through working into the soil of a green cover crop, particularly black-eyed peas. In order to determine definitely whether or not the attack of thrips will bring about pink root, virgin land was secured in Laredo. This was planted first into an onion seed bed. Later some of the healthy green sets were transplanted on this virgin soil for the main crop. Neither the seedlings nor the transplanted sets were sprayed with any insecticide, so that in both cases a severe attack of thrips took place. At the end of the season and at digging time, it was found that the yield was reduced to a minimum, but that there was not a single matured bulb which was affected with pink root. This test and many similar observations conclusively show that thrips by themselves do not cause pink root. Thrips, however, are sometimes a very important factor in favoring the development of the disease in the sense that the plants are badly weakened and root growth decidedly retarded. Such a condition is most favorable for the attack of pink root.

It is believed by some growers that pink root of onions is induced by alkali in the land. Careful chemical analyses were made by Dr. G. S. Fraps of the Chemistry Division of the Texas Agricultural Experiment Station. These results are shown in Table 3, which gives alkali analysis of pink root-infected soils. From Table 3 by Dr. Fraps, it is evident that all of these samples of soil contain some alkali. The alkali content is higher where pink root is present, excepting with sample No. 11557. Surface soil 11528 and 11540 are both high in alkali, and this alkali consists largely of nitrate. Alkali was found near the surface in some of the soils suffering from pink root, such as soils 11532 and 11542, as well as 11588. Soil 11557 did not have much alkali, but this soil received an unbalanced fertilizer consisting of 1000 pounds acid phosphate and 200 pounds of nitrate of soda. It

is possible that this unbalanced fertilizer contributed to the tendency of the plants to have the disease.

From these analyses, as will be shown later, alkali may be developed in the onion districts, but its association with pink root is only incidental. To keep down alkali, the land must be provided with ample drainage, and then the water should be used in such quantities as to wash it out of the soil. Manure, or a rotation of crops which will add vegetable matter, should be used on heavy soils such as Laredo silty loam or Laredo clay loam. This will make the soil more porous and allow the surplus water to penetrate deeper into the subsoil. For alkali soils which are infected with the pink root disease, and in which the alkali is due mostly to nitrates, it is best not to use nitrate of soda as a top dressing, but to use some other form of nitrogen, preferably sulphate of ammonia.

Table 3.—Alkali in parts per million of soil.

Sample No.	Kind of Soil.	Kind of Alkali.			Total Alkali.
		Nitrates	Sulphates	Chlorides	
11528	Webb fine sandy loam, surface soil, much pink root	1050	237	114	1401
11529	Subsoil 11528, 6 to 12 inches	750	258	125	1133
11530	Subsoil 11528, 12 to 24 inches	1050	95	166	1311
11531	Subsoil 11528, 24 to 36 inches	300	208	197	705
11532	Alkali scrapings	5650	1465	2501	9616
11533	Webb fine sand, near road, some pink root	120	286	284	690
11534	Subsoil 11533, 6 to 12 inches	90	204	148	442
11535	Subsoil 11533, 12 to 24 inches	0	201	99	300
11536	Webb fine sandy loam, no pink root	30	300	191	521
11537	Subsoil 11536, 6 to 12 inches	30	296	172	498
11538	Webb fine sand, good soil, no pink root	30	216	147	393
11539	Subsoil to 11538, 6 to 12 inches	8	200	218	226
11540	Laredo silty loam, much pink root	4200	0	472	4672
11541	Subsoil to 11540, 6 to 12 inches	1500	54	417	1971
11542	Alkali scrapings	450	570	345	1365
11543	Laredo clay loam, some pink root	3	438	429	860
11544	Subsoil to 11543, 6 to 12 inches	0	302	261	563
11545	Laredo silt loam, no pink root	15	320	244	579
11546	Subsoil to 11545, 6 to 12 inches	5	237	241	483
11547	Laredo silt loam, no pink root	3	176	203	382
11548	Subsoil 11547, 6 to 12 inches	0	138	219	357
11549	Webb fine sandy loam, no pink root	3	213	180	396
11550	Subsoil to 11549, 6 to 12 inches	0	160	201	361
11557	Laredo silt loam, much pink root	0	226	170	396
11558	Subsoil to 11557	0	233	117	350
11559	Webb fine sandy loam, much pink root	8	298	289	595
11560	Subsoil to 11559, 6 to 12 inches	10	217	256	483
11588	Soil near peeler			9950	9950
11589	Subsoil to 11588			3298	3298

It is probable that the alkali increases the liability of the onion to disease by decreasing its resistance. Other adverse influences could have a similar effect. In order to determine definitely whether traces of alkali in the soil will induce pink root of onions, infected soil was secured at Laredo from nearly the same spots where the samples for the chemical analyses were taken and which were referred to in Table 3. This soil was distributed in five-inch pots and disinfected with formaldehyde at the rate of one pint in twenty gallons of water. Three pots were untreated and left as a check. Ten days after treatment, the pots were sown to onion seeds, which sprouted normally. The seedlings were then allowed to remain in these pots for nearly ten weeks, and they were thinned as they grew larger. Ultimately, as the plants were

pulled out for final examination, all in the check pots showed a high percentage of pink root, whereas those in the soil treated with formaldehyde were all healthy. This proved conclusively that, although these soils show traces of alkali as indicated in Table 3, this alkali is apparently not sufficiently strong to injure plant growth, and it does not develop pink root where the soil is sterilized with formaldehyde. But in the check pots where the soil was not sterilized, pink root was present on many of the seedlings. This proved definitely that the trace of alkali in the soils of Table 3 was not responsible for pink root, but that the latter was induced by a definite parasite in that soil. Furthermore, alkali in the soil is not a constant factor. It varies, rising and falling with the increase or decrease of water in the soil; whereas pink root is on the increase where onions are grown too long on the same land.

To determine definitely the cause of pink root, the following experiments were carried out:

Artificial Inoculation. In order to obtain the causal organism of pink root, over 1000 plate cultures were made from onion roots which showed typical pink root disease. Over twenty-five various fungi were isolated, among which were two species of *Fusaria* (Fig. 2, d to g). Each of the organisms was tested out as to its pathogenicity. The method employed was as follows: Typical onion soil was secured from Laredo and steam sterilized at fifteen pounds pressure, for three hours at two-day intervals. When the soil in the pots cooled down, pure cultures of each organism were introduced in each of a set of two pots which were planted with healthy onion sets. These plants were allowed to grow for two months. After that time, the plants were taken out and examined for pink root. Of all the organisms tested, only one species of *Fusarium*, which is here referred to as *Fusarium* No. 1, was capable of reproducing pink root. The general results of the inoculations with this *Fusarium* is shown in Table 4. From this table it is seen that *Fusarium* No. 1 was able to induce pink root infection, although the percentage was small compared to the infections obtained when healthy plants were planted in pink root soil. There seems no doubt but that *Fusarium* No. 1, tentatively named *F. malli*, is one of the organisms which is the cause of pink root. In nature, however, it seems probable that other organisms, especially species of *Fusaria* in combination with *F. malli* help to increase its virulence. This is perhaps why small percentages of infection are secured with *F. malli* in artificial inoculations and high percentages of infection are secured by merely planting healthy sets in a pink root-infected soil. The role of the possible association of other organisms with *F. malli* in increasing its virulency is now being further studied and will be reported at a later date. At the present time it is sufficient to state definitely that the cause of pink root of onions, shallots and garlic is a fungus, *Fusarium malli*, and that possibly other fungi, especially *Fusarium* No. 2, may be associated with it to increase its virulency.

Table 4.—Artificial Inoculation.

Source of Fusarium Used for Inoculation.	Kind of Soil Used.	Host Used.	Date of Inoculation.	Date and Per Cent of Infection.
F. No. 1, isolated from diseased onion plants in seed bed.	Steam sterilized pink root soil.	25 healthy onion sets grown from seed on steam sterilized soil.	June 15, 1918.....	Aug. 10, 14 per cent.
F. No. 1, isolated from pink root soil.	Steam sterilized garden loam...	28 healthy green sets from seeds grown on steam sterilized soil.	June 10, 1920.....	Aug. 3, 5 per cent.
Check.....	Pink root soil from Laredo.....	42 healthy green sets from seed grown on steam sterilized soil.	Healthy sets planted in pink root soil, July 1.	Aug. 26, 100 per cent.
Check.....	Pink root soil from Laredo.....	42 healthy green sets from seed grown on steam sterilized soil.	Healthy sets planted in pink root soil, July 6.	Sept. 1, 100 per cent.
Check.....	Steam sterilized soil*.....	42 healthy green sets from seed grown on steam sterilized soil.	Sets planted in steam sterilized soil, June 1.	Sept. 18, all healthy.
F. No. 1, isolated from pink root-infected shallots.	Steam sterilized soil*.....	Egyptian onions from Temple, Texas.**	May 10.....	July 2, 15 per cent.
Check.....	Steam sterilized soil*.....	Egyptian onions from Temple, Texas.	Sets planted July 18.....	Sept. 15, all healthy.
F. No. 1, isolated from diseased onion sets.	Steam sterilized soil*.....	19 garlic bulbs secured from local market apparently free from pink root.	May 8.....	July 19, 24 per cent.
Check.....	Steam sterilized soil*.....	19 garlic bulbs secured from local market apparently free from pink root.	Garlic bulbs planted in healthy soil May 8.	July 19, all healthy.
F. No. 1, isolated from diseased green sets.	Steam sterilized soil*.....	22 mature healthy onions secured from local markets and originally grown in healthy field.	June 1†.....	July 10, 5 healthy, remainder rotted by <i>Aspergillus niger</i> .
F. No. 1, isolated from diseased green sets.	Steam sterilized soil*.....	50 tubers Irish cobbler potatoes	June 15***.....	Aug. 10, 2 partly decayed by <i>Aspergillus niger</i> , remainder healthy.

*The soil was steam sterilized at 15 pounds pressure for three hours at two-day intervals.

**These sets were secured from Substation No. 5, Temple, Texas, where the Egyptian onions grew on a black waxy soil and where pink root never has been observed before.

†It is evident that from this check the bulbs secured at a local market were previously infected with pink root.

***Method of inoculation consisted in inserting bits of mycelium of Fusarium No. 1 in the slits made in the scales of the bulb.

