Agricultural Experiment Station

—OF THE—

AGRICULTURAL AND MECHANICAL COLLEGE,

AUBURN, : : ALABAMA.

BULLETIN No. 36, : : : : MARCH, 1892.

SOME LEAF BLIGHTS OF COTTON,

GEO. F. ATKINSON, BIOLOGIST.

CONTENTS.

☞The Bulletins of this Station will be sent free to any citizen of the State on application to the Agricultural Experiment Station, Auburn, Ala.

All communications should be addressed to
EXPERIMENT STATION, AUBURN, ALA.

THE BROWN PRINTING CO., PRINTERS, MONTGOMERY, ALA.

I. YELLOW LEAF BLIGHT.

Several of the maladies of the cotton plant are indiscriminately termed "rust" or "black rust." As I have repeatedly taken occasion to remark it is very unfortunate that the name "rust" was ever applied to any disease of the cotton plant at present known in the United States.

Unfortunate in the first place because none of the true rusts are yet known to attack cotton in the United States, although recently a true rust has been found to attack cotton in certain parts of South America.* In the second place as a popular name it carries with it such indefinite and variable characteristics as to be applied to nearly every diseased appearance of the plant. In one locality it means one thing, and in another locality quite a different thing. Again, in the same locality different diseases at successive periods in the same season are often termed "rust." It is obvious that with this confusion existing it is nearly or quite impossible to discuss intelligently any one of the so-called "rusts." So we frequently find that much of the discussion of "cotton rust" is contradictory.

For these reasons I have decided to speak of the disease of cotton fully described below as yellow leaf blight, and I urge upon all who observe closely enough to distinguish it

NOTE.—In a study of this disease in all of its phases the writer has found it necessary to give considerable attention to the effects produced by soil conditions. Acknowledgments are due to the following gentlemen who aided him by the loan of literature not easily accessible: Hon. Edwin Willits, Assistant Secretary of Agriculture, Washington, D. C.; Dr. Wiley, Chemist of the Department of Agriculture, Washington; Mr. Harris, Director of the Office of Experiment Stations, Washington; and Prof. A. N. Prentiss, Cornell University, Ithaca, N. Y.

* Lagerheim. Journal of mycology, Vol. VII, No. 1, Washington, D. C.

from other diseases to adopt this name and use it under all circumstances when speaking and writing of it. We can thus do away with the present confusion, reach a position from which we can intelligently experiment, and finally successfully treat it. There will be this advantage in diagnosing the disease, that the first part of the name has some reference to the appearance of the leaf in its earlier stages, while blight is a very appropriate word to express the final stages of the disease when it proves fatal.

I shall use the term yellow leaf blight here in all cases where I am satisfied the disease spoken of is that one, even though it may have been reported to me under another name. My correspondents will therefore understand why it is if that term is thus used.

It is not without some misgivings that just at this time I should undertake to lay before the cotton planters of the State the results of this year's experiments in preventing the disease, and recommend a careful and intelligent trial, on a small scale the first year, in preventing it. For, considering the present over-production of cotton compared with the small production of food stuffs in the Southern States, it might seem an idle thing to do. Especially so since it has been several times suggested to me, by some who have looked at the matter hastily and superficially, that instead of desiring to know how to prevent the diseases of cotton now, we would do better to discover some new enemies of the plant. It is not likely such persons would view with alarm the destruction of a sufficiently large portion of the cotton crop to insure a good price provided they knew their own crop was secure and the yield would be abundant. But would they regard the matter in the same light if their own crop should be injured to the extent of 25 to 50 per cent. while their neighbors produced full crops, even though the price of cotton should be low?

The fair way to look at the matter is, that with the in-

creasing competition in cotton culture through the increased acreage of the past few years and the constantly decreasing productiveness of many soils, we should take advantage of the results of research which show that judicious fertilizing, more careful preparation and cultivation of the land, proper means for preventing loss by disease or insects, will more than counterbalance the cost of their use. Those who endeavor to do these things well, and plant less cotton in order that they may do it well, and at the same time raise more of their own food stuffs, are the ones who will reach the greatest success in cotton culture in the future.

According to the plan proposed in Bulletin No. 27, May, 1891, entitled "Black Rust" of Cotton, and here treated of as yellow leaf blight, an extended series of investigations have been carried on during the past summer to determine more fully the nature of this widespread disease, and if possible, a remedy. In that bulletin were described several fungus organisms which "play an important part in the disease." *The late time in the season at which the investigations were begun that year (July) prevented a thorough consideration of the etiology of the disease. It could only be noted that these organisms were present and that their growth hastened the destruction of the plant. The investigations this year confirm that view of the case. But at the same time they have demonstrated that the organisms do not initiate the disease, they only aggravate it.

A Physiological Disease.—It is a physiological disease, the condition of the plant being one of imperfect nutrition or assimilation. We are not at present in a position to say with certainty whether it is induced by the lack of some nutritive element in the soil, or whether the physical condition of the soil has become deranged either by long cultivation, by washing away of the surface soil, or in some cases an original detrimental physical condition of the soil, when

*See, also, Botanical Gazette, Vol. XVI, March, 1891.

the disease is said to appear any year under all conditions. It is certainly not exclusively due to an impoverished condition of the soil, for it appears in some of the richest lands of the State. It may be that both of these conditions are more or less responsible for the trouble.

To appreciate the peculiar appearance accompanying the first stages of the disease, when it can quite readily be recognized in comparison with other affections of the leaf, one must note the general form of the leaf as well as the venation, the courses through which nutriment is distributed and the final areas through which it is diffused in reaching the ultimate units or cells of the leaf. The leaf is palmate, the main ribs, or veins, radiating from a common point at the junction of the petiole to several points on the leaf circumference, so that the leaf is either undivided, as in the case of the first few leaves developed after the cotyledons and the young leaves in the axils of the branches; or three to four or five lobed or pointed, one of the main veins extending into the corresponding lobe of the leaf. From these few main veins smaller ones branch in a monôpodial fashion nearly at right angles, reaching out into the triangular area lying between. From these again still smaller branches extend which themselves are branched, and so on until all parts of the leaf are at last intersected by the final smallest veinlets. This network of veins is the medium through which the minute channels course that conduct water and nutritive solutions absorbed by the roots and transported through the circulatory passages of the stem to all parts of the leaf.

