Results of the work done under Fertilizer Control are given in the main in Bulletin No. 46. A considerable portion of the time of the chemists has been occupied in this work.

The work on pests of shade and ornamental trees and an experiment on plum rot is given in Bulletin No. 47.

From April to November most of the time of the Director was given to the Dairy Tests by the World's Columbian Exposition at Chicago.

These Tests of Dairy breeds of cattle have been a subject of much interest to all interested in Dairy work, and especially to the Stations, but the question of how to get a sufficient number of representative cows of the different breeds together in an experiment without entailing an expense altogether beyond the resources of any Experiment Station, has prevented any systematic work in this line by our Experiment Stations, except in a few instances where but from 2 to 4 cows of each breed were used. In all such cases results must be necessarily unsatisfactory. Through the efforts of Chief Buchanan, Department of Agriculture, World's Columbian Exposition, the Exposition authorities inaugurated a breed test of Dairy cattle on a very extended scale.

In order to conduct the test, Mr. Buchanan called to his assistance the Association of American Agricultural Colleges and Experiment Stations. This Association appointed a committee to conduct the tests. As a member of that committee, I gave most of my time from April to May. The results obtained at a cost of about $70,000 will soon be available to the Stations, and thus the test has furnished opportunity for the study of dairy problems such as only could have been secured under the auspices of such an organization as the World's Columbian Exposition. The tests are very full and complete. Nothing in the dairy line has heretofore approached these tests in number of cows under test, in length of time the tests cover, or in the completeness of the records.

PUBLICATIONS.

Four Bulletins have been published and are incorporated in this report. Some 11,000 copies of each of these Bulletins have been distributed in the State.

M. A. Scovell, *Director*.

Analysis of the Air-Dried Material.

Station Number.	2130	2131	2276	2277
	Per Ct.	Per Ct.	Per Ct.	Per Ct.
Nitrogen	0.108	0.067	0.200	0.515
Potash	.532	.515	Trace.	.015
Phosphoric Acid	.096	.080	.592	.423
Lime	.198	.175	....	....
Insoluble Residue	86.446	82.486	....	....

2114. Ashes of hickory wood, sent by Mr. A. P. Farnsley, Louisville, Kentucky.

2233. Nitrate of potash, purchased of Messrs. H. J. Baker & Bro., for use in fertilizer experiments.

Station Number.	2114	2233
Lime	36.86 Per Cent.	....
Phosphoric Acid	1.15 "	....
Potash	4.50 "	46.08 Per Cent.
Nitrogen	....	12.70 "

2083. Phosphatic limestone from the soil near the surface, on the farm of Dr. R. J. Spurr, near Greendale, Fayette county, Kentucky. (See previous reports).

A soft, porous rock, in thin pieces, chalky in appearance and feel, and brownish in color. Qualitative tests showed the presence of fluorides, but only traces of carbonate of lime.

Station Number.	2083
Phosphoric Acid	36.16 Per Cent.
Equivalent to Phosphate of Lime	78.96 "
Insoluble Residue	4.04 "

poison uniformly suspended in the water, and as the operators are not very careful in regulating the quantity of poison used, it becomes of interest to determine whether it may not sometimes be deposited in notable quantity upon the leaves, and also whether a perceptible amount of arsenic may not remain in the cured tobacco, notwithstanding the claim of those who use this method that, if the spraying is done before the plant is topped, none will remain. As a preliminary study of this question, the writer obtained three samples of leaf tobacco in the condition in which it is put on the market by the farmer. One of these was from a crop that was said not to have been sprayed after topping; the number of applications, or their time, was not known in either case. Each sample was dried and ground, and 100 grams of each digested at a moderate heat, with dilute hydrochloric acid, filtered, and the solution treated with hydrogen sulphide, and the precipitate purified from organic matter by drying and treating with nitric and sulphuric acids, and precipitating again with hydrogen sulphide, after reduction with sulphurous acid, according to well-known methods. The sulphide of arsenic was then separated by solution in carbonate of ammonia solution. In each instance, notable quantities of both copper and arsenic were obtained, the smallest being from the tobacco which was not sprayed after topping. This being intended only as a qualitative test, no care was taken to recover all the arsenic, but as the quantity obtained was weighable, the largest precipitate of sulphide was oxidized by hydrochloric acid and potassium chlorate and determined as magnesium pyroarsenate, yielding a quantity equivalent to 4mg arsenious oxide from 100 grams of tobacco.

It is proposed to continue the investigation this winter upon a larger number of samples.

Orchard Grass (*Dactylis glomerata*).

This well-known species was planted in a plot by the side of another in which timothy was grown, and showed so many desirable qualities by comparison that it seems worthy of mention in this connection. Of the two, the orchard grass plot has always shown the best growth, and, if we might judge from them alone, is the more valuable for meadow.

Rescue Grass (*Bromus schraderi*).

This rather coarse grass is said to be valued in England, where several crops are cut in a year. It does well with us, sending up a uniform growth of coarse, light green blades. It produces in June flattened heads, finally becoming brown, and with a tendency to droop because of their weight. When cut it sends up a new growth of blades promptly, and even in winter brightens up quickly during periods of mild weather, showing that it is perfectly at home with us.

English Rye Grass (*Lolium perenne*).

This is said by seedsmen to be "the staple grass of Great Britain," but in our plot, has not at any time given evidence of the qualities for hay it is claimed to have. About the middle of June it has shown, thus far, a rather slight growth of culms about two feet six inches high, with blades at the base from nine to ten inches in height. It remains confined to the lines in which its seed was drilled, and does not appear in any way calculated to compete for favor with such grasses as orchard grass, timothy and English blue-grass.

Crimson Clover, Italian Clover (*Trifolium incarnatum*).

This beautiful annual clover is worthy of cultivation for ornament, if for nothing else. It has good qualities as a forage plant besides, having been shown by analysis to compare well with red clover in nutritiousness. Planted in the fall, it matures early in the spring, in time to give place to some other crop. That grown on the Station farm measured, when mature and in blossom, one foot and ten inches in height. It received its name from the elongated bright crimson heads, which are at their best about the middle of May.

The complete failure of the apple crop for 1893 prevented a continuation of our experiments on apple rot. They will be continued, if possible, this season. An experiment on plum rot was made and reported on in Bulletin No. 47, confirming the results of our work of the previous year with Bordeaux mixture, and showing that the rotting of plums can, to some extent, be checked by the use of this preparation.

The experiment started by me in the fall of 1889 with a view to settling the question as to the length of time broom-rape seed retains its vitality when in the soil, was continued with the result that seeds planted in 1889 germinated and produced broom-rape in 1893, but the plants were few in number, and weakly, from which I am led to hope that another season will show them to have lost their power of germination. The matter is of considerable importance to growers of hemp and tobacco, since it will determine the time which land infested with broom rape must be avoided for crops which this pest attacks.

Experiments were made also with several of the patent insecticides and fungicides, usually with the result, however, that for effectiveness they were shown to be not equal to such well-known materials as bluestone, sulphur, Paris green, hellebore, etc. One experiment is worth reporting here, since it suggests a means of getting rid of an abundant and injurious pest of this part of the country. The melon aphis is a small dark green insect, like the rose aphis of hot-houses. It is extremely abundant here, and collects in large colonies on the under side of melon leaves, causing them to curl up in such manner that the insects can not be reached by employing the usual sprays. The knapsack sprayer made by Wm. Boekel & Co., of Washington, was used first, the undersprayer being attached with the idea that the under sides of the leaves could be reached with its help. But it was found to be impracticable, because of the time required in passing along each vine and spraying every leaf. Tobacco smoke was next tried, the melon vines being rolled up and covered with a wooden box, or tub, then puffing the smoke under the edge with a bee-smoker. By this treatment the aphides were stupified for a time, but if watched afterward for several hours were found to recover. Bisulphide of carbon was next employed, a tub being inverted over the vines as before, and a saucer containing a tablespoonful of the bisulphide being placed under its edge. The fumes of this substance were found to kill the aphides completely, and if not applied too long will do no injury to the vines. Since the aphides usually appear on one or two vines in a field and spread from these as a center, it should be possible by means of the bisulphide to check the injury of the pest.

O her work during the season consisted in studying the life-histories of shade-tree insects, several of which were unusually injurious during the season of 1893. Part of the result of this work is published in Bulletin No. 47 of the Station.

The most notable insect injury during the season of 1893 was that done by grasshoppers in meadows and cornfields. The species concerned in this work were the large spotted bird grasshoppers (Schistocerca americana), a species closely related with the locust of the Bible, and a small red-legged species which occurs everywhere in the United States, and is sometimes mistaken for the Kansas grasshopper. Such outbreaks occur usually during exceptionally dry seasons, such as that of last summer, but do not often continue for more than two seasons in succession. The species concerned in last year's injury may be sufficiently abundant to call for attention next summer, but will probably not again appear in destructive numbers for a number of years. When doing serious mischief in cornfields, the application of Paris green is to be recommended as the best calculated to destroy them; the fodder from the sprayed plants must, however, not be fed to stock. I have in preparation a report on the injurious locusts of the State, in which the matter of remedies will be treated in detail.

In conclusion, let me say that the work of the department is going forward satisfactorily. The equipment is improving, and the collections each year becoming more valuable. I have only one recommendation to make for its improvement, which is, that conservatory facilities be provided, so that experimental work on plant diseases and life-histories of insects can be prosecuted to better advantage.

This matter has already been called to your attention in another connection, hence I need not dwell upon it here.

Yours respectfully,

H. GARMAN,

Entomologist and Botanist.

15. *Cyrtophyllus concavus*, Harris. The common Katydid is moderately common locally throughout the State.

16. *Amblycorypha oblongifolia*, DeGeer. Occasional. Taken only at East Hickman, Lexington and Nortonville.

17. *Amblycorypha rotundifolia*, Scudder. Frequently observed about Lexington towards fall on weeds and grasses under trees in woodland pastures.

18. *Microcentrum lauriolium*, Linn. Common everywhere on black locust and other trees. Known from its peculiar note, which resembles the sound made by striking two pebbles together.

19. *Scudaeria curvicauda*, DeGeer. A common species in open fields and meadows. East Hickman, Lexington, Nortonville, Glasgow Junction.

20. *Scudderia furcata*, Brunner. A smaller and less common species than the preceding. Taken only at Bryant and Lexington.