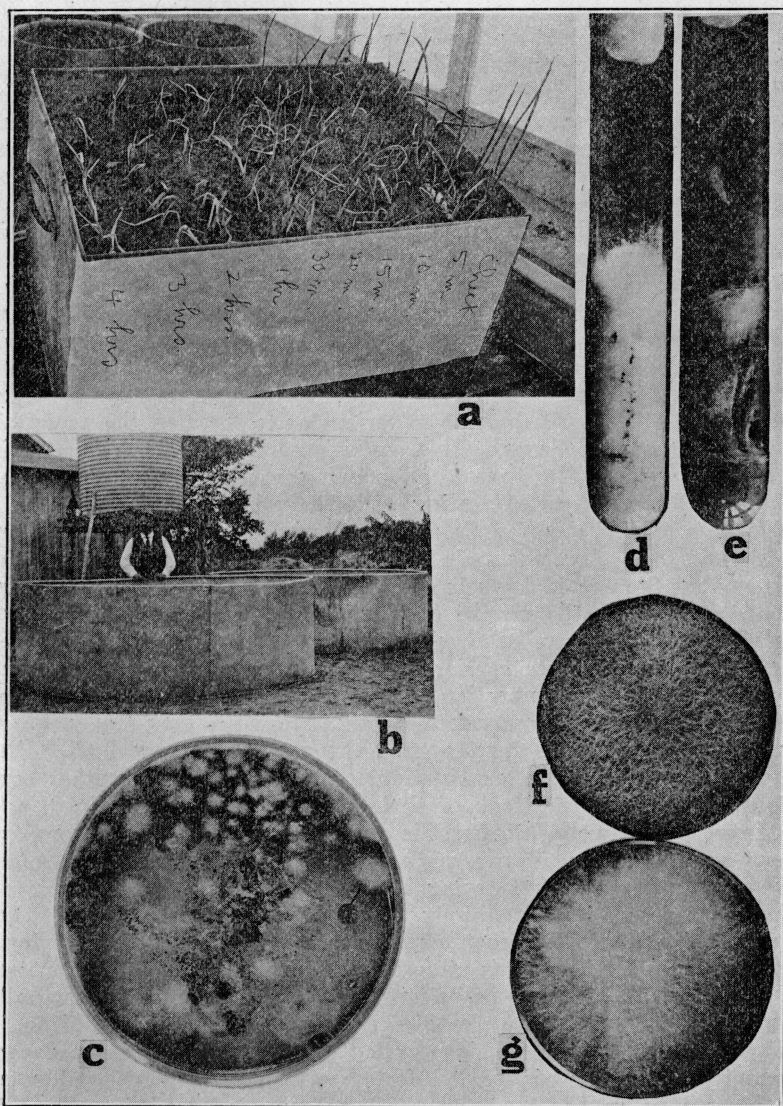


Figure 2.

- (a) Green onion sets treated for various lengths of time in formaldehyde solution.
- (b) Tanks for dipping onion sets against thrips.
- (c) Crush culture from onion roots infected with pink root, showing *Fusarium* growth and a few bacterial colonies.
- (d) *Fusarium* No. 2 on potato plug.
- (e) *Fusarium mali* on potato plug for comparison and showing the thick mass of pionnotes.
- (f) Plate culture of *Fusarium mali* on hard bean agar.
- (g) Plate culture of *Fusarium* No. 2 on hard bean agar.

CARRIERS AND CONDITIONS WHICH FAVOR PINK ROOT

Careful studies both in the field and in the laboratory have shown that the spread of pink root and the amount of loss from this disease depend on many factors, chief of which are as follows:

The Soil. It is a well known fact that the largest onions and the heaviest yields are produced on lands which are rich in humus and plant food, and which have not as yet been exhausted through a system of one-crop farming. Likewise, the greatest damage from pink root is actually met with on lands known to be deficient in plant food, chief of which may be mentioned nitrogen and humus, especially where onions were grown on the same land for a period of years.

In order to determine whether or not the soil is a possible carrier of pink root, experiments were planned as indicated in Table 5. From this table there seems no doubt whatsoever that the soil is a carrier of this disease. This means that if a soil once becomes infected with pink root, and if onions or garlic are grown successively for a period of years, the disease will become so serious as to threaten the profitable culture of these two crops. This condition has actually happened in many onion sections in Texas, and many growers are now confronted with the sad experience of dealing with badly infected land.

The Sets. In Webb County, and in Texas in general, dry sets are not planted to produce the main crop for market. It is found by most growers that the use of dry sets results in producing too many "splits" or "doubles" which the market does not want. Hence onion seeds are planted in seed beds and the resulting green sets transplanted in the field. That the soil is a carrier of pink root has already been shown on page 15. In this connection, it was not very difficult to show that seed beds, when made on infected land, produced pink-root diseased sets; and that these in turn carried the malady to new land. Frequently, because of poor germination, or of unfavorable weather conditions, or of a severe attack of thrips, the seed beds are ruined, and the grower is compelled to buy his green sets elsewhere and from unknown sources. In this way, pink root may be introduced into one's land without his even suspecting it.

In order to determine definitely whether or not green or dry sets are possible carriers of pink root, experiments were carried out as indicated in Table 6. From this table it is conclusive that when green sets are grown on soil known to be infected with pink root, they will actually become infected and carry the disease from place to place. This in reality is a condition which is prevalent; namely, the onion seeds are frequently planted on pink-root infected soil. Later the infected green sets are transplanted to the field, and the disease is introduced. In this way pink root is spread broadcast without the grower's suspecting it. Furthermore, when such sets are planted in the fields, they are handicapped in the sense that they have to struggle hard to overcome the effect of the pink root. This is only possible when soil and climatic conditions are favorable.

Sudden freezes, or a sudden drouth due to an unavoidable breakdown of the irrigation plant, will invariably result in further weakening of the plants and eventually in poor yields or total failure. Any shock which will set back the diseased onion plant will only increase pink

Table 5.—The soil as a carrier of pink root.

Soil Used for Inoculant.	Soil Inoculated.	Host and Number Used.	Date of Inoculation.	Date and Per Cent of Infection.
Diseased pink root soil.....	Steam sterilized pink root soil.....	35 healthy sets.....	Feb. 6, 1917	April 2, 70 per cent.
Diseased pink root soil.....	Steam sterilized pink root soil.....	35 healthy green sets previously grown in greenhouse.	April 3, 1917	June 10, 69 per cent.
None.....	Steam sterilized pink root soil.....	35 healthy green sets previously grown in greenhouse.	April 3, 1917	June 10, all healthy.
None.....	Pink root soil.....	35 healthy green sets previously grown in greenhouse.	April 3, 1917	June 10, 80 per cent.
Pink root soil.....	Steam sterilized pink root soil.....	35 healthy green sets grown in greenhouse.	Feb. 15, 1917	June 10, 72 per cent.
None.....	Healthy soil from College Station truck garden.	35 healthy dry sets.....	Feb. 10, 1917	March 15, all healthy.
Pink root soil.....	Steam sterilized pink root soil.....	35 healthy green sets grown in greenhouse.	May 10, 1917	July 1, 75 per cent.
Pink root soil.....	Unsterilized sweet potato sandy loam from Delaware.	35 healthy sets grown in greenhouse...	July 15, 1917	August 28, 80 per cent.
None.....	Steam sterilized sweet potato sandy loam from Delaware.	35 healthy dry sets.....	July 15, 1917	August 28, all healthy.
None.....	Unsterilized sweet potato sandy loam from Delaware.	35 healthy dry sets.....	July 15, 1917	August 28, all healthy.
Cut off roots from infected green sets.	Steam sterilized pink root soil.....	35 healthy green sets grown in greenhouse.	June 1, 1917	August 10, 38 per cent.
Cut off roots from infected green sets.	Steam sterilized pink root soil.....	35 healthy green sets grown in greenhouse.	June 1, 1917	August 10, 31 per cent.
Cut off roots from infected green sets.	Steam sterilized pink root soil.....	35 healthy green sets grown in greenhouse.	June 1, 1917	August 10, 39 per cent.
Cut off roots from infected green sets.	Steam sterilized sweet potato sandy loam from Delaware.	35 healthy green sets grown in greenhouse.	July 3, 1917	August 15, 52 per cent.
None, check.....	Steam sterilized sweet potato sandy loam from Delaware.	35 healthy green sets grown in greenhouse.	July 3, 1917	August 15, all healthy.
None.....	Steam sterilized pink root soil.....	35 healthy green sets grown in greenhouse.	July 3, 1917	August 15, all healthy.
None.....	Unsterilized truck garden soil, College Station.	35 healthy green sets grown in greenhouse.	July 3, 1917	August 15, all healthy.

Table 6.—Onion sets carriers of pink root.

Nature of Onion Sets.	When and Where Planted.	Results.
Diseased sets from Laredo*.....	In sweet potato sandy soil from Delaware, March 3, 1916.....	All pink root, November 3.
Diseased sets from Laredo*.....	March 3, 1916, watermelon soil shipped from Prairie View**.....	All pink root, November 3.
Diseased sets from Laredo*.....	November 3, roots cut, planted in steam sterilized soil.....	January 22, 1917, all pink root.
Diseased sets from Laredo*.....	November 6, roots cut off, planted in steam sterilized soil.....	All pink root.
Healthy sets from Laredo soaked in 5 per cent formaldehyde for five minutes.....	November 3, 1916, steam sterilized soil, roots cut off.....	Not a trace of pink root.
Diseased sets from Laredo.....	Roots cut off, planted in pink root soil.....	All very bad case of pink root.
Sets with doubtful pink root from Laredo.....	November 9, steam sterilized soil, roots not cut off.....	All pink root.
Sets with doubtful pink root from Laredo.....	November 9, in steam sterilized soil, roots cut off.....	30 per cent pink root.
Sets with yellow roots from Laredo.....	November 13, roots cut off, planted in steam sterilized soil.....	4 per cent yellow and pink root, all others pink root.
Sets with yellow roots from Laredo.....	November 13, roots cut off, planted in steam sterilized soil inoculated with soil and roots from seed bed showing yellow root.	All show yellow and pink root.
Diseased sets from Laredo.....	November 6, 1916, roots cut off, planted in steam sterilized soil to which was added soil from pink root bed as well as bits of diseased pink roots cut off from diseased sets.	January 23, 1917, all definite yellow and pink root.
Diseased sets from Laredo.....	November 6, 1916, roots cut off, planted in steam sterilized soil to which was added soil from pink root bed as well as bits of diseased pink roots cut off from diseased sets.	January 23, 1917, all definite yellow and pink root.
Healthy sets from Laredo.....	November 9, 1916, roots not cut off, soaked for 10 minutes in 2 per cent formaldehyde, planted in steam sterilized soil which was then inoculated with pink root cut off from infected sets.	January 23, 1917, all typical yellow root.
Healthy sets from Laredo.....	November 9, 1916, roots not cut off, soaked for 10 minutes in 2 per cent formaldehyde, planted in steam sterilized soil.	All healthy.
Healthy sets from Laredo.....	November 9, 1916, roots cut off, soaked for 10 minutes in 2 per cent formaldehyde, planted in steam sterilized soil inoculated with pink root.	All yellow and pink root.
Diseased sets from Laredo.....	November 14, roots not cut off, planted in steam sterilized soil.....	January 23, all pink and yellow root.
Healthy sets from Laredo.....	November 6, 1916, roots cut off, planted in steam sterilized soil inoculated with pink root soil.	January 23, all pink and yellow root.
Healthy sets from Laredo.....	November 6, 1916, roots not cut off, planted in steam sterilized soil inoculated with pink root soil.	January 23, all pink and yellow roots.

*Diseased sets here means those affected with pink root.

**This soil never grew onions as far as was known.

root. The only appreciable way of assisting infected sets to overcome the disease is to encourage rapid growth so that new roots may be developed faster than they are destroyed by the disease. For practical purposes, therefore, it is essential always to begin with a healthy soil and healthy sets. When one pulls sets for transplanting he should carefully inspect them, and discard those which show pink root, even though this process of selection would mean a loss of diseased sets and extra labor. Under normal labor conditions, culling would cost about from \$6 to \$10 per acre. In buying green sets, one should secure them from localities known to be free from pink root, or he should see that the sets are accompanied with a certificate as to freedom from disease.

Poor Leveling. Repeated field observations have shown that wherever infected soil in the seed bed, or in the beds of the main crop, is not properly leveled, a condition which prevents the even distribution of water, pink root is very prevalent. Improper leveling results in numerous high spots where water cannot reach. Pink root is actually more prevalent and more severe in these higher spots. Sets growing in these dry higher spots are naturally weakened and hence become a ready prey to pink root.