It will be seen that the ultimate ramifications of this network of veins divides the leaf tissue into quite small angular areas and that the circulatory channels in the veinlets lie along the borders of these areas. Now it is clear that as the nutritive substance pass by diffusion from the channels in the veinlets to the areas between them, that the cells

of these areas lying closest to the ribs will be the first to obtain nourishment, and the cells toward the centre of these small angular areas will be the last. When there is an abundance of the nutritive solution, containing all the necessary elements, all the cells of these areas will be well supplied, and, other things being equal, will remain healthy and green. But if the supply is deficient either in quantity or quality the first cells to feel this deficiency will be those in the centre of these angular areas, while all the cells lying along the track of the distributing channels may be well supplied for a time. The effect of this deficiency, either in nutrition or assimilation, is shown in a partial disorganization of the chlorophyl, or green substance, which causes it to become yellow in color. At first this change in color is quite indistinct, but gradually becomes more marked until it is plainly seen. Where this takes place it gives to the leaf a checkered appearance, the cells along the channels in the veinlets which bound the yellowish areas remaining quite green for sometime. Sometimes the disease progresses more rapidly so that the smaller veins are also yellow and it is only along quite close to the larger veins and their branches that the green color is present. *In the farther progress of the disease, if the weather continues quite dry, the leaf after awhile will gradually dry, become shriveled, and fall off. If rain and hot weather succeed each other, semi-parasitic fungi grow in the leaf, absorbing the living substance for their own growth.

These fungi are microscopic plants, but when produced in great numbers they give a dark brown or black appearance to the leaf. When the plant is badly diseased it will die without the injuries produced by these organisms if the weather is not suitable for their production and dissemina-

*Cotton frequently has a yellow cast affecting all parts of the leaf, as well as the tender parts of the stem, even when fertilized with Kainite. This yellow cast is quite different from the yellow leaf blight. Nitrogenous fertilizers will usually prevent this yellow cast.

tion, but the attacks of the fungi always hasten the disease and increase the injury.*

While the question of the etiology of the disease was a matter of doubt, the experiments were arranged so that careful tests could be made of fungicides in three different places in the vicinity of Auburn, one at Mathews Station, and another at Hope Hull. In three cases liquid applications were made, the fungicides used being the well known Bordeaux mixture and the Eau celeste. In the other cases four different powders were used, the fungicide ingredients in all being copper sulphate and the menstrum varying to test the adhesive property of several substances. In all cases where the disease appeared in the experiment tracts, not the least benefit was derived from the application of fungicides. It would be, therefore, quite superfluous to enter into a detailed statement of their application, their only value being in the nature of confirmatory evidence of the conclusion arrived at from an entirely different standpoint, that the disease is a physiological one.

Experiments with Fertilizers.

The experiments with fertilizers produced results which indicate that with some experimentation for different soils and careful preparation of the proper fertilizers planters will be able to control the disease, or at least to check it, or to reduce the annual loss sustained on its account, to a minimum.

Three experiment tracts were employed, one on the station farm at Auburn, one at Mathews Station, and one at Hope Hull.

Experiments at Mathews Station.—These were conducted on the farm of S. B. Mathews, who very kindly attended to the application of the fertilizers according to directions.

*For a description of the fungi referred to here, see Bulletin No. 27, Ala. Agricultural Experiment Station, May, 1891.

There were fourteen plats, all treated in the same manner as the first fourteen plats on the experiment tract at the college farm, in Auburn, to which the reader is referred for the arrangement. As the disease did not appear in this tract, any further discussion is unnecessary.

Experiments at Hope Hull.—These were conducted on the farm of A. H. Clark, to whom the writer is very grateful for the special care given in carrying out the plan as well as for the valuable information given from several years intelligent observation of the disease. The experiment was conducted in what is known as black land, and has the reputation of being liable to the disease.

The kind of soil, manner of preparation, and time of application of the fertilizers is thus described by Mr. Clark:

"The experiment was made on black land with a little admixture of gray, washed from an adjacent hill.

"The land was prepared about 1st April, 1891, by running a deep centre furrow and then bedding out in five feet rows—the basis fertilizer, 667 lbs. phosphate and 333 lbs. cotton seed meal being applied on each side of list, that is, the first two furrows we make in bedding. The other fertilizers were applied on each side of the drill where the plants stand, 9th June, 1891.

"The first cultivation was given with a solid sweep, thus thoroughly distributing the basis fertilizers—the subsequent cultivations were all given with a flat sweep barely scraping the surface.

"The land is very fine corn land, not adapted to cotton, but well suited as an experiment tract for yellow leaf blight."

There were twelve plats, consisting of three rows each. The plan for the intercultural application of kainite, nitrate of soda, and salt with the checks is shown in Table I. Plats 4, 8 and 12 were treated with fungicides, but as stated above, they had no effect, and these plats are, therefore, treated as checks.

In the same table will be found the number of stalks diseased in the middle row of each plat on Sept. 6, as counted by Mr. Clark, also the percentage of disease in each middle row, as well as the yield per acre of seed cotton, as determined later :

TABLE I.

Fertilizer, lbs. per Acre.	No. stalks diseased in middle row, Sept. 6.	Per cent. of disease in middle row.	Seed cotton per Acre.
No. 1. Kainite 200 pounds	24	13.33	1088
" 2. " 400 "	8	4 44	1291
" 3. Check	39	21.67	1104
" 4. "	47	26 11	1048
" 5. Nitrate of soda 200 pounds	54	30 00	959
" 6. " " 400 "	64	35 56	1040
" 7. Check	62	34.44	711
" 8. "	66	36.67	784
" 9. Salt 200 pounds	53	23.33	1015
" 10. " 400 "	34	18.89	1186
" 11. Check	68	32 22	931
" 12. "	73	40 56	997

The following is quoted from Mr. Clark's letter of September 6th :

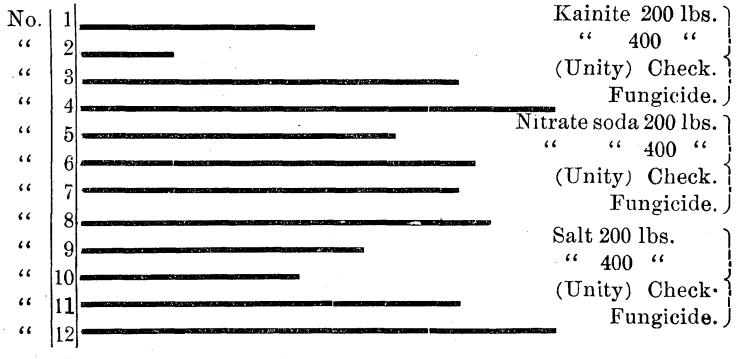
"Plainly there is a lack of homogeneity in the tract as a whole, regarding the liability of the plant to rust. Nos. 3, 7 and 11, all checks, show this, and Nos. 4, 8 and 12, all treated with fungicides, but which can be considered almost as checks, show the same thing. Hence we can only compare applications with checks close at hand, and say—

Nos. 1, 2 and 4 with No. 3.
Nos. 5, 6 and 8 with No. 7.
Nos. 9, 10 and 12 with No. 11.