21. *Conocephalus sp.* A single immature representative of this genus is in the Station collection, Nortonville.

22. *Xiphidium fasciatum*, DeGeer. Very common, especially so on hemp, and on weeds in stubble.

23. *Xiphidium nemorale*, Scudder. Rather more common even than the preceding. Examples brought in by Mr. Jordan, of the Station, September 14, 1893, were placing their eggs in the tender stems of rose bushes.

24. *Xiphidium ensiferum*, Scudder. Not rare. Lexington, Bryant.

25. *Xiphidium glaberrimum*, Scudd. Very common everywhere.

26. *Xiphidium nigripes*, Scudder. Frequent. Lexington, Georgetown, Nortonville.

27. *Xiphidium concinnum*, Scudder. Not common, two examples, Lexington.

28. *Thyreonotus pachymerus*, Burm. A single example is in the collection from Tyrone on the Kentucky river. Mammoth Cave, (Scudder).

GRASSHOPPERS (FAMILY ACRIDIDÆ).

29. *Pezotettix gracilis*, Bruner. Occcasional. Lexington, East Hickman, Providence.

60. *Anisomorpha buprestoides*, Ställ. In a list of Illinois Orthoptera (Bulletin Illinois State Laboratory of Natural History, 1, p. 60) Dr. C. Thomas states that this species has been observed in Kentucky. I have myself collected it in Johnson county, Southern Illinois, and have no doubt but that it occurs also in Western Kentucky.

PRAYING MANTIDES (FAMILY MANTIDÆ).

61. *Stagmomantis carolina*, Linn. Not very common in Eastern Kentucky. Abundant in parts of Western Kentucky. Noted as especially common at East Cairo.

ROACHES (FAMILY BLATTIDÆ).

62. *Blatta germanica*, Fab. Very abundant in dwellings.

63. *Ectobia flavocincta* Scudder. One example, Lexington.

64. *Periplaneta orientalis*, Linn. Common.

65. *Ischnoptera pennsylvanica*, DeGeer. Common.

66. *Cryptocercus punctulatus*, Scudder. A single example of this singular species was taken at Maysville, June, 1892, by Prof. C. W. Mathews.

DIVISION OF HORTICULTURE.

M. A. SCOVELL, *Director :*

DEAR SIR: In accordance with your request, I submit herewith the report of the Horticultural Division for the past year. The work of this division has been greatly aided since my last report by the employment of an assistant, Mr. A. T. Jordan, who commenced his duties in April, and has proved himself a faithful and efficient worker.

Varietal tests of vegetables have as heretofore occupied a considerable portion of our time during the past season. Considerable additions have been made to our collection of small fruits during the year, especially of strawberries, and it is expected

BULLETIN No. 44.

BORDEAUX MIXTURE FOR APPLE PESTS.

BY H. GARMAN, ENTOMOLOGIST AND BOTANIST.

APPLE ROT.

Probably no enemy of the orchardist destroys more fruit, and is the occasion of more loss in Kentucky, than the rot-fungus, known to botansts as *Glœosporium versicolor*. It is no uncommon thing for three-fourths of all the fruit on a tree to be rendered worthless by its attacks. In the latter part of summer, we find in many orchards the ground covered with well-grown apples, suitable for marketing as far as size and maturity are concerned, yet not worth gathering up because of the rot with which they are wholly or in part affected.

These fallen apples are, as a rule, not windfalls which have been invaded after they were blown down, but, in most cases, began rotting on the trees. Very many invaded apples can, during much of the summer, be found clinging to the branches, the rot forming a deep brown patch about the calyx end, or else starting from a break in the skin, due to the thrashing of the twigs or the gnawings of insects; more rarely starting at the stem end of an apple, and gradually widening from this until the opposite pole is reached. Hundreds of dollars are lost each year from this destructive work on the fruit, and farmers known to me do not get enough apples for their own use, where in early days they secured splendid crops of excellent fruit. The rotting is not confined to particular varieties, though some are much more liable to it than are others. It takes fruit at any stage of growth, from the time it is about three-quarters of an inch in diameter until it is ripe. Damp weather appears to accelerate its injuries, but it is not dependent on this, and during the dryest months of the dryest summers may be found among growing fruit.

I have already called attention to this rot in one of the Station reports. The pest is so abundant and widespread in the State that it has seemed best to devote considerable attention to it, and I have undertaken a series of experiments with a view to learning what will save apples from its attacks.

THE SOURCE OF APPLE ROT.

It is sometimes assumed that this decaying of apples is a spontaneous breaking down and giving way to unfavorable influences of the atmosphere, of poor soil, deficient nourishment and the like, just as a piece of meat becomes putrid when exposed to the air during warm weather. The decomposition of meat under such circumstances, while apparently a spontaneous return to the earth and air of the substance of which it is composed, is really not strictly spontaneous at all, and if it were protected from the attacks of certain small fungi (the bacteria or microbes of current literature), it would not rot. This protection is what we afford to meat when we "can" it; it is what we do for fruit when we "put it up." In these cases, though the operator is often ignorant of the reason why his work, to be successful, must be done according to definite methods, the treatment is for no other purpose than to keep these commodities from the floating micro organisms of the air. Expose such canned meats or fruits to the air and they will, in the course of a few hours, be found teeming with this minute life, and if left to themselves are speedily rendered unfit for use.

The rotting of apples on the trees is a very similar case, but the decay is much more evidently not spontaneous. It is just as certain that the apple rot will not attack fruit on the trees, if the spores of the fungus of which the technical name is given above does not get access to them, as it is that potatoes will not grow in a field in which no potatoes have been planted. The fungus causing this rot is a plant of rather complicated structure and life-history, which is, as far as we know, dependent upon apples for its sustenance. The apple then does not become disorganized by the effect of heat, moisture or poor nourishment, but is destroyed by a vegetable parasite of relatively large size, being discernible when only slightly enlarged by the microscope, and in some of its conditions even perceptible to the naked eye. I dwell upon these things because there is a tendency to consider such diseases as this rot beyond our control, a tendency which often leads to a neglect of precautions which might easily be taken, and which would tend greatly towards remedying the evil done by the parasite. When it is impressed upon the mind of the fruit-grower that this rot is not due to the weather, but to a parasite, I feel sure he will be prompt to take up the matter of stamping it out.

Doubtless most farmers have observed during the winter numbers of dried and shriveled apples clinging to the twigs of apple trees. These are generally the remains of fruit which rotted on the trees during preceding summers, and from some cause remained adhering to the twigs instead of falling to the ground. It has been suggested and believed that these mummified apples bear the spores of the fungus which attacks growing fruit, but I am not aware that any one has hitherto tested the truth of this surmise by attempting to convey the rot to sound apples. In preparing for the experiments here reported an examination of the orchard on the Experiment Farm was made early last spring before the leaves were out. It was found that most of the trees retained these withered apples. From a pint to a quart of them could have been taken from most of the trees. They varied from .24 to 1.36 inch in diameter, the smaller ones being much the more common, probably because the weight of the larger fruit invaded by rot tends to pull it from its attachment. A large proportion of the smaller examples stood upright on their stems, and it is apparent therefore that they were the remains of immature fruit. The tenacity with which these small ones adhere leads me to think they remain for several years on the trees. Of course it is not probable that all of these mummified apples were destroyed by rot, but an examination of a considerable number of examples shows that most of them bear the spores of the fungus. In fact I have not thus far found a single example that did not bear some. Contrary to my expectation, they were more abundent as a rule on the smaller mummies. On specimens of an ash-gray color, the result of a lifting of the cuticle, they were especially abundant, the ruptured pustules beneath the cuticle still apparently containing a large part of the spores which developed there.

Thousands of the microscopic spores were thus embedded in a single one of these dried up apples, and as was proved by experiment they needed only to be introduced into the substance of sound apples to germinate and produce the characteristic change known as rotting. Again and again spores taken from the old fruit which remained on the trees during the winter of 1891–92, and possibly longer, were seen to produce the disease and eventually to yield the black fruiting pustules containing new spores, when introduced into sound fruit taken from the cellar or obtained from the market. To test the matter still further some of the spores were sowed upon sterilized gelatine containing an infusion of apple, and here the result was very much like that obtained by planting them on the apples. The gelatine, where invaded by the growing threads, became of a dark color, finally of a sooty black, and eventually small black nodules appeared at the surface containing the characteristic spores. These winter spores are very much larger than those produced during the summer, and are developed in the midst of the nodules instead of on the outside. Under the microscope they look not unlike a rather large elliptical seed. They are covered by a thick brownish outer coat, and contain a coarse granular material, in some instances with one or several round clear spaces. The latter become larger and more evident when they are placed in water or apple juice for germination. Those obtained from rotting apples are considerably smaller, on an average, than those grown on gelatine, as would be expected from the difference in the media. Examples from an apple destroyed by an artificially induced rot measured .027 mm (.0011 inch) in length and .012 mm (.0005 inch) in width. Other spores from a culture of the fungus made on gelatine measured .037 mm (.0015 inch) in length and .015 mm (.0006 inch) in width.

It will be seen by these measurements that the spores which convey the disease to fruit are very small, much too small to be seen with the naked eye, and yet they are as evidently the source of the rot which takes the apples as melon seeds are the source of melons which grow in our fields.

It is so evident from the most superficial study of the subject that the removal of the dried-up apples from the trees in winter would remove the source of contamination to growing fruit, that it seems strange that some practical man has not hit upon it as a means of preventing the mischief. Certainly thousands of minute spores, capable each one of destroying an apple, and then of generating new spores sufficient to take a crop, would be removed from the trees by this process. An experiment reported below seems to justify all that has been claimed for the procedure on general principles. In experiment 442 every one of these mummified apples, amounting to about a quart, was removed from the tree, and I believe it was during the summer the cleanest and most thrifty tree of any in the orchard, and in August it yielded the best fruit taken from any of the treated trees.

EXPERIMENTS 442 AND 443.