Irrigation. It is very essential from the point of view of preventing pink root to encourage rapid and vigorous growth of the plant, once it has been set out in the field. A vigorous young onion set, when transplanted in the field, will develop new roots within three days after the transplanting, provided, however, that the soil contains sufficient moisture and nourishment. Hence it is important that irrigation should be given immediately after the transplanting. It is not desired to convey the idea that there is danger of losing plants from slight delay in following with irrigation after the setting out of the young onions, but that an appreciable delay in irrigation immediately after the transplanting will delay the formation of new roots, and this is favorable to a severe infection of pink root.

Weather Conditions. It is a known fact that weather conditions have a direct influence on the spread or the limitation of pink root. While it is desirable to plant seed beds early, this should not be done too early in the season. On the other hand, too late sowing is undesirable because the crop will have to make most of the growth for bulbing during the hot weather. A check in growth of the crop brought about by freezing, or delaying bulbing and maturity into the season of extreme hot weather, is equally favorable to pink root. An attempt is frequently made to grow green onions during the entire year to supply the table demands of the local market. Observations have shown that when this is done under Webb County conditions, which practically means growing onions during the hot summer months, these onions suffer very severely from pink root, much more so than when they are grown in the same soil early in the season. Furthermore, the land itself becomes badly infected and unfit for another crop of onions. From a practical consideration, therefore, only one crop of onions should be grown on the same land during the year. If possible, the crop should be matured and harvested before the hot weather strikes it.

Eel Worm. It is believed by many, that eel worm causes pink root. This is not the case because, as was already shown in Table 4, pink root is caused by a definite parasitic *Fusarium*. Eel worm is a para-

site infesting the roots which is distinct and should not be mistaken for pink root. Eel worm infestations are characterized by swellings on the growing roots (Fig. 1, g). These swellings are induced by the presence of minute worms (*Heterodera radiculicola*) within the tissue of the attacked roots. While it is certain that the eel worm does not cause pink root, it frequently opens the way for pink root infection (1) by weakening the plants, (2) by wounding the roots and by thus opening the way for infection. Growers should, therefore, make doubly certain not to plant onions in a soil known to be infested with both pink root and eel worm. To disregard this would mean extremely poor yields or certain failure. Furthermore, the treatment to sterilize soil infested with eel worm is too expensive on a large scale to justify the cost. Such land should be devoted to the culture of the true type of Hairy Peruvian alfalfa, which has proved so valuable in Webb County.

It is claimed that cyanamid will rid a soil of eel worm and also act as a fertilizer, because of the nitrogen which it contains. A quantity of cyanamid was sent to the writers with the request to try out its effect on nematode control. Some of this was applied outdoors to an onion field infested with nematode and pink root. The field treatment with cyanamid amounted to 300 pounds per acre, given at two intervals. The first 150 pounds were applied November 22, and the second amount, January 19. The field effect of the cyanamid is shown in Table 7. From this table it is evident that cyanamid at the rate of 300 pounds per acre actually increased the total yield of marketable onions per acre. However, in the carefully checking up its effect on nematode, it was plainly evident that it did not control this pest. Its beneficial effect in increasing the general yield was probably due to the available nitrogen which it contains; hence in this respect it deserves consideration.

Further outdoor trials with cyanamid in the seed beds, using it at the rate of 250 pounds, 500, 1000 and 2000 pounds per acre, showed no ill effect on germination, or on the general growth of green sets. It also failed to reduce or control either nematode or pink root.

It has been stated that field applications of cyanamid at the rate of 2000 pounds (1 ton) per acre exerted no ill effect on germination, or on the general growth of the onion plants in the field. It was, therefore, thought desirable to try stronger applications of cyanamid with the hope of controlling nematode and perhaps pink root. Accordingly, experiments were carried out, in the greenhouse, on onion plants and on cowpeas (black-eyed variety), both growing in badly infested soil. The amount of cyanamid is indicated in Tables 7 and 8, which varied from $3\frac{1}{2}$ tons to $402\frac{1}{2}$ tons per acre. The results of these amounts on onions is shown in Table 7. From this table it is seen that cyanamid, when applied at the rate of $3\frac{1}{2}$, 7, $10\frac{1}{2}$, 14, and $17\frac{1}{2}$ tons per acre, retarded the growth of the plants, and neither the pink root nor the nematode was kept in check. Furthermore, applications varying from 35 tons to $402\frac{1}{2}$ tons per acre actually killed outright the green onion sets. From this experiment, it is evident that cyanamid up to one ton may be safely applied in field conditions where it would probably exert a stimulating effect on the general growth and on yield, but it will not control nematode. Applications stronger than one ton per acre will result in severe injury to the crop. The effect of strong applications of cyanamid on the black-eyed peas is well shown in Table 8.

From this table it is seen that with an application of 3½ tons, growth is gradually checked, and this checking of growth varies directly as the number of tons per acre were increased from 3½ to 7½. In the further increasing of the amount from 7½ to 402½ tons per acre, the growth was practically inhibited. As to the effect of cyanamid on nematode control in the black-eyed pea, it was found that an application varying from 3½ to 14 tons per acre had no effect whatsoever in reducing the amount of root knot. However, when applied at the rate of 17½ tons up to 140 tons, the nematode was actually reduced, and its activity was only confined to the few surface rootlets. Furthermore, with an application at the rate of 175 tons to 402½ tons per acre, the root sys-

Table 7.—Effect of cyanamid on control of pink root and nematode.*

Amount Cyanamid Used Per Pot.	Amount Cyanamid in Tons Per Acre.	Date of Planting and Number and Kind of Host Used.	Results and Date.
1 gram	3.5	Feb. 11, 1918, 35 pink root and nematode affected green sets.	March 20, 1918, 100% nematode and pink root, poor growth.
2 grams	7	Feb. 11, 1918, 35 pink root and nematode affected green sets.	March 20, 1918, 100% nematode and pink root, poor growth.
3 grams	10.5	Feb. 11, 1918, 35 pink root and nematode affected green sets.	March 20, 1918, 100% nematode and pink root, poor growth.
4 grams	14	Feb. 11, 1918, 35 pink root and nematode affected green sets.	March 20, 1918, 100% nematode and pink root, poor growth.
5 grams	17.5	Feb. 11, 1918, 35 pink root and nematode affected green sets.	March 20, 1918, 100% nematode and pink root, poor growth.
10 grams	35	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
20 grams	70	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
30 grams	105	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
40 grams	140	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
50 grams	175	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
60 grams	210	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
70 grams	245	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
80 grams	280	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
90 grams	315	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
100 grams	350	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
115 grams	402.5	Feb. 11, 1918, 35 pink root and nematode affected green sets.	Plants all dead.
Check**...	Check.....	35 healthy green sets grown in greenhouse, Feb. 11, 1918.	

*Soil used in this experiment was from a pink root and nematode infected field from Laredo, in duplicate 5 inch pots.

**Soil used was steam sterilized.

tem was practically burned, and in no case could there be found a single root knot swelling; indicating apparently that, at the rate of these enormous applications, the nematode was actually controlled, but growth as well as root system was nearly destroyed. In general, therefore, it may be safely stated that cyanamid is not able to control root knot as far as the tender herbaceous crops are concerned, but its use as a fertilizer for onions deserves further trials.

Thrips. Like eel worm, thrips are not responsible for the direct cause of pink root, but merely weaken the plants and open up the way for this disease. When young sets are attacked by a large number of thrips, the vitality of these plants is decidedly undermined, and they

frequently die out or produce undersized and unmarketable onions, even though the crop grows in an otherwise healthy soil. If, in addition to thrip injury, the soil is also infected with the organism of pink root, the result is usually disastrous, since in this case the infected plants have neither root to afford support nor top growth to supply vigor. It may therefore be said with certainty that when thrip infestation occurs on onions grown on a healthy soil, the effect is bad enough, although there is a possible chance for a fair yield. An attack of thrips, however, becomes disastrous on plants grown in pink root infected soil. In this case, then, it is practically useless to attempt to produce a marketable onion after it has been badly attacked by thrips, and spraying or dusting would be wasting time and money. In practice it has been repeatedly demonstrated that, if the soil is free from pink root, if it is well supplied with rapidly acting fertilizer, and if at the same time the plants are thoroughly sprayed or dusted to hold down thrips, other things being equal, the chances are for a good normal yield. On the other hand, when the plants are grown on a pink root infected soil which is deficient in proper fertilizer elements, no amount of treatment to destroy thrips will help the infested plants to regain their vigor and produce a normal yield.

That thrips do reduce the yield of onions grown on pink root soil is better shown in Table 11. The plants in Table 11 were grown on a badly infected pink root soil which was variously treated with fertilizers. The plants on this soil, however, were badly attacked by thrips before any spraying or dusting could be carried out, and the result as far as the yield was concerned was practically negligible.

When the onion grower is compelled to grow his onion crop on pink root-infected soil, every precaution should be taken not to allow the thrips to get the upper hand. Here spraying or dusting should be carried out arly and repeatedly as the thrips appear. In practice, to control thrips the plants are sprayed with Black Leaf 40. This solution is prepared as follows: Three to five pounds of good laundry soap are dissolved in boiling water. This is then slowly mixed in a barrel of cold water, making a total of forty gallons. To this soap solution is added $\frac{1}{4}$ pint of Black Leaf 40, also known as Nicotine Sulphate. For securing best results, high-power spraying machines are required, and these should be equipped with Vermorel nozzles. The onion plants should be thoroughly sprayed from side and top, entering into the crotch so as to reach every thrip, young or adult which may be crawling around any portion of the exposed parts of the host. This spraying should be repeated every three or four days after the thrips appear so as to control completely the pest. Frequently it is desirable to dip the sets in Black Leaf 40 solution, just as they are pulled from the seed beds and before they are planted in the field. In that case the same solution of Black Leaf 40 is used as mentioned above. To treat plants for about thirty acres by dipping, one ten-pound can of Black Leaf 40 to every 50 or 60 pounds of ordinary yellow soap dissolved in water will suffice. The soap is dissolved in galvanized tin tanks (Fig. 2, b) and poured into 1000 gallons of water, to which is then added the ten pounds of Nicotine Sulphate. The green sets are soaked for one hour and are then ready for immediate planting.