Making this comparison, the actual number of stalks on each row averaging 180 we find." (See Table I for per

cent. of disease.) "Now taking groups of four plats, check rows representing unity, and comparing with each other, the resultant diagram will give probably a fair comparison of the whole tract." (See Diagram I for comparative amount of the disease.)

DIAGRAM I.



"Showing general result in their order of benefit at this day to be—

400 lbs. Kainite 1st.
400 " Salt. 2nd.
200 " Kainite 3rd.
200 " Salt. 4th.

Nitrate of soda either detrimental or of no benefit."

Also from Mr. Clark's letter of November 9th, I quote the following :

"I have gathered the cotton from our experiment tracts—the weights are as below stated. "(See Table I.)" The results are not a fair indication of what we might expect another year, as the season was bad for cotton production—too wet in the early part, with no rain for the past two months. My crops on these lands is 25 per cent. less than last year.

"If we could throw out No.'s 7 and 8 the results would be satisfactory and intelligible. I cannot account for the

product from these two tracts being so small, but they were as reported and one checks the other. I recall that some eight or ten years ago my ditch bank that protects this plot broke, several rows were badly washed, but that it was exactly at this place I cannot say. It was somewhere on this experiment tract and it was not at either end.

"Referring to my report of September, as to the condition of the plats with regard to the yellow leaf blight—you will see that the scales show about the same result as the eye did at that date, that is to say, a comparison of the yield from No 2, kainite, with the average of checks 3 and 4 shows about the same increase as a comparison of No. 10, salt., with the average of checks 11 and 12; but if we compare the total increased yield from the two kainite tracts with that from the two salt tracts, the latter shows better results.

"There can be no doubt as to the effect of kainite, as my former experience is the same as that of this year, but I think to thoroughly prevent the disease would require not less than 500 or 600 lbs. per acre, or possibly a smaller quantity confined to the drill. The action of salt this year invites further experiments with larger quantities applied in the same way, and smaller quantities applied in the drill."*

Experiments on the station farm, Auburn. Table I exhibits the arrangement of the plats, yield of seed cotton per acre, and the condition of the plant on September 12. Plats 1–16 were arranged by myself, after consultation with Prof. J. S. Newman to determine the amount of the fertilizers to be used. Plats 17–20 were added by Prof. Newman. The plats consist of three rows each, ex-

*NOTE.—The nitrate of Soda would probably produce better results when applied earlier. According to Dr. McBryde the yield is as great when applied with tho other fertilizers as when applied as a top dressing. (South Carolina Agricultural Exp. Station, Clemson Agricultural College, July, 1891.)

tending a distance of 35 yards. The land was fertilized the previous year with compost consisting of stable manure, cotton seed meal and acid phosphate.

TABLE II.

1891—COTTON EXPERIMENTS WITH FERTILIZERS.

Plats 1-35 of an Acre, 3 rows to plat, planted May 6th, 1891.

Plat No.	Fertilizers used per Acre, when and how applied.	Seed cotton, lbs. yield per acre	September 12.
1	200 lbs kainite May 6	973	Healthy.
2	400 lbs kainite May 6	850	Healthy.
3	200 lbs kainite May 6, 200 lbs nitrate soda July 3	801	Healthy, Very green.
4	400 lbs kainite May 6, 100 lbs nitrate soda July 3, 100 lbs nitrate soda July 14	924	Healthy, Very green,
5	No manure	465	All diseased.
6	No manure—fungicide, wet	430	All diseased.
7	200 lbs kainite May 6, 200 lbs cotton seed meal May 6	871	Little diseased.
8	200 lbs kainite May 6, 200 lbs cotton seed meal May 6, 200 lbs acid phosphate, May 6	955	Little diseased.
9	No manure	532	Badly diseased.
10	No manure—fungicide, wet	591	Badly diseased.
11	" " dry	542	Badly diseased.
12	200 lbs acid phosphate May 6	640	Badly diseased.
13	200 lbs acid phosphate May 6, 66⅔ lbs nitrate soda July 3, 66⅔ lbs " " July 14, 66 3-3 lbs nitrate soda August 10	637	Badly diseased.
14	200 lbs acid phosphate May 6, 200 lbs kainite May 6	931	Little diseased.
15	No manure	521	Badly diseased.
16	No manure—fungicide	553	Badly diseased.
17	200 lbs blood and bone meal May 6	696	Badly diseased.
18	200 lbs bone meal May 6	605	Badly diseased.
19	1000 lbs compost May 6	661	Badly diseased.
20	75 lbs nitrate soda May 6, 200 lbs acid phosphate May 6.	966	Little diseased.

The results are very satisfactory as well as interesting. September 12th, plats 1, 2, 3 and 4 were perfectly healthy, every stalk by actual observation being free from the disease. In plats 5 and 6, the checks, every plant was diseased. Plats 3 and 4 were greener than plats 1 and 2, showing the effect of the intercultural application of nitrate of soda. Plats 7, 8, 14, and 20 while little diseased, were far healthier than the remaining ones. In all of these plats, 1, 2, 3, 4, 7, 8 and 14, it was easy to see, by comparison with the others, that the entire or partial prevention of the disease was due to the kainite. The partially diseased condition of plats 7, 8 and 14 might be accounted for on the ground that the acid phosphate and cotton seed meal may to a limited extent inhibit the action of the kainite,* while it can be readily seen by comparison that they do increase the yield. 400 or 500 lbs. of kainite would probably have prevented the disease altogether up to that date, and with the other fertilizers have increased the yield still more.

Plat 13, which was very badly diseased, shows that the nitrate of soda applied interculturally produces very little effect. Plat 20 was very little diseased, but here the nitrate of soda was applied May 6th, when the cotton was planted. It may have a beneficial effect when applied early, while all the experiments this year show that interculturally, or late as July, it produces no effect as a preventative of the disease. However, plats 1 and 20 should be thrown out of consideration as we will find it necessary to do when we consider the yield. On either side of the experiment tract the cotton in the field was planted in rows which ranged down to a sloping hill-side, so that the outside rows in plats 1 and 20 received some of the fertilizers washed down during rains. This was

*Note.—The cotton seed meal might inhibit to a certain extent the action of the kainite, since it probably decreases the surface tension of the film of surface water, and makes the plant more susceptible to drought, while the acid phosphate probably hastens maturity.