Early in the spring of 1892, before the leaves were out, every shriveled apple was removed from a tree in the Experiment Farm orchard, and it was then sprayed with Bordeaux mixture until the branches and trunk were gray. The tree selected for this treatment was one of two of the same variety, standing side by side. The name of the variety I am unable to give. It is said to be a janet, and the fruit agrees in color, shape and to some extent in flavor, with the janets commonly used for winter keeping; but it is a fall apple, and averages larger than the late-keeping janets grown in the same orchard. These trees were selected for experiment because of the tendency of their fruit to rot and fall off. In 1891 no apples of consequence were obtained from either tree because of the destructive work of the rot-fungus. The treated tree was given the number 442 and the check tree was numbered 443. They appear to be of the same age, but No. 443 is somewhat the larger, having thus a possible advantage in bearing power.

After the apples had "set," later in the spring, the whole orchard was sprayed for codling-moth, these trees receiving their share of the poison. This codling-moth work was done from May 16 to May 18, inclusive.

On May 23 No. 442 was sprayed with Bordeaux mixture, two gallons of the preparation being used.

June 6 the tree was sprayed again, about three gallons of the mixture being employed.

July 6 it received a third and final application, four gallons being used this time.

The tree received no other treatment during the season, but the lime and copper could be seen on the leaves and trunk at all times until cold weather set in. Between sprayings it was to some extent washed from leaves most exposed to rains, but would probably have been evident in the fall if only the first application had been made.

The effect on the leaves of the spraying was very marked from the beginning. The tree bore a more thrifty appearance, the leaves were of a better color, and were actually larger than those of the unsprayed check tree. As the season progressed the difference became more and more decided, and in the fall when the unsprayed tree looked draggled and bare from the loss of leaves, and the mutilation in one way or another of those remaining, the sprayed tree still bore a full load of well developed, well colored leaves. This difference was due to a number of causes. In the first place, the scab-fungus (*Fusicladium*) worked without hindrance on the leaves of the unsprayed tree, causing some of the leaves to curl up, and checking the growth of the others. The spraying prevented the growth of this fungus almost entirely. In the second place, a peculiar spot disease of the leaves was very destructive to the unsprayed tree, and was much less abundant and did no perceptible harm to the sprayed tree. And finally the insects which occur upon apple trees seemed to find the sprayed leaves less to their taste than the unsprayed ones. I attribute the small average size of the leaves of 443 as compared with 442, to the injury from the scab-fungus, and to the spot-disease. As showing the condition of the two trees towards fall, the following quotation is made from notes recorded August 27:

Exp. 442.—Tree in good condition. Leafage full. Some leaves turning yellow, but not more than should be at this season. Spot disease so noticeable on unsprayed tree does not show here except on occasional leaves, and has not done appreciable harm to these. Mixture abundant on trunk and lower leaves. Upper leaves pretty well washed clear. Very little evidence of the presence of the scab-fungus on the leaves.

Exp. 443.—Leaves in very bad condition as to spot-disease. Frequently with numerous small spots; often with extensive blotches, sometimes including whole leaf. Small spots often broken away, leaving holes in leaf. Many leaves down. Branches with a bare appearance, due to small size of leaves, and to the falling of others. Some scab-fungus on leaves.

Fallen Apples.—We began to examine the apples which fell from both trees on the 17th of June. Most of the apples then down were such as did not "set," and perhaps would, in many cases, have fallen without respect to the spraying.

It was probably owing to the presence of these, and to the fact that no apples had hitherto been collected under the trees, that a larger number was obtained at this time both beneath 442 and 443 than on several succeeding dates. From the sprayed tree, we took seventeen apples, and from its check ten. At the next date of examination, June 25, only two apples were taken under the sprayed tree, and ten were collected under the check. From July 1, the number of fallen apples gradually increased until the time of picking, August 20, when 149 were examined from the sprayed tree, and 132 from the check. If it had not been for the storms of wind, the increase would doubtless have been quite regular until the last. It will be seen, by reference to my Table 1, that the number of fallen apples under the check tree was, with one exception, smaller all dates of examination than under the sprayed tree. This was not due to a better condition of the apples as to rot, and, I think, is entirely the result of the fact that, while as many blossoms were formed on the check as on the sprayed tree, fewer of them resulted in fruit. The total number of apples collected beneath the sprayed tree were 488, just about 25 per cent. of the whole number upon the tree; and while only 395 apples were collected under the check tree, yet these constitute about 35 per cent. of the whole crop borne, giving a difference of 10 per cent. in favor of the spraying. In other words, this experiment shows, as far as one test can, that 684 apples would have fallen from the treated tree if it had not been sprayed, whereas, the number which actually fell was only 488.

Rot in Fallen Apples.—The brown discolorations characteristic of this rot early made their appearance, and the fact that the number of affected apples gradually increased during the summer is not to be taken as an indication so much of an increase in their prevalence, as in the fact that their growth is rather slow, so that the result of injury is not an early loosening of the hold on the tree. Affected apples continued to grow, apparently, with undiminished rapidity, a state of things which is permitted by the almost invariable start of the rot at the eye. First and last, a good many apples were invaded at the side, the growth proceeding from breaks in the skin. But it was only occasionally that a genuine case of rot starting from the stem was observed. These facts suggest the probability of a transfer of the spores of the fungus to the young apples while the latter were still erect on their stems. Certainly the opportunity for infection at the eye of apples which hang eye downward is much reduced. Size and general vigor of fruit seemed to have little influence either in discouraging or inviting attack. The largest, most symmetrical apples, without a blemish on the skin, as often showed the gradual spread of the growth from the eye as did the smaller, more defective ones.

The rot became unmistakable on the fallen apples about the first of July. In the middle of the month about half of all those down were affected. During August four collections were examined from each tree, and at each date of examination the number of affected apples was greater under the untreated tree, although the total number down was in each case less than the number from the sprayed tree.

In more definite terms, the proportion of rotting to sound apples grew less and less during the summer for the sprayed tree, and on August 20, was at about 31 per cent. of the whole number down at this date, while the proportion of affected to sound apples from the check tree remained constantly in the neighborhood of 50 per cent. of the whole number fallen.

The total number of rotting apples taken from beneath the sprayed tree during the summer was 183, equaling 37 per cent of the whole number which fell from the tree.

The number attacked by rot taken under the check tree was 215, or $54\frac{2}{5}$ per cent. of the whole number which fell.

Picked Apples.—The rapidity with which the apples fell during the middle of August, indicated that they were ripening, and on the 20th of this month all were removed from the two trees under observation.

From the sprayed tree were taken 1467 apples, weighing 222 pounds (averaging thus 2.40 oz. per apple), in the main symmetrical, clean skinned and of good quality—certainly much the finest yield of fruit obtained from this tree during the three years I have observed it. 175 (about 12 per cent.) of these picked apples were affected with rot, seven of them being entirely invaded, and the remainder in varying degrees.

From the check tree were taken 748 apples, weighing 53 pounds (averaging 1.12 oz. per apple). They were very irregular in size, often unsymmetrical, and the best of them were scarcely worth gathering. 352 (47 per cent.) of this lot were rotting, 51 of which were entirely destroyed.

Throwing out the rotting apples of both lots we have therefore from the sprayed tree 1292, and from the check tree 396 apples not affected with rot, there being a trifle over three times as many apples from the former as from the latter. But since the apples of the two lots differed widely in size and quality, a better idea of the result will be obtained from a comparison by weight. Estimating from the average weight of apples from the sprayed tree we get for the 1292 apples about 194 pounds, and in the same way, estimating from the average weight per apple, we get for the 396 apples from the check tree a total weight of 28 pounds, the check tree thus yielding by weight about one-seventh the product of the sprayed tree.

Summary.—It remains to bring together in one paragraph for the sake of clearness the general results of the spraying. The whole number of apples examined, including both fallen and picked, was for the sprayed tree 1,955, of which 358 (about $18\frac{3}{10}$ per cent.) were affected with rot. The total number of apples from the check tree was 1,143, of which 567 (about $49\frac{1}{2}$ per cent.) were more or less injured by the rot-fungus. Hence, if the sprayed tree had been affected with rot to the same extent as its check, it would have lost about 968 apples instead of 358. In other words, $31\frac{1}{5}$ per cent. of the whole number of apples borne by the sprayed tree during the season were saved from the rot.

Keeping in mind the fact that this is a single test on a single variety, we may consider that it proves, as far as it goes, that spraying with Bordeaux mixture, in connection with the removal of all dried up apples on the twigs, results in the following benefit:

1. An increase in the size of leaves.
2. A prevention of the spot disease of leaves.
3. A prevention of the growth of the scab-fungus on leaves.
4. An increase in the size and weight of the apples.
5. An increase in the number of apples.
6. A lessening of injury from rot.

EXPERIMENTS 444 AND 445.

Two young Ben Davis trees were selected for this test. They have always been among the most thrifty trees in the orchard, and stand near each other in the same row. The sprayed tree (444) has the appearance of being somewhat smaller, but in most respects the two are as much alike and as well suited for the purposes of an experiment as could be desired.

The withered fruit was not removed from these trees, and they received no attention until May 23, though they had been sprayed for codling-moth somewhat earlier. On May 23 No. 444 was sprayed with two gallons of Bordeaux mixture. On June 6 three gallons of the mixture were applied by spraying to the leaves, and on July 6 the same tree received four gallons of the mixture. It received no further treatment. The leaves were made quite gray with the lime and copper, and retained this hue until they fell in the autumn. There was a noticeable difference in the condition of the leaves of the two trees with respect to the spot-disease, but it was not as evident as in the case of experiments 442 and 443. There was no perceptible difference in the size of the leaves, and I am therefore disposed to attribute the splendid condition of the foliage on No. 442 as compared with No. 444 to the spraying done before the leaves appeared and to the removal of the withered fruit. The leaves on 444 were, however, at all times in good condition, and were retained longer in the fall than were those on the check tree. The spot disease was started on both trees before the first spraying, and made perceptible progress during the season on the check tree, invading and sometimes completely destroying leaves. I could not see that there was any very marked spread of the disease on the treated leaves. In the fall when the apples were removed the check tree had lost many of its leaves, some of the branches being quite naked. At the same time the leaves on the sprayed tree were more abundant and more uniformly distributed on the branches.

Fallen Apples.—As in the experiment already reported, the first examination of fallen apples was made on June 17, when 29 apples were collected under the sprayed tree and 53 under the check tree. Doubtless, as in the other cases, most of these were apples which failed to set and were not brought down by any special disease. At several subsequent dates of examination a smaller number of apples was examined, but with a gradual increase in the number, reaching in the case of the sprayed tree a maximum of 118 on September 9, after which date there was a very gradual decline until the time of picking the apples, when 51 were taken under the sprayed tree. In the case of the check tree the increase in numbers of fallen apples continued until August 27, when 174 were collected for examination, and afterwards a tolerably steady decline occurred, 38 being examined on the day of picking.