Table 8.—Effect of Cyanamid on nematode infected soil.*

Amount Cyanamid Per Pot.	Amount Cyanamid Per Acre in Tons.	Date of Planting, Number and Kind Host Used.	Effect of Growth.		Result.
			Length of Vines.	Length of Roots.	
1 gram	3.5	Mar. 30, 1918, 35 black-eyed pea seeds..	7½ in., fair growth.....	8 inches.....	Roots all covered with nematode.
2 grams	7	Mar. 30, 1918, 35 black-eyed pea seeds..	7 in., fair growth.....	8 inches.....	Roots all covered with nematode.
3 grams	10.5	Mar. 30, 1918, 35 black-eyed pea seeds..	6 in., fair growth.....	8 inches.....	Roots all covered with nematode.
4 grams	14	Mar. 30, 1918, 35 black-eyed pea seeds..	5½ in., rather poor color..	8 inches.....	Roots all covered with nematode.
5 grams	17.5	Mar. 30, 1918, 35 black-eyed pea seeds..	5 in., poor color.....	7 inches.....	Nematode galls fine but scattered near surface of root.
10 grams	35	Mar. 30, 1918, 35 black-eyed pea seeds..	3½ in., poor growth.....	6 inches.....	Nematode galls fine but scattered near surface of root.
20 grams	70	Mar. 30, 1918, 35 black-eyed pea seeds..	2 in., poor growth.....	5 inches.....	Nematode galls fine but scattered near surface of root.
30 grams	105	Mar. 30, 1918, 35 black-eyed pea seeds..	2½ in., poor growth.....	4 inches.....	Nematode galls fine but scattered near surface of root.
40 grams	140	Mar. 30, 1918, 35 black-eyed pea seeds..	2 in., poor growth.....	3½ inches.....	Nematode galls fine but scattered near surface of root.
50 grams	175	Mar. 30, 1918, 35 black-eyed pea seeds..	1½ in., only two seeds germinated.	Practically no root system.	No nematode.
60 grams	210	Mar. 30, 1918, 35 black-eyed pea seeds..	1 in., poor germination...	Root system badly burned	No nematode.
70 grams	245	Mar. 30, 1918, 35 black-eyed pea seeds..	No germination.....	No root system.....	No nematode.
80 grams	280	Mar. 30, 1918, 35 black-eyed pea seeds..	No germination.....	No root system.....	
90 grams	315	Mar. 30, 1918, 35 black-eyed pea seeds..	No germination.....	No root system.....	
100 grams	350	Mar. 30, 1918, 35 black-eyed pea seeds..	No germination.....	No root system.....	
115 grams	402.5	Mar. 30, 1918, 35 black-eyed pea seeds..	No germination.....	No root system.....	
Check**.....	Check.....	Mar. 30, 1918, 35 black-eyed pea seeds..	8 in., good growth.....	9 inches.....	Abundance nematode.

*Soil used in this experiment was from pink root and nematode infected soil from Laredo, in duplicate 5 inch pots.

**Soil used was steam sterilized.

Instead of spraying for thrips with Black Leaf 40, they may be controlled by dusting with what is known as 3-in-1 Contact Insecticide and Fungicide. This is called 3-in-1 because its action is claimed to be threefold: (1) as a repellent; (2) as a contact insecticide; and (3) as a fungicide on account of its sulphur. For purposes of best results with this product, a good powder gun of the latest design is required for dusting, the operation being repeated at intervals of from three to five days, depending upon the severity of the attack.

Where the soil is known to be infected with pink root, and when the grower has reason to fear an attack from thrips, it would be advisable to plant the crop reasonably early and make every effort to induce early maturity. Likewise, spraying should begin early, and one should avoid any possible delay with repeated treatments, the lack of which may result in a rapid spread of the thrips.

TIME OF APPEARANCE OF PINK ROOT

Ordinarily, under seed-bed conditions, no pink root becomes apparent soon after the seed sprout. In fact, very little pink root is noticeable after the first few waterings and under thirty days. However, the disease increases after thirty to forty days, and with the later waterings it becomes very abundant at the age of seventy days. With the main crop, pink root becomes very bad in the field as the season advances, and especially when the soil temperature rises. The severity of the disease in the field will also depend on any serious check to the growth of the crop.

EFFECT OF SOIL TEMPERATURE ON THE PREVALENCE OF PINK ROOT

Mention has already been made above that in the seed bed, pink root generally appears after thirty to forty days. Since the seeds are planted in the seed bed early in September, and at a time when the soil temperature is fairly high, the pink root disease finds favorable conditions for rapid spread. Furthermore, in closely watching the prevalence of pink root in the field, one is convinced that the disease is at its height at the time when the onion plants are about to begin bulbing. The disease reaches its maximum at about harvest time. In studying this effect and its correlation with soil temperatures as indicated in Tables 9 to 12, one will notice that the higher soil temperatures occur during May, at which time the pink root is at its height in an infected soil.

PINK ROOT DISEASE OF ONIONS AND ITS CONTROL IN TEXAS. 23

Table 9.— Soil temperature readings for December, 1917.

Dec., 1917.	Outside.			One Inch.			Three Inches.		
	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.
1.....	36	72	68	48	72	70	52	70	72
2.....	48	84	80	49	84	80	54	76	74
3.....	48	82	70	48	82	72	59	74	72
4.....				57	86	80	58	78	
5.....				60	79		62	74	
6.....				60	70		63	70	
7.....	50	76		54	68		54	68	
8.....	50	93		54	85		58	76	
9.....	57	82	76	59	80	79	64	72	76
10.....	50	68	64	60	64	60	56	61	62
11.....	59	74	65	58	68	66	58	68	66
12.....	50	69	64	56	68	66	59	57	56
13.....	62	64	55	59	63	60	61	64	63
14.....	46	70	65	52	62	59	54	63	60
15.....	65	74	63	60	73	64	62	71	64
16.....	63	65	65	63	62	62	63	62	63
17.....				60	65	70	63	67	70
18.....	60	70	68	62	68	66	64	70	69
19.....	60	74	70	63	73	70	66	71	68
20.....	50	80	70	55	77	70	55	74	70
21.....	70	85	74	68	81	75	67	72	76
22.....	75	83	75	65	74	70	64	73	72
23.....	68	87	79	65	82	78	68	78	77
24.....	68	90	80	65	77	74	68	76	72
25.....	60	64	66	63	67	65	67	68	67
26.....	50	70	62	59	69	69	62	70	70
27.....	51	77	64	55	80	66	61	72	66
28.....	58	77	71	58	77	74	62	73	71
29.....	46	60	57	52	58	58	56	58	58
30.....	32	67	62	43	67	62	49	63	61
31.....				48	84		52	77	
Mean temperature.....	65, 3/13			65, 9/31			65, 5/31		

Table 10.— Soil temperature readings for January, 1918.

Jan., 1918.	Outside.			One Inch.			Three Inches.		
	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.
1.....	36	72	68	48	76	70	52	70	72
2.....	39	83	80	48	84	80	55	76	74
3.....	55	82	70	55	82	72	59	74	73
4.....				54	86		58	78	
5.....				60	79		62	74	
6.....				60	69		63	70	
7.....	50	76					54	68	
8.....	50	93½		54	84½		58	75	
9.....	56½	82	74½	56½	80½	79	64	72	76
10.....	72½	96		70	91		73	84	
11.....	21	90		42	65		47	64	
12.....	29	46	41	46	55	53	54	57	58
13.....	40	76		51	75½		52½	70	
14.....	45	62		53	59		55	60	
15.....				47	72		52	65	
16.....	42	73		50	79		54	72	
17.....									
18.....	51	91		52	72½		56	72½	
19.....	71	72		64	86		66	83	
20.....	70	97½		62	83		64	81	
21.....	46	82		48	68		51	65	
22.....	53	80		45	72		47	68	
23.....	55	75		55	70		55	70	
24.....	41	72		49	72		54	66	
25.....	36	76		48	69		52	68	
26.....	57	88		56	72		57	71	
27.....	45	48		54	52		58	56	
28.....									
29.....	54	66		56	70		58	66	
30.....	43	86		51	81		55	74	
31.....	47	57		55	65		56	65	
Mean temperature.....	64, 37/50			63, 9/16			63, 1/2		

Table 11.—Soil temperature readings for February, 1918.

Feb., 1918.	Outside.			One Inch.			Three Inches.		
	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.
1	37	34		41	45		42	45	
2	33	57		39	54		42	50	
3	28	70		37	57		40	57	
4	31	61		38	68		42	63	
5	45	75		46	62		52	65	
6	56	79		48	78		52	72	
7	46	86		52	79		52	78	
8	63	83		55	79		60	76	
9	55	56		54	55		56	57	
10	45	48		49	50		52	53	
11	50	64		48	58		52	56	
12	43	82		45	73		48	70	
13	48	84		53	71		53	71	
14	65	87		64	80		63	73	
15	68	80		67	78		66	76	
16	65	55		66	68		66	69	
17	50	48		57	56		58	59	
18									
19									
20									
21									
22									
23									
24									
25	61	94		61	82		61	80	
26	56	82		60	78		60	75	
27	66	94		66	86		66	81	
28	65	75		68	72		70	70	
Mean temperature.....	61, 4/21			60, 13/42			60, 29/42		

Table 12.—Soil temperature readings for May, 1918.

May, 1918.	Outside.			One Inch.			Three Inches.		
	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.	7:00 A. M.	2:00 P. M.	5:00 P. M.
1	52	54		59	59		60	60	
2	50	60		55	65		58	62	
3	56	75		58	75		58	75	
4				60	82		63	75	
5	65	92					67	85	
6	66	90					67	84	
7	65	93					68	86	
8	65	95					68	87	
9	68	88					68	82	
10	65	70		66	68		67	68	
11	65	82					66	76	
12	66	90					68	83	
13	66	97					66	90	
14	67	85		66	84		69	73	
15	60	60					64	62	
16	45	57		49	56		57	59	
17	51	70		52	75		57	71	
18	47	75					53	69	
19	45	83					53	73	
20	57	88					62	80	
21	65	74					66	70	
22	62	82					62	77	
23	50	83					64	77	
24	51	83					65	77	
25	51	84					64	78	
26	60	85					65	81	
27				66	88		66	82	
28				72	84		73	81	
29	65	82		68	80		68	77	
30	60	75		62	73		67	70	
31	60	83					65	80	
Mean temperature.....	69, 2/7			69, 7/12			69, 28/31		

It is unfortunate that complete data on soil temperature under Laredo conditions, where most of these studies were made, are not as yet fully available.

More soil temperature studies are now being made under greenhouse conditions in soil temperature boxes, such as are used at the Wisconsin Agricultural Experiment Station, where the temperature may actually be maintained at any desired degree. From the brief studies presented above it may be safely stated that the grower should do everything possible to plant his crop at such a time that the greatest amount of growth will be made when the soil temperatures are fairly low, ranging from 60 to 75 degrees Fahrenheit. Avoid sowing seed beds so early that soil temperatures will yet be too high, and hence be favorable for pink root development. Also, avoid seeding too late, which would throw the period of bulbing during the hot months of the year, at a time when a high percentage of pink root may be developed. Furthermore, great attention should be paid to the necessity of frequent waterings during the bulbing period. This will encourage rapid growth and will help to keep the soil fairly cool. When planting is done late, everything possible should be done during the hot months of the year, so as to reduce the soil temperature by several degrees just preceding the bulbing period. This, of course, will be accomplished by irrigation.

THE CAUSAL ORGANISM

From previous discussion it becomes evident that a *Fusarium* fungus, tentatively named *Fusarium malli* Taub.,* is the cause of pink root of onions. The organism was grown on a variety of media, chief of which were potato plugs, hard lima bean agar (Fig. 2, d to g), and hard rice agar. It should be stated that *F. malli* somewhat resembles *Fusarium oxysporum*, but differs sufficiently to make it distinct from the latter. The mycelial growth of *F. malli* varied very little on the three kinds of media above mentioned. The spore measurements, however, that is, the macroconidia, seemed to be greatly influenced in size by the media on which the fungus grew. The largest sized spores were obtained on hard bean agar and the smaller sized on potato plugs. Furthermore, microconidia were apparently formed only on hard bean agar on the scant mycelium which grew on the border near the glass of the tube. A description of *Fusarium malli* follows.