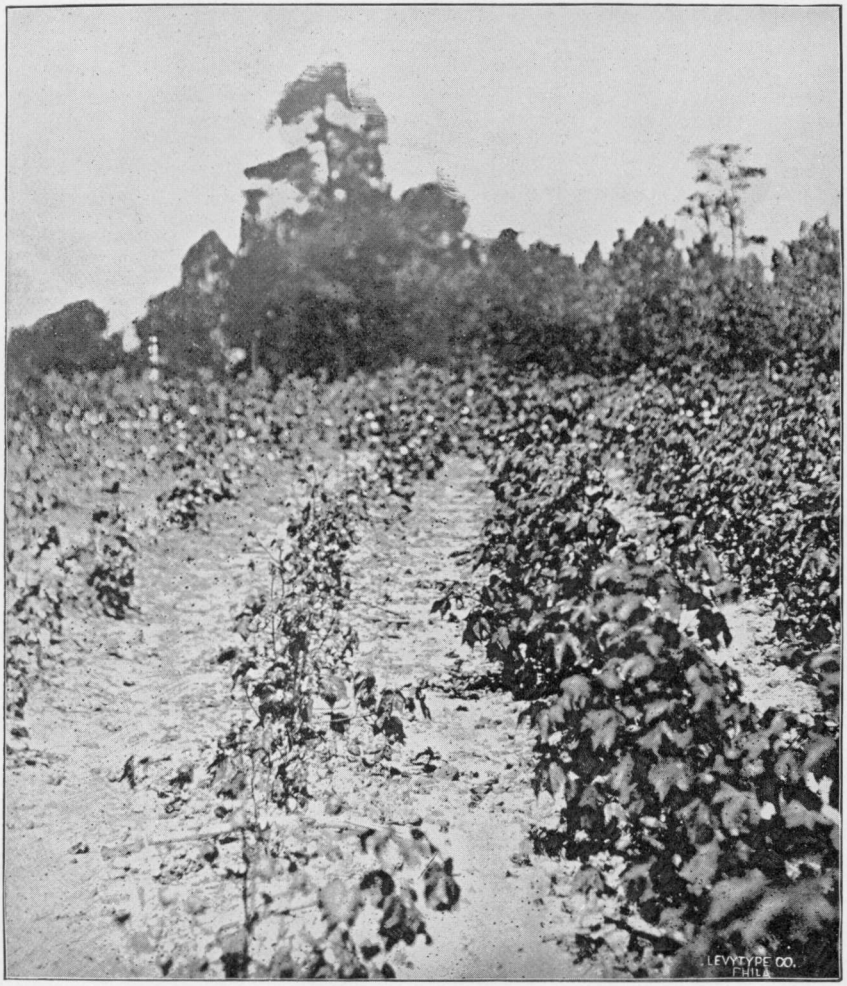
quite evident to the eye, these rows being much more vigorous than any others on the entire tract. The other plats were not vitiated, however, for at the ends of the plats the field cotton was rowed transversely, or across the ends, so that no wash would be carried on to the tract at the ends. By a study of the table it is noted that the nitrate of soda applied interculturally, practically did not influence the yield. Plat 1, by comparison with the effect of kainite in the other plats at the rate of 200 lbs. per acre, shows an increase in yield of about 100 lbs. of seed cotton per acre. Allowing the same increase from field wash for plat 20 that has been allowed for plat 1, there is left to the credit of the 75 lbs. nitrate of soda applied at the time of planting, about 150 lbs. seed cotton per acre. This is based, however, on a single plat and does not offer such reliable testimony as if based on several.

The yield on the kainite plats is increased from 70 to 100 per cent. above that where no fertilizer was used, and an average of 40 per cent. increase over that of any other single fertilizer or combination, without the kainite used.

During the latter part of September I photographed plats 4 and 5. The result is reproduced in Plate I.

These experiments indicate then that with such a season as the past one, and where the other nutritive matters are present, kainite not only tends to prevent the disease, but also increases the yield.

It is claimed by many that, during seasons when rains are abundant and well distributed through the season, so that there is no period of drought, the kainite does not increase the yield. Such seasons are usually quite free from the disease. This tends to show that the disease is due to a detrimental physical condition of the soil, inducing improper circulation of water in the soil, and will be referred to again under the discussion of the physical condition of the soil.



NOTHING. KAINITE.

PLATE I.

Kinds of Soils on Which the Disease is Likely to Appear. The disease is liable to occur on many soils where the surface soil has largely been washed away by rains; on very porous soils, whether sandy or lime lands, and on poorly drained low ground. It is of more frequent occurrence in what is known as the prairie section, but in years like the past one it occurs in the sandy uplands as well.

At my request Mr. Clark has prepared the following statement of lands in the prairie section which according to his observations are subject to the disease.

"As regards the liability of different soils in my section to produce the disease called yellow leaf blight in cotton—

1st. If the surface soil is washed away, and the subsoil of whitish color filled with particles of lime is exposed—the cotton will always blight.

2nd. If the soil is black gunpowder or loose gray—cotton will blight more or less every year.

3rd. Good, heavy, well-drained clays seldom blight, in fact last year was the only one in eleven years that clay lands blighted with me, and it was not developed even then as much as on other soils.

In the first case the land is very poor—bad for any crop. Second case—fine for corn, and good for cotton in a year when it does not blight. Third case—if gray or black, good for corn and cotton—if red, better adapted to cotton."

Notes on the History of Kainite as a Preventive of the Disease.

For a number of years kainite has been regarded by some as a preventive of the disease, or at least as beneficial in prolonging the life of the plant, so that it is better enabled to hold its leaves. It would be well nigh impossible to review all the evidence on this topic which has been presented in various agricultural, or non-agricultural papers. Therefore I shall confine myself to a presentation of the facts

gathered from the most trustworthy sources which have come to my notice.

It is impossible for me to say whether or not all the diseases referred to below are the same as yellow leaf blight. I am quite confident, however, that some of them are. I am sure that the disease does exist to some extent in North Carolina, for I have had it described to me by very intelligent men. However, I will follow the course I proposed at the beginning, and only use the term, yellow leaf blight, when I have myself seen the disease, or I am convinced that the party reporting it knows how to distinguish it from the other affections of the cotton plant.

In the treatment of all diseases we expect some failures, and it would be a most remarkable fact if kainite was a preentive of the disease in all cases. Some of the reported failures are undoubtedly due to a failure to properly diagnose the disease. For example, kainite will not prevent what I have been accustomed to term a bacterial disease. I noted that in my experiment tract at Mathews Station. In one case where kainite has been reported to me as a failure to prevent "rust," I found on sending for specimens of the disease that it was not yellow leaf blight, but the disease spoken of above.