By reference to Table I, it will be seen that at each date of examination, up to and including September 2, a larger number of apples occurred under the check than under the sprayed tree. By this time most of the apples had fallen from the check tree, and on subsequent dates the relation was reversed, the sprayed tree from September 9 until September 30 losing the most fruit. From June 17 to September 30, the sprayed tree lost a total of 562 apples, while during the same period the check tree lost 1181 apples. A comparison of these totals with the entire number borne by each tree shows that the fallen apples from the sprayed tree constituted about 46$\frac{1}{5}$ per cent. of the entire crop, while the check tree lost nearly 85 per cent. of all its fruit.

From the above it appears that the Bordeaux mixture kept from falling something like 39 per cent. of the whole crop, and that the apples which fell, notwithstanding the spraying, were retained longer on the tree than they would otherwise have been.

Rot in Fallen Apples.—The rot appeared on fallen apples from the sprayed tree more tardily than on the check, less than a fourth of the apples down on August 2 being affected, while at the same date of apples collected under the check tree nearly 44 per cent. were rotting. The record of examinations of apples from the two trees is very similar to that of 442 and 443. The same gradual increase in the number of rotting apples was observed, with larger number of decaying apples generally in the lots from the check tree. From the sprayed tree were obtained 187 affected apples, constituting about $35\frac{1}{5}$ per cent. of all those which fell. Under the check tree we found during the summer 594 affected apples, or about 50 per cent. of all the fallen fruit.

Picked Apples.—The apples were taken from these two trees September 30th, the sprayed tree yielding 655 apples, weighing 112 pounds, the check tree, only 213 apples, weighing $37\frac{3}{4}$ pounds. Among the former were only 11 apples (about $1\frac{7}{10}$ per cent.) affected with rot. Among the 213 from the check tree were 54 (about $25\frac{2}{5}$ per cent.) bearing more or less trace of rot. Omitting the rotting apples from both lots, we have as a result of the spraying 644 apples on the treated tree and 159 on the check. Oddly, the average weight per apple of the check lot was a trifle greater than that of apples from the other tree. This may have been due to one or more of several causes. I am disposed to think it was a result of the fact that the apples had nearly all fallen from the check tree, leaving at the last only the more vigorous ones clinging to the branches, while on the other hand the sprayed tree retained apples of all sorts more persistently.

Estimating from the average weight per apple, we get for the sound apples taken from the sprayed tree a total weight of 110 pounds, as against a fraction over 28 pounds for the check lot. The sprayed tree consequently bore 82 pounds more sound fruit than its check.

Summary.—No. 444 yielded during the season, including fallen and picked apples, a total of 1,217 apples. The check, No. 445, yielded a total of 1,394 apples of all sorts. Under the sprayed tree and from it were taken 209 apples ($17\frac{1}{5}$ per cent. of the whole number) affected with rot, and from its check 648 ($39\frac{3}{10}$ per cent.) rotting examples were obtained, from which it is apparent that $22\frac{1}{10}$ per cent. of the whole number of apples on the sprayed tree were kept from rotting—that something more than twice as many apples would have rotted if the tree had not been sprayed. The following may be given as the general result of the spraying in the two experiments:

1. A prevention of much of the spot disease on the leaves.
2. A prevention of the growth of the scab-fungus on the leaves.
3. A lessening of injury from rot.
4. An increase in the final yield of sound apples.

EXPERIMENTS 446 AND 447.

Two more trees were selected for experiment in the spring of 1892, and were treated exactly as were 444 and 445. They were russets, and both were of rather larger size than the trees used for preceding experiments. The treated tree received in all nine gallons of Bordeaux mixture,—2 gallons on May 23, 3 gallons on June 6, and 4 gallons on July 6. The effect on the leaves of the spraying was, as in the other tests, decided, but was not so evidently in favor of spraying as in 442 and 443, in which, it will be remembered, the first application was made before the leaves came out. The spot-disease was started on both trees before the bluestone was applied, hence the most that could be expected was the checking of its spread among the leaves. The effect of the mixture in preserving the leaves was seen in the latter part of August, when the upper leaves of the sprayed tree had been deprived largely of the mixture by rains. These leaves began to turn yellow and fall soonest, so that the branches became almost bare, while the lower branches still retained a full load of leaves. The leaves on the sprayed tree averaged the larger. In notes made August 27, the condition of the foliage is described as follows:

Exp. 446.—Leaves good in the main; some turning yellow;

some spot-disease ; some fallen. Bordeaux mixture thick on lower leaves, mostly gone above, where leaves are thinner also.

Exp. 447 (check).—A scant load of leaves, many having fallen ; branches in places bare from this cause. Spot-disease rather common.

Fallen Apples.—The rate at which the apples fell from these trees agrees in the main with that of the other trees tested. The sprayed tree retained its fruit longest, the fallen apples rising to a maximum of 500 on the 9th of September, whereas, its maximum number of 284 was reached by the check tree August 27. These apples should have been picked not later than the first of September. It was delayed until September 30, by which time most of them had fallen, the number from the check tree being at this date a trifle the larger. The apples which fell during September were fully grown, and of as good quality as those finally taken from the branches. Under the sprayed tree were collected, up to and including September 30, 1,522 apples as against 1,100 apples taken beneath the check, the latter having thus what looks like an advantage in the matter of keeping its fruit ; but, as already explained, there were among these, apples which should properly have been picked, and the rate at which the fruit fell from the two trees shows that the spraying served to keep the apples from falling. As it stands, about $90\frac{3}{10}$ per cent. of the whole number borne were dropped by the sprayed tree, and $86\frac{1}{2}$ per cent. of the lot borne by the check tree fell, giving a difference of $3\frac{2}{5}$ per cent. in favor of the check tree.

If the apples had been picked, as they should have been, August 27, we should, up to and including that date, have collected beneath the sprayed tree 606 apples, constituting $39\frac{9}{10}$ of its whole crop, and 569 apples from the check, constituting $44\frac{7}{10}$ per cent. of its whole number of apples. This would have reversed the relation, giving an advantage of $8\frac{4}{5}$ per cent. to the sprayed tree, a result in close accord with those obtained in the other experiments.

Rot in Fallen Apples.—The 593 apples, showing traces of rot, which were collected between June 17 and September 30 under the sprayed tree, make about 39 per cent. of the whole number of fallen apples. Five hundred and twenty rotting apples, $47\frac{3}{10}$ per cent. of the whole number down, were collected under the check tree. The advantage in the matter of rotting is thus $8\frac{3}{10}$ per cent. in favor of the apples collected under the sprayed tree.

Picked Apples.—It has already been explained that the apples had nearly all fallen off these two trees when those remaining on the branches were picked. We took September 30th from the sprayed tree 164 apples, weighing 27 pounds, and from the check 172 apples, weighing $29\frac{1}{2}$ pounds, giving a difference of $2\frac{1}{2}$ pounds in favor of the check tree. Although the check tree had thus an advantage by number and weight, when we come to consider the proportion of rotting to sound apples, we find again a difference in favor of the sprayed tree, only $24\frac{5}{10}$ per cent. of its fruit being affected, while $33\frac{1}{10}$ per cent. of the check lot showed rot.

Properly, we should consider all the apples which fell from these trees after August 27 as a part of the crop to be harvested, and if we include these with those which were actually picked we get 1080 apples as the final yield of the sprayed tree, and 703 as the yield of the check. This, it will be seen, brings the result of the experiment more nearly into accord with the others. During this period $39\frac{1}{5}$ per cent. of all apples from the sprayed tree showed rot, and $50\frac{1}{5}$ per cent. of those from the check tree were affected. Omitting, as was done in considering the other experiments, all of these rotting apples, we should have from the sprayed tree 657 sound apples, weighing about 91 pounds, and from the check 350 apples not showing rot and weighing about 48 pounds. We get thus a difference of 43 pounds of sound fruit in favor of the sprayed tree.

Summary.—The yield of fruit, including fallen and picked apples, was in this instance considerably greater for the sprayed tree than for its mate. We examined during the season from No. 446, 1686 apples, and from 447 only 1,272, but the percentage of rotting to sound fruit was as in the other cases in favor of the sprayed tree. $37\frac{3}{5}$ per cent. of the whole number of apples from the sprayed tree showed rot. $45\frac{2}{5}$ per cent. of the check lot were decaying. The difference, $7\frac{4}{5}$ per cent., stands to the credit of the Bordeaux mixture.

In some respects this was the least satisfactory of the tests made. The large size of the sprayed tree, especially the wide extent of its branches, may have made the difference by preventing the same thorough application of the mixture to the leaves and fruit that was made in the other cases. Whatever the cause may have been, it did not affect the general result, and we may say of this test, as of the others, that the spraying produced a better condition of the foliage, a larger number of usable apples, and a smaller percentage of injury from rot.

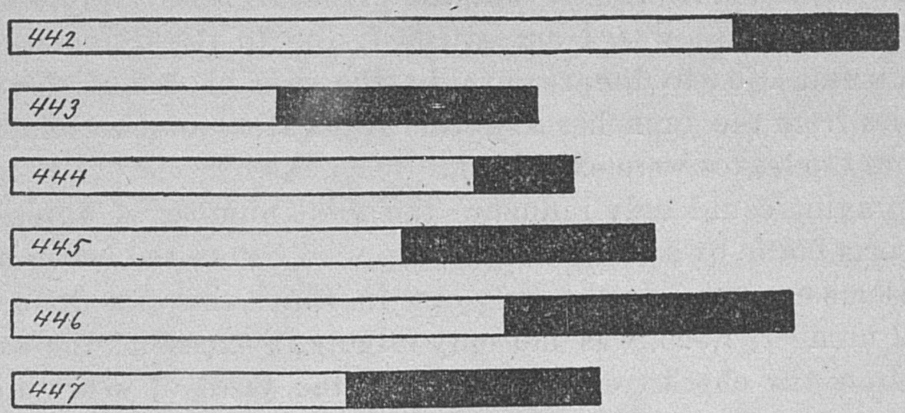


Diagram representing the apples borne by each of the six trees under observation, the black showing the percentage of rot. 442, sprayed ; 443, check on 442 ; 444, sprayed ; 445, check on 444 ; 446, sprayed ; 447, check on 446.