Microconidia (Fig. 3, d) formed on aerial mycelial branches, varying in shape and in size and slightly pedicellate. Of the macroconidia, the three septate type seems to dominate (Fig. 3, e), probably over 98 per cent. The remaining 2 per cent. are four septate; five septate spores being almost rare. On potato plugs, pionnotes numerous, and assuming the color and consistency of butter, thus distinguishing it from *Fusarium oxysporum* which only has pseudopionnotes. Three septate conidia vary from 30 X 4u to 40 X 5u. The four septate conidia (Fig. 3, b) have about the same measurements as the three septate. Mycelial growth scant, flat, being replaced early by a heavy layer of pionnotes. Absence of sclerotia, and very little color on starchy media is especially noticeable, except on potato plugs, where the color varies

**F. malli* was named in honor of the Junior Author.

from green to purple. The organism produces an abundance of chlamydospores, which are both terminal and intercalary (Fig. 3, a, c and f); the zero septate dominate. Frequently and in old cultures, they are found in chains or in large masses as though held together by mucilage. *F. mali* is pathogenic on onions and garlic, causing a disease known as pink root.

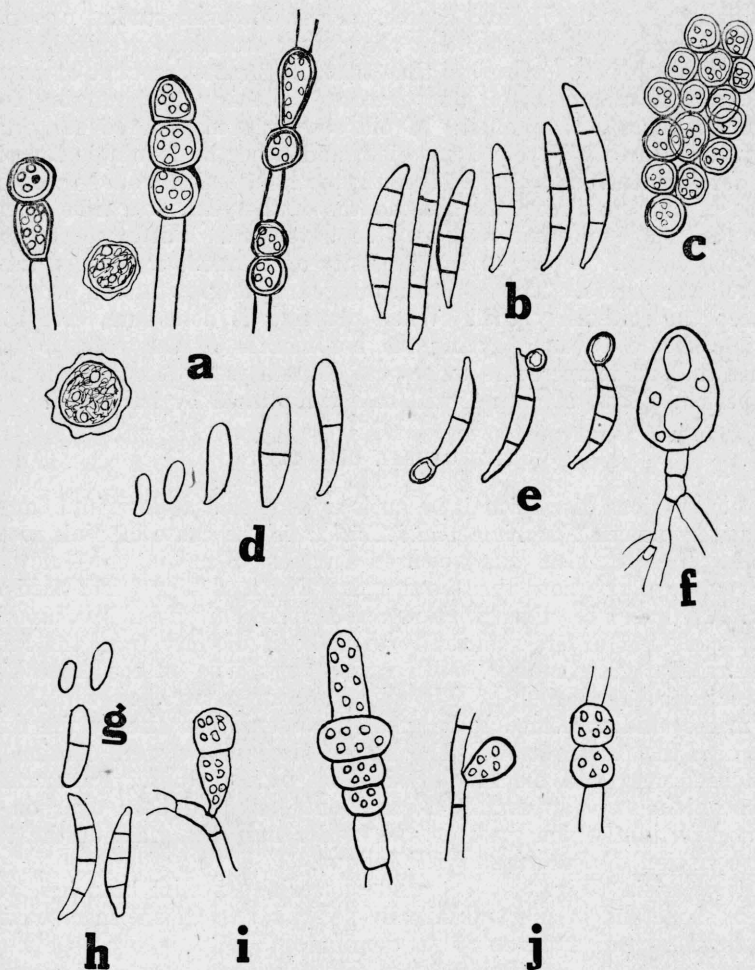


Figure 3.

(a, c and f) Chlamydospores of *Fusarium mali*. (b and e) Three and four celled macroconidia of *Fusarium mali*. (d) Microconidia of *Fusarium mali*. (g and h) Micro- and macroconidia of *Fusarium No. 2*. (i and j) Chlamydospores of *Fusarium No. 2*.

OTHER FUSARIA ASSOCIATED WITH *F. MALI*

Of the many other species of *Fusaria* isolated from pink root of onions is one carried in the laboratory as *Fusarium No. 2* (Fig. 2, d and g; Fig. 3, g to j), which invariably seems to be associated with *F. mali*, and which resembles somewhat *Fusarium martii*. However,

it seems to differ from the latter by the fact that it produces macroconidia very sparingly. These when present are three and four septate, varying in size from $32 \times 5\mu$ to $50 \times 5.2\mu$; microconidia predominating; absence of pionnotes and pseudopionnotes; sclerotia numerous, single or in groups varying in color from dark green to dirty gray green; mycelial growth abundant, fluffy, thick, slightly raised, imparting practically no color to substratum. However, a distinct brownish gray color is imparted to hard rice agar media; chlamydo-spores numerous, large, terminal or intercalary. *Fusarium* No. 2 is apparently non-parasitic but seems to increase the virulency of *F. mali*.

The parasitism, on Irish potatoes, of *Fusarium mali* and *Fusarium* No. 2 has not been definitely ascertained because of the fact that of the numerous inoculations made, the checks rotted as readily as those that were inoculated, although every aseptic condition was observed. It was difficult, however, to secure, on the local market, potatoes which were absolutely sound and free from bruises or blemishes. This accounts for the negative results of these inoculations. This parasitism is now being further investigated.

FALSE BLIGHT

In plants suffering from pink root, or during seasons of extreme heat and drouth, the tender tips of the rapidly growing onion leaves are sometimes inclined to wither and to die down gradually from the top to the bottom of the plant; withering which gives the plant the appearance of having blight resembling that which is known in the northern states as downy mildew (*Peronospora schleideniana*). Such withered leaves turn white and dry up. The term blight, therefore, in this case is misleading, primarily because the downy mildew blight is not known to occur in the Laredo onion districts in Texas, and also because the trouble, as far as is known, does not seem to be caused by any parasitic organism, but may be brought about by various conditions. The trouble becomes apparent: (1) When the plants suffer from lack of moisture and are suddenly supplied with an abundance of water. (2) Attacks from onion thrips will reduce the vigor of the plant, and thus check its growth and result in the premature dying of the tips of the foliage. (3) Badly diseased plants suffering from pink root, and hence lacking in vigor, will often manifest the symptoms of the false blight just mentioned. Not infrequently the blighted foliage later becomes covered with a number of various fungi, chief of which may be mentioned *Macrosporium parasiticum* Thuem. and *Macrosporium porri* Ell. These species of fungi are never found on healthy foliage, hence they probably are saprophytes or semi-parasites.

STUDIES OF POSSIBLE CONTROL METHODS

From a practical consideration it is important to know not only the cause of the disease, but also the best means of control. Various methods were tried out with a view of determining which of these could be best carried out in practice, requiring the minimum expense and labor.

Effect of Fertilizer. Claims are frequently made by growers that certain fertilizers will cause pink root. In order to determine whether

or not fertilizers have any effect in controlling or favoring pink root, tests were carried out on two different farms, and on soils known to be infected with the pink root disease. The fertilizers were applied in dry land ahead of seeding. Irrigation followed soon after the seed was sown. The seeds were sown September 17, 1917. A count of the percentage of pink root plants was made when the sets in the seed bed were 60 days old. The general results of these tests are shown in Table 13. From Table 13 it appears that the use of certain fertilizers, such as tepary bean ashes, acid phosphate, on plats 1 and 2, Farm No. 1, would tend to reduce considerably the amount of pink root in the seed bed. However, from the results on plats 1 and 2, Farm No. 2, it is seen that the same fertilizers showed about as much pink root development as did the other fertilizers on the remaining plats. From these tests it is plain that no general conclusion can be reached as to the difference in effect of the various fertilizers. Furthermore, plats 1 and 2, Farm No. 2, were much more seriously infected with pink root than plats 1 and 2 of Farm No. 1. This probably explains the apparent difference in results. All things being equal, it seems that fertilizers do have a tendency to retard the development of pink root in the seed bed, and this is done, not in reducing the amount of disease, but by accelerating growth and encouraging formation of new roots faster than old ones are destroyed by the disease. No fast rules, however, can be laid down as to the kind of fertilizer to use for the seed bed. Each grower should make a close study of this problem and test the various fertilizers in various places on his farm, in order to determine which combination is best under his own particular conditions.

Table 13.—Comparison of effect of fertilizer on pink root soil used in seed bed at Farm No. 1 and Farm No. 2.

Farm No. 1*			Farm No. 2*		
Fertilizer Used Per Acre.	Plat No.	Per cent Pink Root.	Fertilizer Used Per Acre.	Plat No.	Per cent Pink Root.
Tepary bean ashes.....	1	4.2	Tepary bean ashes.....	1	19.6
Acid phosphate 1180 lbs.....	2	7.5	Acid phosphate 1180 lbs.....	2	31.4
Mesquite wood ashes 5225 lbs..	3	14.5	Mesquite wood ashes 5225 lbs..	3	14.1
Tankage 1140 lbs.....	4	17.5	Tankage 1140 lbs.....	4	13.5
Check.....	5	24.13	Check.....	5	22
Acid phosphate 450 lbs..			Acid phosphate 450 lbs..		
Nitrate of soda 110 lbs.....	6	27	Nitrate of soda 110 lbs.....	6	19.3
Manure only, 24 tons.....	7	24.13	Manure only, 24 tons.....	7	28.9
Cotton seed meal 570 lbs.....	8	21.5	Cotton seed meal 570 lbs.....	8	20.5

*Names of owners are purposely omitted.

In comparing Table 13 with Table 14, one sees some effects of fertilizer on growth in a healthy soil. From Table 14 it is found that there are traces of diseased plants in various fertilized plats on supposedly healthy land which has never grown onions before. No doubt this is due to the fact that the tools which were used in plowing and preparing the seed beds, and later for the cultivation, had been previously used on the pink-root infected fields on the same farm; hence, introducing the fungus to the healthy seed beds by carrying soil particles which adhered to the plows and other implements.

Effect of Lime and Sulphur. It is often claimed that applications of lime or sulphur on pink-root infected soil will control the disease. The results of various applications of lime and sulphur, singly and in combination, on pink-root infected soil at three different farms, showed that neither lime nor sulphur had any effect whatsoever in reducing the amount of pink root in the seed bed.

Table 14.—Effect of fertilizer on pink-root free land in seed bed at Farm No. 3.

No. of Plat.	Fertilizer Used Per Acre.	Not Limed, Per Cent Pink Root.	Limed, Per Cent Pink Root.
1.....	Check.....	Trace.....	Trace
2.....	Nitrate of soda 150 lbs.....	None.....	None
3.....	Sulphate of ammonia 120 lbs.....	None.....	None
4.....	Sulphate of ammonia 245 lbs.....	1 plant.....	1 plant
5.....	Nitrate of soda 230 lbs.....	1 plant.....	1 plant
6.....	½ Cyanamid 500 lbs.,** ½ check.....	1 plant, none.....	1 plant, none
7.....	8 tons manure†.....	1 plant.....	2 plants
8.....	Cotton seed meal 1000 lbs.....	1 plant.....	2 plants
9.....	Check.....	1 plant.....	1 plant
10.....	Cotton seed meal 1000 lbs.....	4 plants.....	4 plants
11*.....	Mesquite wood ashes 4700 lbs.....	2 plants.....	2 plants

*In Plat 11 the plants were decidedly burned as a result of an excess of wood ashes.

**Cyanamid shows distinct stimulation.

†The application of fresh manure just ahead of seeding does not seem to be so beneficial. In this test, drilling in the seed followed immediately after the application of quickly acting fertilizer without any apparent ill effect on germination. This was also true with an application of 245 pounds sulphate of ammonia and 230 pounds nitrate of soda per acre. From this it seems that as long as the land is irrigated immediately after the application of fertilizer and frequently enough thereafter that there is no ill effect from such a practice.