The first experiments with kainite as a preventive of the disease, of which I have knowledge, were conducted in North Carolina and reported by Dr. Dabney, then Director of the North Carolina Agricultural Experiment Station.* In this connection the following quotations from that report will be found interesting. P. 68. "Not infrequently it (kainite) has been used entirely alone, so applied it did well in special cases. For example, in soils good in all other respects, but upon which cotton would be invariably destroyed by rust without it, it has been very often used with most satis-

*Annual report of North Carolina Agricultural Experiment Station for 1882.

factory results." From pages 71–73. "So far as our experiments go, kainite appears to be the most effective agent which has ever been used against those destructive and mysterious diseases of cotton which we call 'rust' and 'blight.' Thorough draining, liming or marling, and good general manuring, have all cured stubborn cases of rust. But they have all failed in many other cases. It is now the quite general opinion that kainite will prevent the rust in cotton, in a great majority of cases at least. The illustrations of this are very numerous, and there is hardly a dissenting voice. One farmer says a certain amount of kainite prevented the rust on a certain soil a dry season, while the same amount failed to do it a second and very wet season. Otherwise there is hardly a doubt expressed that kainite can be used in combination with other manures in such a way as to effectually prevent rust aud the shedding of bolls. . . . One farmer says 'kainite is to rust what quinine is to chills—a specific.'

"We can cite only a few illustrations. Mr. A. F. McCallum, Roberson county, says his first trial of kainite was upon a ten acre lot upon which cotton always rusted. 'In 1880 I planted the lot in cotton, using 200 lbs. per acre of a good ammoniated superphosphate and pine straw. Made an average of 260 lbs. per acre. The rust commenced July 1, and almost ruined the cotton. In 1881 (a dry season, as was 1880) I used the same amount of ammoniated superphosphate and pine straw, with the addition of 200 lbs. of kainite per acre. Cultivated in the same manner as in 1880. I gathered an average of 700 lbs. seed cotton per acre.'

"A striking instance is reported by Mr. J C. Wooten, Sr., Lenoir county. 'The land had been well prepared,' he writes, 'and manured with compost, the cotton came up and did very well until June; it commenced rusting or frenching at this time and looked very badly. I applied on the 3rd

and 4th of July, on top of the cotton bed, by sprinkling it along the row on the cotton plants, 200 lbs. per acre of kainite. Soon after this was applied it changed color and commenced growing and has made a fine weed, well filled with cotton. I am now picking the cotton and it is very good. Without the kainite it would not have made one-half that is now matured. I think if I had applied the kainite sooner the cotton would have been still better.'

"Mr. H. M. Johnson, Johnston county, reports some experiments with kainite on typical cotton-rusting soil. He says: 'The experiment was conducted on cold, damp pond land, where cotton invariably took the rust early in the season. In all such cases the kainite causes the cotton plants to retain their leaves until the latest time in the fall, thus developing the largest amount of fruit.'"

In 1887 Mr. Clark, of Hope Hull, Ala., published a note on some experiments with kainite*, which led him to believe that it would prevent the yellow leaf blight in cotton. I quote from that note as follows: "The whole field blighted in August and September (1886) with the exception of the three rows where the kainite was applied."

Prof. J. S. Newman tells me that in some experiments on cotton with different fertilizers about 1885 or 1886 he noted that where kainite or muriate of potash was used the plant held its leaves longer than where it was not used. I regret that I cannot have access to the bulletins published on the subject at that time. The bulletins preserved in the library were destroyed by fire at a later period. As a result of some experiments in 1890†, he says: "Kainite causes the cotton plant to retain its leaves after they have blighted where none is used." This disease was the yellow leaf blight as I know from actual observation.

* Southern Agriculturist, December, 1887.

† Bulletin No. 22, New Series, Ala. Agr. Exp. Station, page 24.

Unfavorable Physical Condition of the Soil may cause the Disease.

It is well known that the physical, or mechanical, condition of different soils varies greatly not only with reference to the coarser or finer subdivision of its constituent particles, but also with reference to the amount of vegetable matter or humus which it contains. It is also well known that plants are greatly influenced by the physical character of the soil. The same soil is even subject to great physical variations during short periods of time, as shown by the different relations of its constituent particles with the varying quantities of water in it, or during longer periods by continual cultivation, removal of vegetable matter, exposure to heat, the washing of rains, etc. It is now believed by some that in many cases the physical condition of the soil can be changed for good by the application of certain chemicals which change the inter-relation of the constituent particles of soil and influence the circulation of water. Plants suffer greatly from improper circulation of water in the soil. There are cogent reasons for believing that the yellow leaf blight of cotton is more or less due to defective circulation of soil water. This is apparent to a greater or less degree from a consideration of the following topics:

Hydrostatic Water in Soils.—When the soil contains an excess of water so that it exists as a liquid, as in low or poorly drained land, the absorptive activity of roots of other than aquatic plants is greatly interfered with, since this excess of water excludes more or less of the oxygen which is necessary for root absorption.* The roots of land plants usually obtain their moisture† from either *capillary* water (when the water exists as a thin film around the soil particles, giving them a moist appearance) or *hygroscopic* water

* Goodale, Physiological Botany, pp. 244–245.
Johnson, How Plants Feed, p. 199.
† Ibid, p. 242.

(that which adheres to particles of air-dry soil and does not affect their appearance).

Frequently cotton grown in soil possessing *hydrostatic* water has every appearance of yellow leaf blight. Assimilation is probably disturbed much in the same way as in a soil which is too dry; in the one case the excess of water prevents the absorptive activity of the roots, so that the plant is powerless to take up the necessary elements of nutrition in the soil; in the other case the soil is too dry and therefore lacks a sufficient supply of moisture to provide for the solution of nutritive matters held in the soil. In wet seasons, or wet periods of a season, the injurious effects of hydrostatic water in the soil is more wide spread than in ordinary or dry seasons. It may happen that during frequent and excessive rains the hydrostatic water in the soil is so abundant as to exclude an amount of oxygen sufficient to seriously interrupt root absorption on soils ordinarily well drained. This would explain why both in excessively dry, or wet, weather, or in dry or wet soils, the disease is more apt to make its appearance.

Summer Droughts.—During summer droughts when usually excessive heat prevails throughout the cotton belt, evaporation of the capillary water in the soil takes place rapidly and the absorptive activity of the roots is increased, thus making a greater drain upon the moisture in the soil. In very porous soils, or those not retentive of moisture the capillary water in the layer of soil occupied by the roots of the plant is soon exhausted. If the physical condition of the soil is good, the evaporation will be less rapid and at the same time the tension of the film being greater more water is lifted up from the subsoil, thus prolonging a favorable condition of things for root absorption, and lessening the possibility of disease.