GENERAL SUMMARY.

The results of each experiment have already been given. It remains now to call attention to the features in which these results differ and agree among themselves, for by this means we shall approach the average result, and may hope to learn something of what could be done by spraying an orchard consisting of trees of various sorts.

In the first place all the tests show an improved condition of the foliage. The leaves of two of the sprayed trees (442 and 446) were larger than those of their respective checks, and in all three of the sprayed trees they were more perfect, being less injured by insects, by the spot disease, and by the scab-fungus. Throughout the summer the trees to which the mixture was applied were more thrifty in appearance, owing to the more healthy green and better general state of the foliage. In every case the leaves began to fall sooner from the checks than from their mates. The improved condition of the leaves must have a decidedly beneficial effect on the quality and size of fruit, and I am disposed to think the final increased yield of fruit from the sprayed trees was due in no inconsiderable extent to this indirect effect of the Bordeaux mixture, and not solely to its direct effect upon the rot-fungus. In the matter of its foliage No 442 was in much the best condition of the three, was in fact very much the finest looking tree in the orchard. The improved result in this case was, I am satisfied, due to the difference of treatment, i. e., to the removal in the case of 442 of the old apples from the branches and the application of the mixture before the leaves were expanded.

Spraying could only influence the total number of apples of all sorts borne by a tree when it is applied before the leaves and blossoms are out. In the only case in which this was done the total number, 1,955, was not only largely in excess of the number from the check tree, but exceeded the yield of every other tree under observation. While a single test can not be considered proof that such treatment would always, or generally, have the same effect, the presumption is, from the very decided result obtained in this case that the method employed in experiment 442 will have the effect of increasing the total number of apples.

The proportion of rotting to not rotting apples was in every case lessened by spraying, and we are in a position to say as a result of these experiments that spraying with Bordeaux mixture will save from rotting from $7\frac{4}{7}$ per cent. to $31\frac{1}{6}$ per cent. of the whole number of apples. Here again the result is decidedly in favor of spraying before the leaves are out, the number of apples saved being 10 per cent. greater for No. 442 than for the best of the other trees.

The result in usable apples is the crucial test of the experiments. From No. 442 were obtained 194 pounds of usable apples; from its check only 28 pounds, giving an excess of 166 pounds in favor of spraying. From No. 444 we took 110 pounds of good apples and from its check only 28 pounds, the difference in favor of spraying being here 82 pounds. From No. 446 were secured 91 pounds of good fruit and from its check 48 pounds, the sprayed tree having the advantage by 43 pounds. In other words, the spraying increased the yield of usable apples from a little less than two-fold to nearly seven-fold. The average of the increased weight due to spraying for the three trees is 97 pounds, which may fairly be considered the increased weight of usable apples which can be expected from trees of all sorts as a result of spraying. In an orchard of 500 trees we might, therefore, expect to increase the weight of usable apples 48,500 pounds.

EXPLANATION OF THE PLATE.

Fig. 1.—Showing the apples picked September 30 from No. 444 (sprayed tree). From a photograph.

Fig. 2.—Showing the apples picked September 30 from No. 445 (not sprayed). From a photograph.

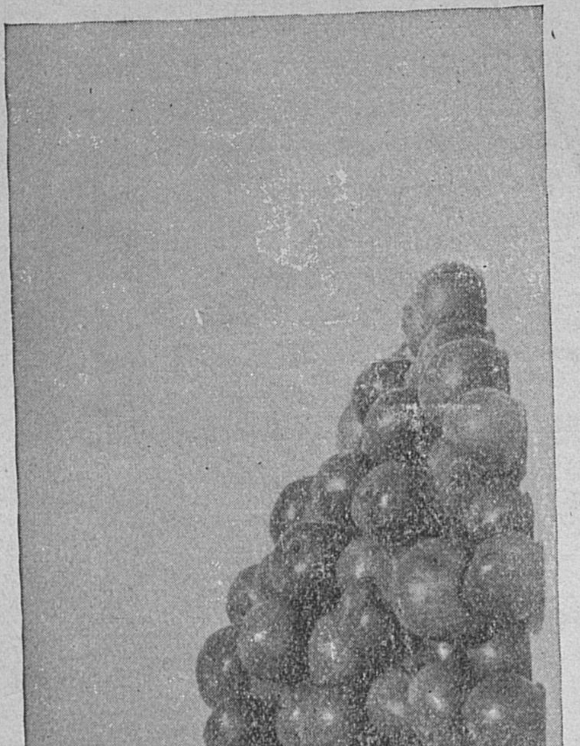


Fig. 2.

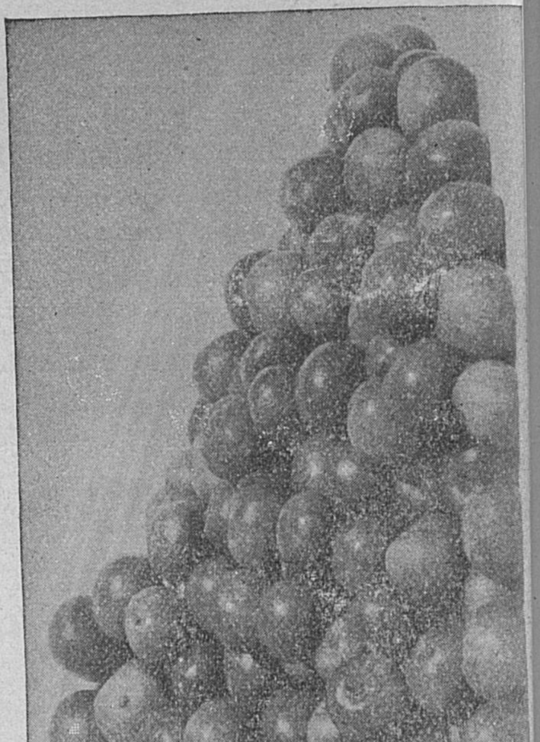


Fig. 1.

TABLE I.—Giving the Results of an Examination of Fallen Apples From Six Trees.

TABLE I—Giving the Results of an Examination of Fallen Apples From Six Trees.

	Experiment 442.			Experiment 443. (Check.)			Experiment 444.			Experiment 445. (Check.)			Experiment 446.			Experiment 447. (Check.)		
	Number of Fallen Apples	Fallen Apples Showing Rot	Fallen Apples Showing Work of Codling-Moth	Number of Fallen Apples	Fallen Apples Showing Rot	Fallen Apples Showing Work of Codling-Moth	Number of Fallen Apples	Fallen Apples Showing Rot	Fallen Apples Showing Work of Codling-Moth	Number of Fallen Apples	Fallen Apples Showing Rot	Fallen Apples Showing Work of Codling-Moth	Number of Fallen Apples	Fallen Apples Showing Rot	Fallen Apples Showing Work of Codling-Moth	Number of Fallen Apples	Fallen Apples Showing Rot	Fallen Apples Showing Work of Codling-Moth
June 17	17	2	...	10	1	..	29	1	1	53	27	..	16	1	2	10	...	...
June 25	2	...	...	10	.	...	12	...	.	30	5	1	5	...	1	14	...	3
July 1	6	3	1	5	1	2	11	...	1	35	..	2	10	...	3	..	...	..
July 8	9	...	8	8	...	2	9	...	1	34	4	3	11	...	7	5	...	3
July 15	23	11	12	16	6	5	16	7	7	35	5	5	6	..	6	12	..	10
July 22	52	33	18	29	19	5	8	2	2	33	10	5	37	5	30	16	2	13
August 2	94	41	50	71	56	10	32	7	11	83	36	17	46	3	33	44	7	33
August 5	41	13	19	38	16	15	26	12	7	111	50	22	59	7	45	32	3	22
August 12	95	34	51	76	41	17	24	14	7	93	43	26	46	7	30	51	11	34
August 20	149	46	98	132	75	51	10	5	5	168	99	58	90	29	58	101	17	78
August 27	...	...	...	...	...	...	47	25	25	174	128	98	280	159	206	284	184	139
Sept 2	..	...	...	...	...	...	42	9	33	82	39	64	230	106	161	189	86	157
Sept. 9	...	...	...	.	...	...	118	64	82	102	56	77	500	218	372	222	143	136
Sept. 17	...	...	...	...		...	72	23	57	72	46	38	70	22	53	59	34	46
Sept. 23	...	...	...	...	...	...	55	10	50	38	25	25	59	19	47	30	16	19
Sept. 30	.	...	...	...	...	...	51	19	43	38	21	21	57	17	30	31	17	23

TABLE II.—Giving Results of an Examination of Both Fallen and Picked Apples From Six Trees.

	Total Number of Fallen Apples	Total Number of Fallen Apples Showing Rot	Total Number of Fallen Apples Showing Work of Codling-Moth	Number of Picked Apples	Picked Apples Showing Rot	Picked Apples Showing Work of Codling-Moth	Total Number of Apples Examined	Total Number Showing Rot	Total Number Showing Work of Codling-Moth	Weight of Picked Apples
Experiment 442	488	183	257	1,467	175	535	1,955	358	792	222 lbs.
Experiment 443 (Check.)	395	215	107	748	352	199	1,143	567	306	53 lbs.
Experiment 444	562	198	332	655	11	208	1,217	209	540	112 lbs.
Experiment 445 (Check.)	1,181	594	462	213	54	50	1,394	648	512	37¾ lbs.
Experiment 446	1,522	593	1,084	164	41	50	1,686	634	1,134	27 lbs.
Experiment 447 (Check.)	1,100	520	716	172	57	78	1,272	577	794	29½ lbs.

APPLE-SCAB.

While the experiments with Bordeaux mixture were undertaken primarily for the purpose of learning what effect the preparation would have on the rot-fungus, several minor objects were kept in view, one of which was to learn the extent to which scabbing of the fruit would be prevented. It has already been stated that the scab fungus was less abundant on leaves of number 442 than on those of number 443, its check. The fruit, also, was less injured by the fungus on the sprayed tree than on the check. No detailed record of the relative injury was kept. The scab-fungus did not appear on the russet trees (446 and 447). It was apparent on both of the Ben Davis trees (444 and 445), and record of its injury was made from September 2 to September 30, inclusive.