Effect of Fertilizers on Yields in a Pink Root Soil. Repeated observations have shown that the best yields of onions, assuming that healthy sets are used, are obtained from lands which have been recently brought into cultivation and which have never produced a crop of onions, or at least lands which have not produced a crop of onions for a long period of years. Yields on new lands frequently average 400 crates per acre. There are, of course, records where 1000 bushels per acre were produced. Such yields are secured only by the use of heavy applications of fertilizer, coupled with special care in the preparation of the land and the management of the crop. On lands affected with pink root, the yields are reduced considerably. Hence special care and fertilizers are needed, to nurse and urge the crop along, in order to obtain reasonable yields. If this is not done, the crop on badly infected soil will be a failure in the sense that yields are too small to be profitable.

In dealing with infected land one finds that the problem is a complicated one, since it is necessary to choose fertilizers that will force rapid growth and produce healthy roots faster than the disease can destroy, in order that the bulbs may attain a reasonable market size. To determine just what are the best fertilizers for accomplishing that purpose, three series of field experiments were carried out on three different farms, all of which were known to be badly infected with the pink root fungus. The results of these experiments are shown in Tables 15, 16, and 17. From Tables 15 and 16 it is noticed that yields are extremely low. This, however, was due to the fact that both fields were early infested by thrips. This severe attack, together with pink root infected soil, resulted in low yields.

Table 15.—Effect of fertilizer on yield† in pink root soil, Farm No. 3.*

No. of Plat.	Fertilizer Used.	Crates Per Plat.		Total Yield in Crates Per Acre, Limed.	Total Yield in Crates Per Acre, Unlimed.
		Limed.	Unlimed.		
2†	Burning trash to ashes.....	1 2/6	5/6	53 2/6	33 2/6
3†	Manure, 25 tons.....	2 1/6	2	86 4/6	80
4†	Nitrate of soda 100 lbs., one application.....	3	2 3/6	120	100
5.....	500 lbs. acid phosphate, one application.....	2	1 5/6	80	73 2/6
6.....	400 lbs. acid phosphate, 100 lbs nitrate of soda.....	2	2 4/6	120	106 4/6
7.....	Check.....	3 3/6	3	140	120
8.....	Wood ashes 1000 lbs. (Mesquite) per acre.....	3 1/6	3 1/6	126 4/6	126 4/6
9.....	Cotton seed meal 800 lbs. per acre.....	3	3 1/6	120	126 4/6
10.....	Tankage 800 lbs. per acre.....	3 1/6	3 2/6	126 4/6	133 2/6
11.....	Check.....	4	3 5/6	160	153 2/6
12.....	Check.....	3 2/6	3 1/6	133 2/6	126 4/6

*Name of owner purposely omitted.

†Crop ruined by thrips. Yields in check plats higher when fertilizer was not used.

Table 16.—Effect of fertilizer on total yield† on pink root soil at Farm No. 4.

No. of Plat.	Fertilizer Used.		Limed.		Unlimed.		Limed. Total Yield Per Acre in Crates.	Unlimed. Total Yield Per Acre in Crates.
	First Application. September 17, 1917.	Second Application. March 5, 1918.	Per Cent No. 1.	Per Cent Boilers.	Per Cent No. 1.	Per Cent Boilers.		
			Pounds.	Pounds.	Pounds.	Pounds.		
a.....	Sulphur 540 lbs.		148	45	62.5	77.5	175.62	127.40
b.....	Sulphate of ammonia 115 pounds...	Sulphate of ammonia 100 lbs.	113	99	78.5	86.5	192.92	150.14
c.....	Acid phosphate 1180 lbs.	Sulphate of ammonia 100 lbs.	123	138	42.5	77.5	237.50	109.20
2.....	Manure only.....		155.5	80	92.5	94	214.30	169.70
3.....	Nitrate of soda 100 lbs.	Nitrate of soda 100 lbs.	118.5	189	73.5	99	279.82	156.96
4.....	Acid phosphate 570 lbs.		59	120	90.5	131	162.88	201.56
5.....	Acid phosphate 450 lbs., Nitrate of soda 100 lbs.	Nitrate of soda 100 lbs.	79	95.5	57.5	76.5	158.78	121.94
6.....	Manure only.....		84	67.5	48.5	53.5	137.86	92.82
7.....	Mesquite wood ashes 5200 lbs.		164.5	109	23.5	66	248.88	81.44
8.....	Cotton seed meal 570 lbs.		227.5	88.5	84.5	108.5	287.56	175.62
9.....	Tankage 1140 lbs.		274	109	183.5	101.5	348.52	186.54
10.....	Manure.....	Muriate of potash 100 lbs.	265.5	71.5	184.5	86	306.66	246.14
11.....	Manure.....	Sulphate of potash 91 lbs.	183.5	76	171	62	236.14	212.02
12.....	Tepary bean ashes.....		124.5	95	173.5	98	199.74	247.06
13.....	Manure.....				114.5	74	171.52

†Portions or all of many plats were ruined by thrips. This explains the irregularity of results.

Table 17.—Effect of fertilizer on yield of onions on pink root soil* at Farm No. 5.

No. of Plat.	First Application, November 22, 1917.	Second Application, January 19, 1918.	Third Application, March 5, 1918.	Total Yield Crates Per Acre.	Per Cent Crates.	
					No. 1 Per Acre.	Boilers Per Acre.
1.....	Cotton seed meal 750 lbs.....		Muriate of potash 100 lbs.....	277	65	35
2.....	Cotton seed meal 1000 lbs.....			280.5	60.3	39.7
3.....	Cotton seed meal 2000 lbs.....			332.5	73.2	26.8
4.....	Check.....			188.1	32.9	27.1
5.....	Tankage 750 lbs.....			223.2	62.2	37.8
6.....	Tankage 1000 lbs.....			252.6	77.4	25
7.....	Tankage 2000 lbs.....			322.5	80	20
8.....			Nitrate of soda 100 lbs.....	228.8	51.3	48.7
9.....	Nitrate of soda 100 lbs.....		Nitrate of soda 100 lbs.....	257	68.7	31.3
10.....	Nitrate of soda 100 lbs.....	Nitrate of soda 100 lbs.....	Nitrate of soda 100 lbs.....	290.2	75.9	24.1
11.....	Cyanamid 150 lbs.....	Cyanamid 150 lbs.....		357.8	81.9	18.1
12.....			Acid phosphate 300 lbs.....	161.2	36.7	63.3
13.....			Acid phosphate 400 lbs.....	150.5	39.3	60.7
14.....	Acid phosphate 300 lbs.....		Acid phosphate 300 lbs.....	145.1	33.4	66.6
15.....	Cotton seed meal 1000 lbs.....			300	69.2	30.8
16.....	Tankage 1000 lbs.....			280.5	66.6	33.4
17.....		Nitrate of soda 100 lbs.....		196.2	57.8	42.2
18.....		Sulphate of ammonia 70 lbs.....		260	71.1	28.9
19.....	Check.....			150	50	50
20.....			Sulphate of ammonia 70 lbs.....	187.7	53.1	46.9
21.....	Sulphate of ammonia 70 lbs.....		Sulphate of ammonia 70 lbs.....	215	60	40
22.....	Sulphate of ammonia 70 lbs.....	Sulphate of ammonia 70 lbs.....	Sulphate of ammonia 70 lbs.....	312.1	74.5	25.5
23.....	Mesquite wood ashes 4000 lbs.....			161.2	43.3	56.7
24.....	Sulphur 52 lbs.....			100	29.4	70.6

*A few plats were either entirely or partly ruined by thrips: hence irregularity of results.

Interpretation of Table 17. It has been indicated, in a general way throughout the discussion of the control methods, that with pink-root infected plants, especially when these are again planted on pink-root infected soil, the only hope of a commercially profitable crop consists in the ability of the grower to supply quickly available plant food in quick succession. The plants must be kept vigorous enough to produce new rootlets as quickly as diseased ones die. By this method the crop will go on through the winter season, reach the bulbing stage, and have a fair chance to produce marketable sized onions. This general proposition is clearly sustained by a study of Table 17, which was the only one of the fertilizer plats which was not so badly attacked with thrips as to interfere seriously with a fairly safe interpretation of the results. The first result indicated in Table 17 is that growers with pink-root infected soil, or pink-root infected plants, should begin with the transplanting of their crops to apply quickly available fertilizers; then in succession to the bulbing and maturing of the crop. The correctness of starting early to give quickly available fertilizers is indicated by the results shown in plats 10, 11, and 22 of Table 17. Two of these were given treatment with nitrate of soda and sulphate of ammonia, about even amounts, at the time the onions were transplanted. Plat 11 of Table 17 was given a slightly larger portion of cyanamid because a longer period of time is required to give up its nitrogen. The second application, of similar amounts, was given each plat in January, about mid-season of the growth of the crop. The third application was given just about the beginning of the bulbing period. The theory of these three tests was to show the value of continuous feeding of diseased plants, and of encouraging a new root growth as fast as others died.

The results show the method to be correct for the reason that plat 10 gave a yield of 290.2 crates per acre, with 45 pounds nitrogen having been applied. Plat 22 produced 312.1 crates per acre, with 42 pounds nitrogen applied; and plat 11, 357.8 crates per acre, with about 48 pounds nitrogen applied. These three yields compared show the highest yields of any amounts of fertilizers, where equal amount, or even double amounts of nitrogen were applied, but which had been applied as is usually done, by heavy applications just ahead of transplanting, or soon after transplanting.

For comparison it is seen that in plat 3, Table 17, about 137 pounds of nitrogen had been applied per acre, with only 332.5 crates per acre yield. This is only slightly above the yields of plats 10 and 22, even though more than three times as much nitrogen had been supplied. Approximately the same result is seen from plat 7, where tankage had been used, and where about twice as much nitrogen had been supplied. This suggests the theory which has been proved in practice where pink root plants, or pink root soils are involved; namely, the liberal supply of nitrogenous fertilizers is not calculated to carry a pink root crop through to maturity, even though the plants boost a disproportionate growth in the beginning. From a study of plats 1, 2, and 7, inclusive, and including plats 15 and 16, Table 17, it is evident that they have all failed to produce a yield in keeping with the amount of nitrogen supplied to the pink root soils and pink root plants, because they failed to give enough nitrogen during the latter part of the growth. In other words; the important fact which must be impressed upon every grower who

has diseased lands or sets, is that he cannot hope to compete with the disease unless he applies such quickly available nitrogen fertilizers as were used in plats 10, 11 and 22, Table 17, so that a supply of nitrogen is available at every stage of the growth of the crop from the beginning to the end. An over supply of nitrogen which may be available faster than the development of the disease, serves no purpose in the control of pink root. On the contrary, that crop will be carried through a diseased soil best which has constantly enough nitrogen fertilizers available to be used by the plants as rapidly as the encroachment of the disease demands. For that reason it must be again repeated and enforced that nitrate of soda, sulphate of ammonia, or cyanamid are the fertilizers which best enable the grower to meet this condition. However, the authors wish to make it clear that they understand the danger of developing what the growers call a "soft" or "tender" growth of the plant by using these fertilizers so early in the growth of the crop. If we were advising concerning the management of a crop of onions on healthy soils, where sets had been used which were free from disease, we would agree that the use of such quickly available fertilizers should not begin until later in the growth of the crop. However, a grower who has infected soil and infected plants has no alternative. He takes greater chances from loss from the disease if he does not use these quickly available fertilizers from the beginning of the growth of the crop, than he takes from the danger of loss to the crop from setbacks of climatic conditions which may injure the tender growth somewhat more seriously than if the nitrogenous fertilizers had not been used so early.