In 1887 Mr. Clark, of Hope Hull, writing in regard to

the relation of the physical condition of soils in the prairie lands to the yellow leaf blight, says :*

"In my seven years' experience in planting on this place, yellow leaf blight has been with us every year but one, although some years it is more destructive than others. It comes in a dry spell of weather following a wet or a wet spell following a dry—my experience is that it matters not which—the disease follows. Only one year have we been free from it and that was in 1882. A phenomenal year in which we had a light shower almost every week.

"Taking into consideration the fact that it never attacks clay lands which retain the moisture long after the other lands are dried up (my plows have turned up moist soil in clay lands when the porous lands were thoroughly parched) and always attacks porous soils excepting in a year that is phenomenal in maintaining in the soil an equilibrium of water, makes me believe that the "hydrostatic" condition of the soil has much to do with inviting the disease.

"In clay lands which retain the moisture longer, the wet and dry extremes are not so sharply defined and the cotton does not blight.

"Finally, I will add, that land on which cotton blights is not always poor, but on the contrary it may be quite productive. If the yellow leaf blight does not attack the plant until late it may produce a large crop. My experimental tract of 1886 showed a product on land that blighted cotton, and on which the cotton blighted badly that year, of about 1600 lbs. seed cotton per acre, same land when the yellow leaf blight was prevented about 1800 lbs.

How Unfavorable Conditions of the Soil May be Changed.

For quite a number of years it has been known that certain physical conditions of soil detrimental to plant growth

*Southern Agriculturist.

can be artificially changed. Some of the means of improving the mechanical condition of soils whereby proper circulation of soil water is brought about are enumerated below. No claim is made of a complete reference to all that has been written upon this exceedingly interesting and very important topic. Only such references are cited as have come to the writer's notice.

The effect which these substances have is not only to increase the surface tension of the film of water surrounding the soil particles, but to so arrange the constituent particles of porous or light soils that the area of the free surfaces of the soil particles shall be increased, thereby increasing not only the power of soils in dry weather to absorb moisture from the atmosphere at night, but also increasing the capillary power of the soil. This not only lessens the rapidity with which evaporation takes place from the surface soil, but exerts a greater influence in lifting up water from the subsoil.

Prof. Wagner,* Director of the Agricultural Experiment Station at Darmstadt, Germany, says :

"Unfavorable physical conditions of the soil diminish the guarantee of a satisfactory effect from commercial manures; and yet, in the use of these it is possible to check the interference of the former with plant development."

Alkaline Lyes Make Soils Cohere.—In reference to the action of these, Storer† says:

"One peculiarity which ashes owe to their alkaline quality is worthy of special attention, since it must often exert a very decided influence on the capillary power of the soils to which the ashes are applied. It is a well established fact, that alkaline lyes, that is to say, either the caustic alkalies, or solutions of the alkaline corbonates, viz., carbonate of

*Hatch Experiment Station, Mass. Special Bulletin. Translation and reprint, May, 1890.

†Agriculture, Vol. II, page 114.

potash, such as is got by leaching wood ashes, and carbonate of soda also, make clay and loam more plastic and adhesive than simple water can. Both carbonate of potash and carbonate of soda tend to keep clay in a 'puddled' or 'tamped' condition, as the terms are. A ball of moist clay or loam thus charged with an alkaline carbonate does not tend to crumble or fall to powder during the process of drying; but remains a hard lump."

Thus potash would not affect favorably the physical condition of heavy clay soils, but would act favorably on the loose soils where cotton is liable to yellow leaf blight more or less every year. In confirmation of this is the observation of some planters in the prairie soils that plowing or bedding such cotton lands while the soil is wet causes it to cohere more closely in drying and tends to prevent the disease.

*Rolling Loose Soils.**—"It seems plain, on the face of the matter, that the tilth of many a porous open soil might be improved if its particles could only be held together a little more tightly than they are held naturally, so that the capillary water may be lifted more freely and retained more forcibly. It was for the sake of securing this result that the Norfolk County farmers laid such stress on having their light soils trampled down firmly by means of cattle and sheep that were fed upon the land, and that the Scotch long since resorted to the use of heavy rollers upon their light lands."

Wood Ashes.†—"I have in fact found, by experiment upon light land, that this very advantage was obtained by the application of wood ashes to the soil. A plat of land dressed during several years with what any farmer would have considered a large quantity of wood ashes became so firmly bound that a yoke of heavy oxen had some difficulty in

*Storer, Agriculture, Vol. II, page 115.

† Storer, Agriculture, Vol. II, page 115.

dragging a plough through the soil in dry summer weather. The furrow where it crossed this plat was a mere mass of clods. Yet through all of the years of the experiments that plat had manifestly been better supplied with water from below than any of the adjacent plats."

*"It was noticed long ago by Lorain that the ground where the log heaps were burned seemed to be moister than the surrounding soil."

It is important to note in this connection what Mr. Clark told me the past summer of an experiment of his with wood ashes. A quantity were scattered about on a plat of gray land where the cotton became diseased (yellow leaf blight) every year. Since the application of ashes the cotton has been healthy, except at the border of the plat where the ashes were applied thinly.

Planters have also told me that sprinkling wood ashes on the leaves when they show the first signs of the disease will prevent it. It is not likely that the effect is through the leaf, but it might happen that a sufficient quantity would thus be applied to the soil to produce the effect.

Muriate of Potash.—"Muriate of potash used with lime forms some "chloride of calcium† which is hurtful to some plants, and which, as Mayer has urged, may 'bind' the land in some cases. It has not yet been determined whether this particular form of binding would always be hurtful for all kinds of soils."

Salt.—Prof. Wagner‡ says in regard to the action of salt: "Common salt (sodium chloride) of the crude preparations has a binding effect on the soil and increases its power to retain water. It is this effect of crude salts which improves the character of light soils, but which, on the other hand,

* Storer, Agriculture, Vol. II, page 116.

† Storer, Agriculture, Vol. II, page 125.

‡ Wagner, Agr. Exp. Station, Darmstadt, Germany.

Hatch Exp. Station, Mass. Translation and reprint. Special bulletin, May, 1890.

deteriorates heavy soils already possessed of too much binding quality. It is not advisable, therefore, to manure heavy soils with kainite or common salt."

In this connection see the effect which salt has in preventing yellow leaf blight as determined by the experiments at Hope Hull detailed above. It is also interesting to note that for many years salt has been regarded by some planters as a preventive of the disease.