Under number 444 during this time 338 apples were collected, 58 of them more or less scabbed. On September 30, from this same tree, we picked 655 apples, of which 62 showed the scabbed skin. We thus obtained a total of 993 apples with 120 ($12\frac{1}{10}$ per cent.) scabbed ones among them.

Under the check tree, number 445, apples to the number 332 were examined, of which 189 were scabbed. 213 apples were picked from this tree, having among them 170 with scabbed surface. Of the total number (545) examined from the check tree, 359 ($65\frac{9}{10}$ per cent.) were scabbed.

On two occasions, May 23 and June 6, after spraying the trees upon which we were making regular observations, the surplus Bordeaux mixture was sprayed upon a janet tree which stood near, being one of several in a row. It was noticed from time to time, that its leaves and fruit appeared to be in better condition than those of its fellows of the same variety, but it was given no further attention until the time of picking on October 8, when the apples from this tree and those from another one as nearly like it as could be found were compared. It was found that the apples on the sprayed tree averaged considerably larger and were comparatively but little injured by the scab. Of 143 pounds of fruit from this tree $45\frac{1}{2}$ ($31\frac{1}{10}$ per cent.) pounds were scabbed.

The apples from the check tree were almost worthless, being small and misshapen, and of 67 pounds taken from the tree there was not a single apple that was not scabbed.

It is believed that the scab-fungus lingers about the trees in the form of spores during the winter, and hence the early spraying practiced in the case of No. 442 might be expected to prove more effective even than applications made later in the season. The scab gets an early start, and trees on which its injuries are severe ought at the latest to be sprayed as soon as the fruit is set. Two sprayings early in the season ought to prove sufficient. A single spraying before the leaves expand would probably do much to lessen injury from the disease.

CODLING MOTH.

It has been claimed that the gnawings of insects occasion much of the rot which invades and destroys fruit. In early times insects were thought to be the direct cause of the decay. Rotting patches were so frequently observed about the punctures made by curculios and other insects that it was a very natural supposition that the admission of the air and moisture from without was all that was necessary to induce decomposition. With a better knowledge of the parasitic fungi, we are now in a position to assert positively that these latter are the primary cause of several of the rots, and that as far as such rots are concerned the gnawings of insects have only the indirect effect of admitting the fungi to the fruit. Of course where the rot-fungus is dependent upon such accidental openings for access to fruit the work of insects is an important factor in causing decay. This appears to be the case with the brown rot-fungus of peaches, plums and cherries. There can be no doubt but that insects are important agents in giving this rot a start, and remedies for it should consequently always take insect injury into account.

The spread of apple rot due to *Glœsporium* one would suppose on general principles to be also greatly influenced by insect injury, but from its habit of entering apples at the eye, breaks of the skin are not essential to it, and the work of the codling-moth influences its spread less than would have been expected. If the mining done by the codling-moth tends to increase the destructive work of this rot-fungus, we should find, with an increase in the percentage of injury by codling-moth, an increase also in the percentage of injury from the rot fungus. The apples examined last summer give us no very safe foundation for a conclusion on this point; for no just comparison can be made between a sprayed tree and one not sprayed, because of the positive effect of the Bordeaux mixture in checking the rot; nor can a comparison between trees belonging to different varieties be expected to give a decisive answer as to this question. Some varieties are more susceptible to codling-moth injury—more attractive to the insect; and the same is true of the fungus, certain kinds of apples being generally badly infested, while others are much less so. A just comparison could only be made between trees of the same variety, all of which were either sprayed or not sprayed. However, an examination of the tables accompanying this paper will throw some light on the relation between the two kinds of injury.

Taking the sprayed trees first, we find that the percentage of codling-moth injury was greatest on No. 446, and that this tree had also the highest percentage of injury from rot, which, as far as it goes, is evidence in favor of an increase in rotting with an increase in codling-moth injury; but the next highest injury from the insect (on No. 444) is accompanied by the lowest percentage of injury by rot which occurred on any of the sprayed trees, No. 442 having a slightly higher percentage of injury by rot than No. 444, with a lower relative injury by the insect.

A comparison of the unsprayed trees gives a somewhat different result. The highest percentage of injury by codling-moth occurred on 447, and was accompanied by the lowest injury from the rot. Number 445 comes next in order with a percentage of injury by codling-moth considerably lower than number 447, but with a higher percentage of rotting apples. Number 443 completes the series with the lowest rate of injury by moth, and the highest rate of injury by rotting. Here we have just the reverse of what would have been expected—a regular increase in rotting with a decrease in insect injury. When we remember that we found a similar relation of the two kinds of injury on two of the sprayed trees (444 and 442), it begins to look as if the injury from codling moth lessened the injury from rot. But we can not entertain such a conclusion for a moment when we know the readiness with which the spores of the fungus grow whenever they fall upon the exposed substance of an apple. The mining of the codling-moth must inevitably increase opportunities for the rot to invade the fruit, and it remains to determine to what extent the work of the insect does increase the rotting.

THE CODLING-MOTH AVOIDS ROTTING APPLES.

The truth of the matter is that the female codling-moth, when depositing her eggs, avoids those apples which have the rot started at the eye, and selects the best fruit within reach. In short, the rot-fungus is a sort of rival to the codling-moth, although the work of the latter is rather favorable than otherwise to the fungus. This explains the fact that in every case of reduced injury from rot as the result of spraying there was last summer an increase in the percentage of injury from the moth. The insects placed their eggs upon the fruit most likely to reach maturity and give the young a chance to attain their growth. The rotting or otherwise injured apple is not so likely to give the young this opportunity, and the instinct of the moths guided them in avoiding such fruit. This supposes the rot to have possession of the field when the moth is ready to place its eggs. And it may be objected that since the egs of the moths are laid in the calyx end of the apple as soon as the latter is formed, and since the rot does not make its appearance until some time later, that the rot fungus can have no such influence on the work of the moth as I have suggested.

In the case of the six trees under observation last summer it was certainly true that the first brood of codling-moth was not influenced in this way by the rot. In fact this brood did very little harm to apples on the trees selected for my experiments. But we have, it seems, to provide at this latitude for the injuries of a second brood of the codling-moth, which last summer appeared long after the rot was started, and did its worst injury to the apples when these were nearly ready for use. Neither the spraying with Paris green given early in the spring nor the Bordeaux mixture had any perceptible effect on this brood, and an inspection of the tables will show that the worst harm was done in every case on the sprayed trees.

Thus number 442 had $40\frac{5}{10}$ per cent. of its whole crop affected with codling-moth, and its check had only $26\frac{8}{10}$ per cent. affected. Number 444 showed an injury from codling-moth amounting to $44\frac{4}{10}$ per cent. of its whole crop, while number 445, the check tree, showed $36\frac{7}{10}$ per cent injury. On 446 the injury amounted to $67\frac{3}{10}$ per cent. while on 447 it reached only $62\frac{4}{10}$ per cent. of all the apples. We are thus driven to the conclusion that the insects selected the trees bearing the finest fruit, and that they avioded the apples already invaded by rot. If the second brood continues in future to be as destructive as last season it will be necessary to adopt other means of combating this pest than by spraying trees in early spring, for it is evident that spraying at that time is only calculated to check the injuries of the spring brood.

CONCLUSION.

The conclusions to be drawn from the data contained in the preceding pages have been incompletely presented in the different sections of this paper. As a matter of convenience it may now be advisable to bring together what the author considers the important results of the experiments, considering the effect of spraying on injury of all sorts, insect and fungus.

1. The advantages of spraying may appear at first thought to be to some extent offset by the higher per cent. of codling-moth injury which occurred on the sprayed trees. Practically, this result has not the importance that might at first appear. Insects always concentrate where they find the most abundant supply of suitable food. The fact that the codling-moth congregated on the sprayed trees is consequently evidence that the

treatment greatly benefited the fruit. If we keep it in mind that the spraying did not increase the number of codling-moths in the orchard, but only led them to desert the poorer fruit of unsprayed trees for the better fruit of sprayed trees, it will be clear that if we had sprayed the whole orchard, no increase of injury would have been witnessed, because the moths would, under the circumstances, have remained scattered. None the less, it is important that some means of combating the second brood of moths should be found, and in the absence of experiments showing what can be done, I would suggest the use of Paris green, to be applied not earlier than July 1, in the proportion of one pound to 160 gallons of water.

2. The improved condition of the foliage is a gain which is not to be overlooked, since it is calculated to have a most beneficial effect on the fruit. It seems to be an invariable result of spraying.

3. The spraying prevented premature falling of both leaves and fruit.

4. The increased weight of apples yielded by the sprayed trees is its own commentary on the good effect of spraying.

5. In only one case was there a decided increase in the size of apples (on No. 442), and this was where the tree had been sprayed before the leaves were out, and the old apples had been removed. On the trees not so treated no difference of consequence was observed between apples from sprayed and check trees. We must conclude, therefore, that the single case of increased size was the result of the early treatment, or else, as it easily might be, was a chance occurrence, due possibly to some difference in the condition of the trees. I am disposed to think it the result of the treatment in this case, but have no ground for insisting on this view other than that the two trees had been observed with some care for several seasons, and no special difference between their fruit or foliage was observed during seasons preceding that of 1892. However, it is a matter to be settled by further experiment.

6. The diminished injury from scab was decided, and is an important gain. The result was invariable on trees affected with this disease.

7. To learn the effect of Bordeaux mixture on apple rot was

the main purpose of the experiment. The results were always in favor of spraying.

NOTE.—The Bordeaux mixture was applied with a Climax Pump, No. 2, made by the Nixon Nozzle and Machine Company, of Dayton Ohio. For a figure and description see circular No. 3, April, 1890, of this Station. The mixture was prepared by the following formula :

a. 22 gallons of water.
b. 6½ pounds of bluestone.
c. 3½ pounds of fresh lime.

Dissolve *b* in three or four gallons of hot water taken from the supply *a*. Slake the lime, and make of it a paste about as thick as cream. Now stir the latter into the bluestone solution, and finally turn the whole into the remaining water. The preparation may be applied with great freedom without injuring foliage.

I have to thank Mr. J. S. Terrill, assistant in my department, for help in spraying and making examinations of apples.

BULLETIN No. 45.

FIELD EXPERIMENTS WITH FERTILIZERS.

---

1. WITH CORN.
2. WITH POTATOES.
3. WITH TOBACCO.

Summary.