It is also clear from plat 11, Table 17, that with a fertilizer which is rich in nitrogen but which at the same time gives it off gradually for a longer period of time, it is much safer to use liberal quantities of it in the beginning of the crop. Cyanamid usually shows about 16 per cent. nitrogen, which it gives off over a period of fifty to seventy days under Webb County soil conditions, with irrigation. Sulphate of ammonia would probably give off the same amount in twenty to thirty days less time, whereas nitrate of soda distributes itself over a still lesser period of time. Hence, if the growers understand this difference and exercise judgment accordingly, they will secure better results with sulphate of ammonia than with nitrate of soda, provided the soils are rich in lime and hence not acid in their reactions. Practically all the Texas Bermuda onion soils are rich in lime, and usually alkaline in reaction. For the same reason cyanamid will give better results than sulphate of ammonia.

To sum up, there seems to be no doubt but that it is advisable and necessary to use fertilizers on pink-root infected land to obtain profitable yields. This is especially true when diseased green sets are used. As a general guide it might be stated that for the average soil infected with pink root, it is necessary to use fertilizer, not less than 1000 pounds per acre, and of a brand which shows an analysis of about 7 per cent. acid phosphate, 5 per cent. nitrate of soda, and 2 per cent. potash. (In general, Webb County onion soils contain sufficient available potash.) In addition, liberal applications of nitrate of soda should be given, at intervals, during the bulbing season.

For purposes of best results, the fertilizer should be applied about thirty days ahead of transplanting time and should be well worked into the soil. As soon as the green sets are transplanted from the seed bed to the field, and after they have become well rooted and well started out, it is advisable to apply the first amount of nitrate of soda to the extent of about 100 pounds per acre. The second application of nitrate of soda should be given in like amount at about the middle of February, provided, of course, the crop shows need of it. The third and last application of nitrate of soda should be given about March 1, at the rate of 100 pounds per acre. From this, it would appear that one heavy application of fertilizer and three of nitrate of soda are recommended for pink-root infected soils. It should, however, be understood that such recommendations are given only to growers who are unable to secure healthy plants or who, for the most part, must depend on pink-root infected sets as well as diseased soil. It should not be forgotten that the use of nitrate of soda will promote rapid, tender growth, and that such plants may suffer severely from sudden frost, or drouth as happens in case of a sudden breakdown in the irrigation plant. This element of risk, however, is not so great in the final results, as it is in taking a chance of producing a profitable crop on a pink-root infected soil which lacks plenty of quickly available plant food. There is no doubt but that soils deficient in humus are doubly unfit for onions. Such soils do not promote rapid growth, which means the development of more pink root. They also fail to take up the usual amount of irrigation water, which in turn is unfavorable to the crop. It is soil deficient in organic matter which needs the maximum amount of fertilizers.

FORMALDEHYDE TREATMENT OF PINK-ROOT INFECTED SETS

Since pink root is carried with the green sets which have previously grown in an infected pink root soil in the seed bed, it becomes evident that some form of treatment is necessary so as to kill without injuring the green sets the disease producing organism. Two standard fungicides were tried, namely, formaldehyde and copper sulphate, and the treatments were carried out on greenhouse-grown sets. The strength of formaldehyde tested was 2 and 5 per cent., respectively. The diseased plants were soaked from five minutes to four hours (Fig 2, a). Some of the diseased roots of the green sets were cut off before treatment, while others were left undisturbed. The results of the treatment are shown in Table 18.

From Table 18 it is seen that pink root was reduced considerably in the 5 per cent. formaldehyde treatment, when the sets were soaked for five minutes. However, at this strength the treated sets were retarded severely in growth and in root formation. Hence, for practical purposes this strength cannot be recommended. With soaking the infected sets for ten minutes, injury was more noticeable; with longer soakings, from fifteen minutes to four hours, the sets were practically all killed (Fig. 2, a). A 2 per cent. formaldehyde solution does not seem to injure appreciably the sets, and apparently destroys the pink root fungus in the sets when soaked for ten minutes, provided the treated sets are planted into a soil free from pink root. From Table 18 it is fur-

Table 18.—Effect of formaldehyde treatment on infected green sets.

Strength of formaldehyde.	Kind and Number of Plants Used.	Length of Treatment.	Other Treatment of Plants.	When and Where Planted.	Results.
5 per cent.	35 Bermuda infected with pink root.	5 minutes.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	1 pink root, others healthy†
5 per cent.	35 Bermuda infected with pink root.	10 minutes.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	3 plants dead, others healthy but dwarfed†
5 per cent.	35 Bermuda infected with pink root.	15 minutes.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	3 plants dead, others healthy but dwarfed†
5 per cent.	35 Bermuda infected with pink root.	20 minutes.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	4 plants dead, 1 pink root, others healthy but dwarfed†
5 per cent.	35 Bermuda infected with pink root.	30 minutes.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	All dead
5 per cent.	35 Bermuda infected with pink root.	1 hour.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	All dead
5 per cent.	35 Bermuda infected with pink root.	2 hours.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	All dead
5 per cent.	35 Bermuda infected with pink root.	4 hours.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	All dead
5 per cent.	35 Bermuda infected with pink root.	4 hours.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	All dead
None.	35 Bermuda infected with pink root.	Check.	Diseased roots not cut off..	Nov. 4, 1916, in unsterilized soil*.	100 per cent pink root.
5 per cent.	35 healthy Bermuda sets	10 minutes.	Roots cut off before soaking	Nov. 6, in steam sterilized soil which was later inoculated with soil taken from pink root field.	100 per cent pink root†
5 per cent.	35 healthy Bermuda sets	10 minutes.	Roots cut off before soaking	Steam sterilized soil*.	No pink root†
5 per cent.	35 healthy Bermuda sets	5 minutes.	None	Unsterilized pink root soil.	All pink root
5 per cent.	35 healthy Bermuda sets	5 minutes.	None	Unsterilized pink root soil.	All pink root
5 per cent.	35 healthy Bermuda sets	5 minutes.	None	Unsterilized pink root soil.	All pink root
2 per cent.	35 healthy Bermuda sets	10 minutes.	None	Steam sterilized soil*.	Yellow roots but no pink root
2 per cent.	35 healthy Bermuda sets	10 minutes.	None	Nov. 9, 1916, unsterilized pink root soil.	Jan. 23, all pink root†

*Soil used in this experiment was taken from College Station where no onions have been grown before.

†Growth retarded one week compared to check. (In all formaldehyde treatments the bottom of the plate peeled off.)

ther seen that when healthy onion sets are treated in 5 per cent. formaldehyde for ten minutes and then planted in a pink-root infected soil, they may later show 100 per cent. infection with pink root. This again indicates that the ten-minute treatment in the 5 per cent. formaldehyde decidedly weakens the plants. The bulb plate in diseased plants actually peels and falls out as a result of treatment with the 5 per cent. strength.

Formaldehyde treatment of diseased sets was also carried out in the field. It was found that the using of formaldehyde at the rate of one pint of the chemical in three to four gallons of water, then clipping the roots and dipping the sets in the solution so as to thoroughly wet them, and then placing the treated sets in sacks and within an hour planting them in the field, would completely kill all the treated plants. It was further found that formaldehyde, at the rate of one pint in twenty gallons of water, and one pint in fifty gallons of water, putting the plants in crates and soaking in barrels of these solutions for ten minutes, decidedly injured the diseased treated plants. Furthermore, one pint of formaldehyde in one hundred gallons of water, the sets being soaked for ten minutes, would kill about 25 per cent of the weaker plants, while the others would start new roots very slowly. Finally, when pink-root infected green sets were soaked for ten minutes in formaldehyde at the rate of one pint in two hundred gallons of water, only one-half of 1 per cent. of the plants were killed; the sprouting or starting of new roots was delayed fully a week. In all the above field experiments the tops of the treated plants were cut off. The use, however, of similar strength of formaldehyde, that is, one pint in twenty-five gallons of water, one pint in fifty gallons of water, one pint in one hundred gallons of water, and one pint in two hundred gallons of water, with the leaves of the sets unclipped, resulted in less serious injury to the plants.

When irrigation immediately follows the planting of dipped sets, the injury is decidedly lessened. The weaker sets are invariably killed. In the summing up of the effects of formaldehyde on pink root sets, it should be stated that such treatment is dangerous, even though weaker strengths, consisting of one pint in two hundred gallons of water are used. Therefore, until further work is carried on, the treating of diseased pink root sets in various lengths of time is not advocated, and should not be attempted by the grower. It is safest to discard diseased sets. From a practical consideration, no treatment is considered useful if it retards growth and the quick formation of new roots. Such a setback exposes the plants to reinfection, which, if it occurs again, is more serious than using untreated diseased plants.

The laboratory treatments of copper sulphate solutions were 1 gram in 500 c.c. of water and 1 gram in 2000 c.c. of water. The results of these treatments are indicated in Table 19. From this table it is seen that the dipping of diseased plants in copper sulphate solution at the rate of 1 to 500 for fifteen minutes to five hours did not cure the pink root. In every case the sets were either injured or killed. This is explained by the fact that the treatment was too strong. As to the treatment in the weaker solution, 1 to 2000, copper sulphate, the roots of the treated sets were not destroyed, even though the treatment was prolonged for four hours. However, pink root was not controlled. Hence, as far as this experiment goes, it is evident that copper sulphate

at the rate of 1 to 500 and 1 to 2000, cannot be recommended. It is possible that fungicides other than formaldehyde or copper sulphate may be found which would destroy pink root in green sets without injury to them. This possibility is now being investigated.

SOIL STERILIZATION OF SEED BED

It has already been stated on page 15 that the pink root organism lives in the soil from year to year. This is true for seed beds as well as for field conditions. When onion seeds are planted in a diseased seed-bed soil, the green sets will become infected and thus carry the pink root fungus to the field. It is imperative, therefore, that the seed should be planted on a healthy seed-bed soil. As far as possible, land which has never been devoted to onions should be used for seed-bed purposes. When this is not possible and the onion grower finds himself compelled to use infected soil, it will, of course, be necessary to sterilize that soil in order to free it from the pink-root germ. Experiments were carried on in the laboratory and in the field with formaldehyde. Steam sterilization experiments were carried on in the laboratory only, as no facilities were at hand to try this sterilization in the field. Several pink-root infected seed beds were treated outdoors with formaldehyde at the rate of one pint in twenty gallons of water and applied at the rate of one gallon to the square foot of bed space. After treatment, the soil was covered with a canvas for twenty-four hours in order to retain the formaldehyde fumes. The seed was sown a week after the treatment. The germination of these seeds was normal when compared to the check. In the treated beds (see Table 20) the percentage of pink root was reduced to 0.6 per cent. The check or untreated plats showed over 80 per cent. pink root on the sets, and this percentage increased rapidly as the season advanced. In the treated beds, pink root did not increase further than a mere trace. This distinctly shows the advantage of treating infected soil with formaldehyde. Similar experiments carried on in the laboratory, in which the same strength of formaldehyde as above was used, yielded 100 per cent. healthy sets in diseased soil. The trace of pink root in the treated beds in the field was, undoubtedly, brought in through accidental infection.

In treating the seed-bed soil with formaldehyde, one should carry out the operation in practice as follows:

The seed beds are prepared in the usual way, with the exception that they are made to average not more than eight feet in width. As the bed is being flooded, a quantity of 40 per cent. formaldehyde is placed in a container and allowed to drip into the water as it enters from the ditch through the cut in the border. The dripping should be so regulated that it will fall at the rate of one pint to twenty gallons of water. With a little experience and calculation, the inflow of water and rate of dripping may be readily figured out. It is best to carry out the formaldehyde treatment after the last preparation of raking, leveling, and harrowing of the bed. This means from five to eight days before sowing the seed.