Humus.—This also has its advocates as a preventive of disease, while the testimony of others is against it. It is very important to observe, however, that so far as I have heard, failures have been reported where there was an abundance of humus in heavy soils; but where the soil was sandy, the effect was beneficial. Humus alone, as is well known, is more retentive of moisture even than clay, and when mixed with porous sand* it greatly improves its capillary power. Aside from its possessing nutritive properties, it tends to prevent this disease of cotton when developed in sandy soils. This may be done by dressing with vegtable composts, or by the growth of "cow peas," allowing the vines to rot on the soil. In this connection farmers will do well to refer to a recent bulletin by Dr. N. T. Lupton, entitled Pea Vines as a Fertilizer.†

Too much organic matter, however, so lessens the capillary power of soils that they dry out quickly.

Kainite.—On the effect of kainite the following quotation is of interest: "Upon heavy impenetrable soils kainite should be used with caution since it renders the ground in the highest degree damp, and this result in such soil is not desirable, while in light dry soil it is of the greatest importance."‡

* See Johnson. How crops feed, p. 162.

† Ala. Agr. Exp. Station, Bulletin No. 14, 1890.

‡Ratschläge für die zweckmässsige anwendung der Kainite—Düngung, Magdeburg, 1890, p. 5.

Effect of cultivation on the retention of moisture.—The more recent practice followed by many farmers of shallow cultivation of the crops by means of the scrape has the effect to conserve the moisture to a greater extent than deep cultivation would in dry seasons. A careful and thorough preparation of the soil before planting is necessary to prevent a too hardened and compact condition. Shallow cultivation at the proper times will keep down all weeds and also lessen the rapidity of evaporation of water from below, since the pores of the soil being larger in the loose upper layer, the surface tension of the film of water will have little force in pulling water up from the undisturbed layer below, because there is an abrupt transition from a less extent of surface of soil particles in the loose layer to the great extent of surface of soil particles in the undisturbed layer. In other words, the loose soil left by the scrape acts as a mulch to prevent a too rapid drying of the underlying soil.

Plants require more water from poor than from rich soils. While it is probably true to a certain extent, as has been frequently stated, that soils strongly charged with nutritive salts are not required to supply so great an amount of water to the plant as those containing but little of these substances,* yet it is also known that plants have to some extent a selective power in root absorption, so that they select generally those substances required for nutrition.

Since writing the above, I have received the report of the Physicist, Prof. Milton Whitney,† on "Soil Investigations," of the Maryland Agricultural Experiment Station for 1891,

* Sachs, Textbook of Physiology.
Die Landwirthschaftlische Versuchstationen 1858, I, page 203.
Botanische Zeitung, 1860, No. 14.
Pflanzen Physiologie, Pfeffer's, Bd. I, p. 151.

† Professor Whitney has been engaged for several years in the study of the physical condition of soils as related to water circulation, and already quite important results have been reached.—See Agr. Science, Vol. IV; also Annual Report S. C. Agr. Exp. Station, 1890.

recently published. On page 257, he says: "Salt and kainite, on the other hand, increase the surface tension of water very considerably and raise it far above that of the soil extract. This probably explains the fact, which has often been commented on, that an application of salt or kainite tends to keep the soil more moist. * * * * *

"By increasing the surface tension of the soil moisture they increase the power the soil has of drawing water up from below in a dry season."

The amount of potash which a plant removes from an acre of ground is no indication of the amount of potash that should be applied per acre, for some plants taking from the ground one-sixth as much potash as certain others require an equal amount of potash applied to the ground.*

The best time to apply kainite if there is any danger of its injuring plants is in the autumn or winter months. It should be plowed in. The injurious chlorides leach out while the nutritive salts are absorbed.†

Effect of Kainite on the Yield of Cotton.

The influence which kainite exerts upon the yield of cotton varies greatly, depending upon a variety of conditions. In dry seasons the testimony is almost universal that kainite increases the yield, at least where used with a basis fertilizer of the character of cotton seed meal and acid phosphate, to supply phosphoric acid and nitrogen, or even when used alone on some soils which have been treated with such a fertilizer for one or more years previous, or in soils well supplied with those elements. The past season has been a good one for such results, since there were two quite long periods of drought.

*Dr. Paul Wagner. Kali—Phosphat—Düngung nach Schultz—Lupitz, P. 71.

†Dr. Paul Wagner. Die Rational—Düngung der Landwirtschlaftlischen Kultenpflanzen. Zweite Auflage, Darmstadt, 1891. (See, also,) Maercher. Die Erfolge der anwendung verschiedener Kalisalze unsbesondere der Kainits in der Praxis. Zweiter Bericht, 1891.

The Experiments at Mr. Clark's show the increase when it was used with a basis fertilizer composed of cotton seed meal and acid phosphate. My experiments at Auburn show an increase from kainite alone on soil treated the previous year with compost composed of stable manure, acid phosphate, and cotton seed meal. In any season on very poor soil deficient in phosphoric acid, nitrogen and vegetable matter, potash alone seems to have very little effect in increasing the yield, but its value when used with nitrogen and phosphoric acid is pretty well established.*

Soils of different mechanical condition also respond in a widely different manner to applications of potash. The following notes are taken from Prof. J S. Newman's report on coöperative soil tests.†

At Uniontown in "black slough bottom" kainite alone decreased the yield from 1702$\frac{3}{4}$ lbs. seed cotton per acre to 1518$\frac{3}{4}$ lbs. The yield was also decreased with kainite in combination with sulphate of ammonia, while the latter alone somewhat increased the yield.

At Athens, on "badly worn red land" when kainite was applied alone, the effect, allowing for corrections, is scarcely perceptible, a slight increase to its credit from 150 lbs to 166 lbs. seed cotton per acre. In combination with sulphate of ammonia there was a decrease, while in combination with dissolved bone black there was an increase of 270 lbs. to 630 lbs.

Dadeville, sandy loam with clay subsoil, kainite alone increased the yield from 720 lbs. to 1260 lbs. per acre; kainite and sulphate of ammonia from 720 lbs. to 870 lbs. Kainite and dissolved bone black from 1020 to 1350 lbs; and kainite, sulphate of ammonia, and dissolved bone black, from 1020 to 1830 lbs.

---

*McBryde. South Carolina Experiment Station. Bulletin No. 2, New Series, Clemson Agricultural College, 1891.

†Bulletin No. 23, New Series, Ala. Agr. Expriment Station, 1891.

At Aberfoil, on "thin sandy soil . . . . four feet to clay . . . . planted in corn for three years without fertilizer except" the previous year when 100 lbs. cotton seed meal per acre was applied, kainite alone increased the yield from 82½ lbs. to 315 lbs. seed cotton per acre; in combination with sulphate of ammonia and dissolved bone black, from 105 to 768 lbs.

As early as 1882, Dabney* found from coöperative experiments that in some soils kainite decreased the yield, producing weed at the expense of fruit, while in other soils it increased the yield, alone in some cases, in other cases in combination with other fertilizers.