Results obtained in 1892 are almost identical with those of the last four years, that is—

First.—Wherever potash was one of the ingredients of the fertilizer used, whether on corn, tobacco or potatoes, there was an increased yield.

Second.—That where phosphoric acid or nitrogen, or both, were used without potash, there was scarcely any increase in yield over those plots receiving no fertilizer.

Third.—That there was a profit in the use of fertilizer in every instance where potash was one of the ingredients.

Fourth.—That there was a loss by the use of fertilizer where potash was not one of the ingredients, except in the tobacco experiments.

Fifth.—That potash fertilizer applied on corn has shown its effect for four seasons after the application.

Experiments in Detail.

THE SEASON.—The season was an average one for the growth of corn.

The following table gives the summary of rainfall, the mean temperature, and the average per cent. of sunshine during the months of April, May, June, July, August, September and October:

MONTH.	Rainfall Inches.	Degrees Mean Temperature.	Per Cent. Sunshine.
April	6.57	53.8	41
May	5 32	62.8	35
June	3.81	75.8	50
July	6.22	75.0	54
August	3.28	74.8	52
September	4.10	68.4	63
October	0.45	57.1	53

THE SOIL.—The soil of the Experiment Station Farm is what is termed a "Blue Grass" soil. It is derived from the Lower Silurian limestone, rich in phosphoric acid. The subsoil is a light colored clay, so retentive as to make the soil deficient in natural drainage. The land is worn, having been in cultivation for many years. It is believed that no stable manure or other fertilizers were applied before the farm was purchased by the Station.

EXPLANATIONS.

The leading elements of plant food are *nitrogen*, *phosphoric acid* and *potash*. Plants feed on other soil-elements besides these, and they are just as essential to plant life as these three, but generally speaking all but these ingredients are furnished to plants in abundance, and therefore in studying what to put on our soils to make them more productive, we need concern ourselves with only these three. Commercial fertilizers are manufactured and sold for the purpose of supplying nitrogen, phosporic acid and potash, and the market prices depend upon these ingredients. Some fertilizers contain one of these ingredients, some two, and some all. Generally speaking, a commercial fertilizer is a mixture containing two of these ingredients, and sometimes all; the proportions varying greatly in the various brands, and often in the same brand. It is at once seen to be a very difficult, if not an impossible task, to test all the various brands sold on a given soil in order to find out those that produced the best effect. It is an easy matter, however, to find out whether a given soil needs potash, phosphoric acid or nitrogen, or any combination of these elements, for a given crop. Having found out this by experiment, we have only to look to the analyses of the various fertilizers to tell which brands, if any, could be used to advantage on the soil and crop tested. If the experiment proved that potash was all that was needed on a given soil for the corn crop, all those fertilizers whose analyses show little or no potash would not produce favorable results, under whatever name sold.

CORN.

The field used for the fertilizer experiments was the same as that used for the experiments heretofore. The plots receiving no fertilizers the past years received none this year, and likewise the plots receiving fertilizers during the past years received the same kind in each case this year. The field in question is nearly level, slightly sloping lengthwise of the plots. Size of plots, one-tenth of an acre. The plots were treated exactly alike, except as to fertilizers, care being taken to plow the entire acre the same day at every working. The hills were thinned to two stalks.

The following table shows the kind of fertilizers applied to the various plots, their amount calculated per acre, the number of pounds of leading elements of plant food applied per acre, and the per cent. of these elements in the various fertilizers:

TABLE I.—Showing Fertilizers Applied and per cent. of Ingredients.

Number	Fertilizer Used.	Number of Pounds	Number of pounds of the leading elements of plant food.			Per cent. of the Leading elements of plant food in fertilizers used.		
			Phosphoric Acid	Potash	Nitrogen	Phosphoric Acid	Potash	Nitrogen
2	No Fertilizer	. . .	. .	. . .	. . .	. . .	. .	. .
3	Acid Phosphate Muriate of Potash Nitrate of Soda	140 160 160	57	80	25.6	12 4	17.	5.5
4	Acid Phosphate Muriate of Potash Dry Dirt	140 160 160	57	80	. . .	12.4	17.	. .
5	Acid Phosphate Nitrate of Soda Dry Dirt	140 160 160	57	. . .	25.6	12.4	. . .	5 5
6	Muriate of Potash Nitrate of Soda Dry Dirt	160 160 140	. . .	80	25.6	. . .	17.	5.5
7	No Fertilizer	. . .	. . .	. . .	. . .	. . .	. . .	. .
8	Muriate of Potash Dry Dirt	160 300	. . .	80	. . .	. . .	17.	. .
9	Acid Phosphate Dry Dirt	140 320	57	. . .	. . .	12.4	. . .	. .
10	Nitrate of Soda Dry Dirt	160 300	. . .	. . .	25.6	. . .	. . .	5.5

By reference to the table it will be seen that acid phosphate containing 40.7 per cent. of available phosphoric acid was used to supply that ingredient, muriate of potash containing 50 per cent. of potash for potash, and nitrate of soda containing 16 per cent. of nitrogen to supply nitrogen.

FIELD NOTES.

Plot No. 2. Growth fair; irregular in height; September 1st, fair; stalks of good size; blades dying some.

Plot No. 3. August 2d, very fine stalks, very tall, dark green in color, leaves green to the ground, all tasseled and silked; September 1st, stalks very large and heavy, with good, long, heavy ears; grain getting hard; leaves green to the ground.

Plot No. 4. August 2d, not so good as Plot No. 3, but much better than Plot No. 2; September 1st, stalks small but tall, with good, heavy ears, blades mostly green.

Plot No. 5. Not as far developed as average plots; about one-half silked; September 1st, falling down to some extent; growth irregular; some ears large, others small; ripening irregularly.

Plot No 6. August 2d, good, all tasseled; color fine dark green; September 1st, a very fine plot, very tall; ears very long; grain hardening.

Plot No. 7. August 2d, low, irregular, only about one-half tasseled; September 1st, only medium, some stalks fallen, leaves drying up.

Plot No. 8. August 2d, good, all tasseled and silked; leaves fired but little at the bottom; September 1st, good, all standing; blades dried up as far as the ears, green above; stalks very tall; grain getting hard.

Plot No. 9. August 2d, growth very irregular; partly tasseled; leaves firing at the bottom; irregular as to stalks; ears generally good; leaves drying up.

Plot No. 10. August 2d, low, irregular, about one-half tasseled with some silks; blades firing at the bottom; September 1st, very irregular; some good ears, most, however, are small; stalks somewhat fallen.

TABLE 2.—Showing Results of Fertilizers on Corn.

Number of Plot	Fertilizer Used.	No. of Pounds of Fertilizer Applied Per Acre	Yield of Ear Corn Per Acre in Bushels of 70 Pounds	Yield of Fodder in Pounds Per Acre	Increased Yield of Corn in Bushels Per Acre	Increased Yield of Fodder in Pounds Per Acre
2	No Fertilizer	....	37.6	2,260	....	....
3	Nitrate of Soda Acid Phosphate Muriate of Potash	160 140 160	61.4	4,150	29 1	1,910
4	Muriate of Potash Acid Phosphate	160 140	50.7	3,290	18.4	1,050
5	Nitrate of Soda Acid Phosphate	160 140	29.4	2,220	....	....
6	Muriate of Potash Nitrate of Soda	160 160	61.7	3,570	29 4	1,330
7	No Fertilizer	....	27.1	2,220	....	....
8	Muriate of Potash	160	52.4	3,260	20.1	1,020
9	Acid Phosphate	140	25.1	1,960	....	....
10	Nitrate of Soda	160	27	2,060	....	....

FINANCIAL RESULTS.

The financial results obtained by the use of the fertilizers in various combinations may be seen in the following table. The acid phosphate costs at the rate of $2.95 per acre, the muriate of potash $3.68, and nitrate of soda $3.60. In these estimates the corn is rated at 40 cents per bushel:

TABLE 3.—Showing Financial Results.

Number of Plot.	FERTILIZER USED.	Cost of Fertilizer Used Per Acre.	Value of Corn Per Acre.	Value of Increased Yield of Corn Per Acre.	Profit or Loss.
2	No Fertilizer.		$15 04	. . . . .	. . .
3	Nitrate of Soda Acid Phosphate Muriate of Potash	$10 23	24 56	$11 62	$1 39
4	Muriate of Potash Acid Phosphate	6 63	20 28	7 34	71
5	Nitrate of Soda Acid Phosphate	6 55	11 76	. . . .	*6 55
6	Muriate of Potash Nitrate of Soda	7 28	24 68	11 74	4 46
7	No Fertilizer.	. . .	10 84	. . . . .	. . .
8	Muriate of Potash	3 68	20 96	8 02	4 34
9	Acid Phosphate	2 95	10 04	. . .	*2 95
10	Nitrate of Soda	3 60	10 80	. . . .	*3 60

* Loss.

THE PERMANENCY OF EFFECT OF POTASH FERTILIZERS.

The object of this experiment was to show the length of time potash fertilizer would remain in the soil and still be available as plant food. This series was begun in the spring of 1888 with the purpose to test the comparative value of different kinds of phosphoric acid fertilizers, but finding our land unsuitable, it was determined to use these plots to test the effect of potash fertilizers. In 1888 no fertilizer was put on Plots 2 and 11, but on each of the other plots was applied the following: Sulphate of potash, 16 pounds; sulphate of ammonia, 26 pounds; dried blood, 10 pounds.

The following table shows the subsequent application of fertilizers where used on these plots:

TABLE 4.—Permanency of Effect of Potash Fertilizers

No. Plot.	Fertilizer Used.	Number of Pounds of Potash Applied Per Acre				
		1889	1890	1891	1892	1888
2	No Fertilizer	....	....	....	....	....
3	Cotton Seed Hull Ashes	115	..	....	....	78.4
4	No Fertilizer since 1888	....	....	....	....	78.4
5	Muriate of Potash	100	80	80	80	78.4
6	Sulphate of Potash	106	....	....	....	78.4
7	Kainit	100.8	....	....	...	78.4
8	No Fertilizer since 1888	....	....	....	....	78.4
9	Tobacco Stems	120	120	120	120	78.4
10	No Fertil zer since 1888	....	....	....	....	78.4
11	No Fertilizer	....	....	....	....	....