Laboratory experiments on sterilizing pink-root infected soil with steam have shown that the causal fungus may be killed by steaming

Table 19.—Effect of copper sulphate treatment on infected green sets.

Strength of Copper Sulphate.	Kind and Number of Plants Used.	Length of Treatment.	When and Where Planted.	Results.
1-2000.....	35 diseased sets.....	5 minutes.....	Nov. 9, sterilized soil.....	Jan. 23, all pink root and yellow root.
1-2000.....	35 diseased sets.....	10 minutes.....	Nov. 9, sterilized soil.....	Jan. 23, all pink root and yellow root.
1-2000.....	35 diseased sets.....	15 minutes.....	Nov. 9, sterilized soil.....	Jan. 23, all pink root and yellow root.
1-2000.....	35 diseased sets.....	20 minutes.....	Nov. 9, sterilized soil.....	Jan. 23, all pink root and yellow root.
1-2000.....	35 diseased sets.....	30 minutes.....	Nov. 9, sterilized soil.....	Jan. 23, all pink root and yellow root.
1-2000.....	35 diseased sets.....	1 hour.....	Nov. 9, sterilized soil.....	Jan. 23, all pink root and yellow root.
1-2000.....	35 diseased sets.....	2 hours.....	Nov. 9, sterilized soil.....	Jan. 23, all pink root and yellow root.
1-2000.....	35 diseased sets.....	4 hours.....	Nov. 9, sterilized soil.....	All showing extreme case of pink root as well as retarded growth.
1-2000.....	35 diseased sets.....	6 hours.....	Nov. 9, sterilized soil.....	All showing extreme case of pink root as well as retarded growth.
1-2000.....	35 diseased sets.....	5 hours.....	Nov. 13, sterilized soil.....	Jan. 23, all showing worst case of pink root, growth stunted, bottom of bulbs slowly drying.
Check.....	35 diseased sets.....	Check.....	Nov. 9, sterilized soil.....	All pink root.
1-500.....	Very slender pink-root infected sets from Laredo.	15 minutes.....	Nov. 13, sterilized soil.....	Jan. 23, 1917, all pink root, slightly retarded growth.
1-500.....	Very slender pink-root infected sets from Laredo.	30 minutes.....	Nov. 13, sterilized soil.....	Jan. 23, 1917, all pink root, slightly retarded growth.
1-500.....	Very slender pink-root infected sets from Laredo.	1 hour.....	Nov. 13, sterilized soil.....	Jan. 23, 1917, all pink root, slightly retarded growth.
1-500.....	Very slender pink-root infected sets from Laredo.	3 hours.....	Nov. 13, sterilized soil.....	Jan. 23, 1917, all pink root, slightly retarded growth.
1-500.....	Very slender pink-root infected sets from Laredo.	5 hours.....	Nov. 13, sterilized soil.....	Jan. 23, 50 per cent killed by treating, others decidedly injured, showing pink root.
1-500.....	35 slightly stouter plants infected with pink root.	17 hours.....	Nov. 4, steam sterilized soil. Immediately after treatment bulbs were apparently sound but outer scales were yellowish due to some chemical change within the tissue, tips and leaves were wilted.	Jan. 23, all plants died.
1-500.....	35 stout but pink root infected plants from Laredo.	17 hours.....	do	All dead except five which showed the worst case of pink root.
1-500.....	30 slender pink root infected sets from Laredo.	17 hours.....	Nov. 16, do	Jan. 23, all dead.

Table 20.—Effect of formaldehyde treatment on pink-root infected soil.

No. of Plat.	Time of Formaldehyde Treatment.	Strength of Formaldehyde Used.	Amount Per Square Foot.	Per Cent Pink Root.
a.....	Sept. 10, 1917.....	1 pt. to 20 gal. water..	2 gallons*†.....	Trace
b.....	Sept. 10, 1917.....	1 pt. to 20 gal. water..	1 gallon*†.....	Trace
c.....	Sept. 10, 1917.....	1 pt. to 20 gal. water..	1 gallon*†.....	Trace
d.....	Sept. 10, 1917.....	1 pt. to 20 gal. water..	1½ gallons.....	Trace
e.....	Check.....	Check.....	Check.....	80 per cent
f.....	Check.....	Check.....	Check.....	80 per cent
g.....	Dec. 7, 1917.....	1 pt. to 20 gal. water..	1 gallon†.....	Trace
h.....	Dec. 7, 1917.....	1 pt. to 20 gal. water..	1 gallon†.....	Trace

†Formaldehyde dripped into water as it flowed in the bed during irrigation.

*Formaldehyde applied just before sowing seed.

the soil at fifteen pounds pressure for two hours. It is, of course, probable that a shorter steaming will accomplish the same results. On a commercial scale, therefore, it is advised that the seed-bed soil should be treated with steam in the same way as the tobacco growers in other states are doing to rid the soil of *Thielavia* root rot. The method of steam sterilization as recommended by Johnson* is as follows: "The most practical method yet devised for the sterilization of seed beds by steam is the 'inverted pan method.' This method was first used by Shamel for sterilizing nematode infested soils in Florida. A galvanized iron pan, six feet by ten feet and six inches deep, is inverted over the area to be sterilized after it has been prepared for seeding. As the edges of the pan are sharp, they can be pressed into the soil an inch or more, thus forming a tight compartment under the pan into which the steam is run 30-60 minutes from a boiler at a pressure of 80-150 pounds. The time of steaming depends largely upon the type of soil and its moisture content and compactness. Loose sandy, moist, but not wet soils, are more easily and rapidly steamed than heavy and wet soils. The pan is made eight inches in depth, which is probably more desirable in some cases. The pan could be made twelve feet in length without losing any efficiency where large boilers are used. The handles should preferably be placed on the sides instead of on the ends, so that the pan could be moved from one section of the bed to another without the operator's walking on the sterilized soil. The weight of such a pan is approximately 400 pounds. A one-inch steam hose should be used to connect it with the boiler. A traction engine such as is used for threshing is most convenient to furnish the steam."

SEED DISINFECTION

Since most of the onion seeds planted in the vicinity of Laredo, and in fact all through the Rio Grande Valley, are mostly secured from the Bermuda Islands, it became necessary to determine whether these seeds were carriers of pink root. Accordingly, a large quantity of untreated seed was planted in pots of steam sterilized soil. This was done for nearly three seasons, and never did a single plant show pink root.

*Johnson, James. The control of damping-off disease in plant beds. Wis. Agr. Expt. Sta. Research Bul. 31:29-61, 1914.

Thus for all practical purposes, this experiment proved that the seed* do not carry pink root. Hence, it is not necessary to treat the seed with formaldehyde as is recommended for seed treatment of other diseases. Onion seeds, when treated with formaldehyde solution stronger than one part in three hundred of water, will actually be delayed in germinating. Hence, it is worse than a waste of time and money to give onion seeds the formaldehyde treatment with a view of controlling pink root since the seed appear not to be carriers of the disease.

EFFECT OF ROTATION

Field observations definitely show that the rotation of crops is beneficial in reducing the amount of pink root, although rotation will not eliminate it altogether from the soil. From a practical consideration, pink root lands should be given a rest from any kind of onions, shallots, or garlic, and be devoted to other crops. At least three to four-year rotation is recommended.

It is popularly believed that onions are the one crop that can be grown continuously on the same land for a number of years. This may be true provided good attention is given to keeping out disease and to maintaining the fertility by applying manure and plowing it under. Great danger lies in the fact that when onions are grown too long on the same land, pink root may eventually be introduced and spread, and in the long run seriously reduce the profitable culture of the crop. When starting with a virgin land, one should not grow onions for more than three or four consecutive years, even though healthy plants are always used. A two-year rotation every fourth year, during which no onions are grown, is strongly recommended for lands free from pink root. In dealing with infected soils, the grower is urged that a four-year rotation without onions be adopted before he may reasonably expect anything like a normal yield, even though he uses healthy plants.

GENERAL CONTROL RECOMMENDATIONS

1. When selecting the soil for onions, the grower should make every effort to secure only virgin lands; that is, soil which has never grown onions, or at most but one or two crops.
2. It is safer to produce one's own green sets than to buy them elsewhere without knowing the soil, and its freedom from pink root.
3. If diseased soils must be used for seed-bed purposes, the bed should be disinfected by drenching with formaldehyde at the rate of one pint in twenty gallons of water applied, one gallon of the solution to the square foot of soil area. Steam sterilization is equally effective and should be used whenever steam facilities are at hand.
4. Since pink root is a disease which is carried over in the soil from year to year, an onion crop should only be grown on land free from pink root.
5. With no alternative, and when onions must be grown on sick soil, the land should receive liberal applications of quickly acting fer-

*Here seed means not the dry sets or bulbs, but true seed resulting from the fertilization of blossoms.

tilizer so as to encourage and maintain vigorous growth and a rapid development of root system. No one fertilizer will suit all soils and conditions. In general, the soils of the Rio Grande Valley, where onions are grown extensively, lack humus. Hence, it will be desirable for each grower to apply plenty of well rotted manure, or plow under cover crops so as to increase materially the supply of organic matter. An analysis of the soil will also assist one to select the proper commercial fertilizer intelligently.

6. Badly infected pink root soils should not be used for onion culture. Such lands should be given a rest from onions, by adopting a four-year rotation in which onions, shallots, and garlic are omitted.

7. In dealing with healthy and pink-root infected soils on the same farm, the grower should not use the same set of tools on both.

8. Everything should be done to avoid a check in the growth of an onion crop.

9. As far as possible, soils low in organic matter, and hence in a poor physical condition, should not be planted to onions until they are built up and their physical condition properly developed.

10. Planting of onion seed should be done not too early in the fall while the soil and climate is still hot and favorable for pink-root development in the seedlings. Neither should seeding and transplanting be so late as to force the crop to bulb and mature during the hot weather of spring, especially during May. Any severe check, or stunting of the plants during the growth and development of the crop will be favorable to more serious pink-root infection.

11. It is especially advisable to avoid late planting of fields known to be infected with pink root. Transplanting of green sets in the field should be followed immediately by an irrigation so as to avoid delay in the development of new roots and new growth. Any such delay will favor pink root getting the upper hand.

12. No fertilizer, or alkali, is directly the cause of pink root. Unfavorable soil conditions may weaken the plants and make them more susceptible to the disease.

ACKNOWLEDGMENTS

The authors desire to acknowledge especially their obligation to the demonstrators, Steve Simon, Geo. W. Derby, and L. J. Christen of Laredo, Texas, who assigned suitable blocks of their farms for experimental and demonstration purposes. Except for their liberality in the assignment of the use of tools, necessary labor, and other minor local expenses, as well as for their hearty cooperation, it would have been impossible to conduct the field trials upon anything like an adequate basis.

To the Barrett Company we acknowledge the donation of the liberal amounts of Arcadian brand of sulphate of ammonia for the tests.

Perth Amboy Chemical Company donated the necessary supply of formaldehyde for the extensive field tests.

We further acknowledge the donation of an ample supply of cyanamid by the Cyanamid Manufacturing Company.

Finally, the Armour Company donated sufficient quantities of both sulphate and muriate of potash, to make the chain of tests complete, at a time when it was practically impossible to secure these elements.