McBryde† has shown (p. 46–47) that as far as yield is concerned the potash can be obtained equally well from kainite, muriate of potash, or sulphate of potash, and that having determined the lowest maximum profitable dose of potash in combination with a certain dose of phosphoric acid and nitrogen, double or quadruple doses of potash without increase of the constants will not increase the yield (p. 38–39).

At my request, S. M. Tracy, Director of the Agricultural Experiment Station of Mississippi, has pointed out the effect of kainite on the yield as determined from several trials on some of the soils of the State. The following quotations are made from publications of that Station:

"In 1888‡ the best results were from the use of cotton seed hull ashes, of which 400 lbs. per acre made an increase in yield of nearly seventy-five per cent. over what was grown on adjoining unfertilized plats, and at a cost of fifty-five cents per one hundred pounds.

In 1889 the greatest increase in yield came from the plats which received 200 lbs. of kainite per acre, and this increase was secured at the smallest expense per hundred pounds,

*Annual Report, N. C. Agr. Exp. Station for 1882.

†South Carolina Exp. Station, Bulletin No. 2, New Series, Clemson Agr. College. 1891.

‡Third Annual Report, Miss. Agr. Exp. Station, pp. 8-9, 1890.

fifty-three cents. The increased yield of 160 lbs. from the use of ten tons of stable manure per acre, cost sixty-two and one-half cents per one hundred pounds."*

At the Holly Springs Branch Station, 1889, "plat 4, which received 200 lbs. of kainite, gave much the largest as well as the most profitable yield of any plat fertilized with a single ingredient, and a larger yield than plat 6, where acid phosphate was substituted for one-half the amount of kainite applied to plat 4."

"† The Station has been in existence three years, and has tested about fifteen fertilizers each season on the yellow clay soils which are typical of the hill regions of the State. In nearly all cases plats have been duplicated each season, and in many cases three or four plats have been used as duplicates. It has been our uniform experience during three seasons that the purchase of concentrated nitrogenous fertilizers is not profitable; that acid phosphate alone is only occasionally profitable; that potash fertilizers, either in the form of kainite, sulphate of potash, or ashes, have always given a fair profit. We have also found that a fertilizer containing a large per centage of potash with a smaller amount of phosphoric acid has invariably given a greater net profit than has any single commercial salt. While good results have always been obtained by the use of a mixture of potash and phosphoric acid salts, results have been still better when the soil has received a fair supply of vegetable matter in addition. Whether this vegetable matter is derived from composting the commercial salts with meal, cotton seed, or stable manure, seems to make but little difference though if manure is used much more will be required than of the meal or seed. The work has been mainly to determine as far as possible the elements most needed, which, as stated above appear to be a liberal supply of potash, to which should be added some other material which will furnish a smaller amount of phosphoric acid and nitrogen, together with the necessary vegetable matter. At present prices, kainite is the cheapest form in which to buy potash, while the other elements needed may be furnished in cotton seed, cotton

*This note on cotton seed hull ashes is inserted because of the presence of potash in the fertilizer.

†Ibid, pp. 14–15.

seed meal, or stable manure, the choice depending on the local supply of each available."

The results of experiments for 1891 have not yet been published, and Prof. Tracy has kindly prepared the following statement of those worked out at this writing:

"In 1891 eight plats were fertilized with variations of Furman's formula," and the plats receiving an application of the compost in which the prescribed amount of acid phosphate was replaced with an equal weight of kainite, gave about 30 per cent. heavier yield than did the plats receiving two parts acid phosphate to one of kainite." "At the branch station at Lake, in the pine woods region, acid phosphate gave much better results than did potash, and the potash plats suffered most from 'rust,' if you know what that is."

Prof. Tracy had formerly sent me specimens of the diseased cotton on these potash plots, and I was not surprised that the potash did not prevent the disease. The disease, while called "rust" by nearly all planters, is very different from the disease treated of in this paper. I am not yet certain as to its etiology. In the early stages the leaves have a water soaked appearance in definite areolate spots, which are lighter in color when viewed by transmitted light. The spots soon become black, later brown in centre and black bordered. Sometimes the spot is a long one following one of the main ribs, with a zigzag border. From the earliest appearance of the disease the tissues are swarming with bacteria. By careful attention to my description of the yellow leaf blight treated of here, any one could distinguish it from this bacterial disease. In my own experiments kainite has had no effect in preventing this bacterial disease.

II. RED LEAF BLIGHT.

"Red rust" is a term frequently applied to a reddened condition of the plant often seen on worn-out sandy land, or uplands. It is a hastened maturity of the plant induced by an impoverished condition of the soil, showing a lack of nitrogen and potash, and probably also phosphoric acid. A red coloring substance, known as erythrophyl, is developed in the cell sap of the leaves.* This can be remedied by proper fertilizing.

* Sometimes a reddening of the leaves is produced by the irritation of mites.—See Bulletin No. 29, New Series, Ala. Agr. Exp. Station, 1891.

At the request of a firm in Baltimore, Boykin, Carmer & Co., I tried a preparation of theirs called "Cerealite" on very poor sandy land, to test its efficacy in preventing this hastened maturity and reddening of the plant. The land was fertilized very lightly with stable manure, about 500 lbs. per acre. As directed by them, the "Cerealite" was applied as a top dressing at the second plowing of the cotton. It effectually prevented the reddening of the plant and prolonged the period of growth and fruiting, also greatly increasing the yield. The contrast was so great between the fertilized plats and the checks that I photographed one average stalk from the former and two average stalks from the latter. They are shown in plate II. The increase in yield of the treated plat over the untreated plat from which the stalks in this photograph were taken was 225 per cent., from 132 lbs. seed cotton per acre on the untreated to 429 lbs. on the treated.

This "Cerealite" was also tried on upland of a better character which was fertilized the present year with compost of stable manure, acid phosphate, and cotton seed meal to determine its value in preventing the yellow leaf blight. There was little of the disease in any part of the tract, but a slight improvement was shown in favor of the "Cerealite." Analysis shows the fertilizing material to be potash and nitrogen.

The same fertilizer was tested on the prairie soils by Mr. A. H. Clark, at Hope Hull. The results were not very marked. The "Cerealite" for all these experiments was in three different forms containing various relative proportions of nitrogen and potash. From other experiments we should expect the potash to show a tendency to prevent the disease. This was the case to a slight degree in two of the forms, while in one there was no improvement. As it was applied inter-culturally we would not expect the nitrogen (probably from nitrate of soda) to produce any effect. Indeed Mr. Clark thinks nitrate of soda applied inter-culturally to the dark prairie soils is really injurious to the cotton plant.

NOTHING.

POTASH AND NITROGEN.