The table which follows gives the yie d of ear corn calculated per acre for each of the plots for the years 1888 to 1892 inclusive:

TABLE 5.—Permanency of Potash Fertilizers—Yield of Corn

Plot Number.	Yield of Ear Corn Per Acre in Bushels.				
	1888.	1889.	1890.	1891.	1892.
2	27.9	39	30 5	34	21.4
3	64.1	78	61	50.6	43.3
4	79 9	69	51	47	31
5	73.6	76	59	47.6	47.3
6	75.4	78	51	49.1	41.9
7	73	76	44	44.6	41.4
8	76.7	67	44	44.1	27.3
9	75.1	84	71	58.1	54
10	77.6	71	47	42.9	28.9
11	25.3	28	17	25	18.7

TABLE 6.—Permanency of Potash Fertilizers—Increased Yield.

Plot No.	Increased Yield Over the Mean of the Unfertilized Plots.				
	1888.	1889.	1890.	1891.	1892
2	....	....	....	....	....
3	37.5	44.5	37.2	21.1	23.2
4	53 3	35.5	27.2	17 5	10.9
5	47.	42.5	35.2	18.1	27.2
6	48.8	44.5	27.2	19.6	21.8
7	46.4	42.5	20.2	15.1	21.3
8	50.1	33 5	20.2	14.6	7.2
9	48.5	50.5	47.2	28.6	33.9
10	51.	37.5	23.2	13.4	8.8
11	....	....	....	....	....

By a study of these tables it will be seen that potash fertilizers applied in 1888 were of benefit to the crops up to and including 1891, and even to some extent in 1892.

2. That those plots receiving fertilizer in 1889 and subsequently, still show its effect on the crop of 1892. It would seem therefore that potash fertilizers applied to our soil in the quantities given show their effect not only on the first crop, but also on the three subsequent crops, and to some extent on the fourth.

POTATOES.

The plots used in studying the effect of fertilizers on potatoes this year were the same that have been used for the same purpose heretofore. The soil of plots number 1, 2, 3, 4, is apparently a little more worn than plots 5, 6, 7, 8, 9, 10. The explanation was given in Bulletin 22, and is as follows:

"The field in which plots 1, 2, 3, 4 were situated, is supposed to have received no fertilizer until 1889, whereas the other portion of the field is supposed to have received barn-yard manure some eight or ten years ago."

The surface of the ground is comparatively level and the soil of the same general character as that on which the corn was grown. Size of plots one-tenth acre each. Potatoes used for seed were Northern grown Early Rose. Large potatoes were cut into half and small ones planted whole. Potatoes were planted 14 inches apart in the row, and rows three feet apart. After the ground was well prepared with plow and harrow, the rows were marked out with a small plow. Fertilizers used were scattered in the row by hand and afterwards slightly mixed with the earth by a brush. The fertilizers were applied and the potatoes planted April 29th, 1892. The season was not a good one for raising potatoes. For the amount of rain, sunshine, etc., see page 60.

Table 7 gives the amount of fertilizers calculated per acre; also the yield of potatoes:

TABLE 7.—Effect of Fertilizers on Potatoes.

Number of Plot.	Fertilizer Used.	Amount Per Acre, Pounds.	Yield Per Acre, Bushels.	Comparative Scale.
1	No Fertilizer	....	72.3	
2	Nitrate of Soda	160	72.1	
3	Acid Phosphate	150	61 1	
4	Muriate of Potash	160	101.6	
5	No Fertilizer	....	77.3	
6	Nitrate of Soda Acid Phosphate	160 150	65.9	
7	Nitrate of Soda Muriate of Potash	160 160	109.8	
8	Acid Phosphate Muriate of Potash	150 160	124.7	
9	Nitrate of Soda Acid Phosphate Muriate of Potash	160 150 160	165.0	
10	No Fertilizer	....	85.7	

TOBACCO.

EFFECT OF FERTILIZERS ON TOBACCO.

The experiments were conducted on ten $\frac{1}{20}$ acre plots. Character of the soil is the same as that on which the corn experiments were made. The land is considerably worn, and prior to the experiments of 1889, had never received fertilizers of any kind, and none have ever been applied to those plots which received none this year. Fertilizers used were applied broadcast just before the plants were set. Plants were placed 18 inches apart in rows three feet wide.

Table showing the kind and amount of fertilizers used and the effect on production of tobacco :

TABLE 8.—Showing Effect of Fertilizers on Tobacco.

Plot Number.	Fertilizer Applied.		Yield Per Acre.				
	Kind.	Pounds Per Acre.	Short Red.	Long Red.	Lugs.	Trash.	Tatol Lbs.
1	No Fertilizer	....	340	...	...	300	640
2	Nitrate of Soda Blood	80 80	440	...	..	460	900
3	Muriate of Potash	160	140	580	130	540	1,390
4	Double Superphosphate	140	180	...	...	220	400
5	No Fertilizer	....	140	20	...	300	460
6	Nitrate of Soda Blood Muriate of Potash	80 80 160	300	500	80	400	1,280
7	Nitrate of Soda Blood Double Superphosphate	80 80 140	80	430	...	370	880
8	Muriate of Potash Double Superphosphate	160 140	80	540	120	400	1,140
9	Nitrate of Soda Blood Muriate of Potash Double Superphosphate	80 80 160 140	...	920	140	400	1,460
10	Nitrate of Soda Blood Muriate of Potash Double Superphosphate	160 160 320 280	..	1,080	60	480	1,620

FINANCIAL RESULTS.

It is somewhat difficult to calculate the value of tobacco raised on the various plots on account of the difficulty experienced in grading tobacco in such small quantities. In giving the value to the crop, we estimate the value of red leaf at 12 cents, the lugs at 6 cents, and trash at 2 cents.

TABLE 9.—Showing Financial Results.

No. of Plot	Fertilizer Used.	Cost of Fertilizer Used Per Acre	Value of Tobacco Per Acre.	Value of Increased Yield of Tobacco Per Acre	Profit or Loss
1	No Fertilizer	....	$46.80	....	....
2	Nitrate of Soda Blood	$4.28	62.00	$26.00	$21.72
3	Muriate of Potash	3.68	105.00	69.00	65.32
4	Double Superphosphate	2.95	26.00	....	*2.95
5	No Fertilizer	....	25.20	....	....
6	Nitrate of Soda Blood Muriate of Potash	7.96	108.80	72.80	64.84
7	Nitrate of Soda Blood Double Superphosphate	7.23	68.60	32.60	25.37
8	Muriate of Potash Double Superphosphate	6.63	89.60	53.60	46.97
9	Nitrate of Soda Blood Muriate of Potash Double Superphosphate	10.91	126.80	90.80	79.89
10	Nitrate of Soda Blood Muriate of Potash Double Superphosphate	21.82	142.80	106.80	84.98

* Loss.

BULLETIN No. 46.

COMMERCIAL FERTILIZERS.

INTRODUCTION BY A. M. PETER.

The study of the chemistry of plants in comparatively recent years has established certain important facts, the knowledge of which is necessary to the intelligent use of fertilizers, and especially of that class called "Chemical," or "Commercial Fertilizers."

PLANT FOOD DERIVED FROM SOIL AND AIR.

A growing plant increases in size and weight by constantly adding to itself new material drawn from the soil and the air through its roots and leaves. Aside from the water which plants contain, the greater part of their substance is drawn from the air. When a plant is burned, most of the substances that come from the soil are left in the ash, except a very important one, nitrogen, which is largely derived from the soil; and the small amount of the ash, as compared with what was burned, shows roughly how much more of the substance of the plant comes from the air than from the soil.

IMPORTANCE OF SOIL SUPPLY.

Yet, although relatively small in amount, it is found that unless the soil is capable of furnishing certain substances in the required quantity, and in a condition to be taken up by the roots, plants will not thrive. The substances which are most important in this respect, for the reason that they are most likely to be deficient in soils or to become so by cropping, are *potash*, *nitrogen* and *phosphoric acid*; and it is these that commercial fertilizers are intended to supply, and they are referred to in our Bulletins and analyses as the "*essential ingredients*" of commercial fertilizers. Even if the season is favorable and the soil otherwise in good condition, plants will not reach perfection where any one of these substances is absent from the soil or deficient in quantity, or exists in such an insoluble combination as not to be taken up by the roots.

To use commercial fertilizers intelligently and economically then, a farmer must know—

First.—Whether his soil needs potash, nitrogen or phosphoric acid for the production of the desired crop.

Second.—What "essential ingredients" can be supplied by the commercial fertilizers he can obtain.

HOW TO DETERMINE WHAT A SOIL NEEDS.

The best way to determine the first point is by field experiments in which we apply fertilizers containing each one, two, or all three of the "essential ingredients" to separate plots of equal size, say 1-10 or 1-20 acre; tend all alike during the growing season, and carefully harvest and weigh the crop from each plot separately. By comparing the yields of the plots we can usually determine whether the soil on which the experiment was made is very deficient in one or more of the "essential ingredients" of fertilizers. Experiments of this kind have been made at the Station farm with corn, potatoes, tobacco, wheat, hemp and grass, and the results in detail have been published in the Bulletins of the Station, to which we refer the reader. Copies of nearly all of these Bulletins can still be furnished on application.

GOOD RESULTS FROM POTASH ON THE BLUE-GRASS SOIL.

For lack of space we can only call attention here to the very remarkable agreement of these results for a series of years in showing the benefit derived from a liberal use of potash fertilizers on the soil of the Station farm. In nearly every instance potash produced a very marked increase in the yield, and in some cases it was the most profitable fertilizer used. The use of potash and nitrogen, or of potash, nitrogen and phosphoric acid together, often produced a still greater yield, but the profit was often taken up in the additional cost of the nitrogen, which is the most expensive constituent of fertilizers. A very conspicuous exception to the above statement was proven in the case of tobacco, where the greatest profit was obtained from the use of potash and nitrogen together. The tobacco crop requires a great deal of both of these, but a comparatively small amount of phosphoric acid.

It must not be supposed that the results obtained upon the blue grass (limestone) soil of the Station farm will hold good all over the State. There is a great variety of soils in our State, and upon a large part of them, especially for grain crops, the use of phosphatic manures is found to be profitable. They serve to show, however, the need of determining by experiment the requirements of each kind of soil to guard against the unnecessary expenditure for fertilizers which supply ingredients that the soil is already capable of supplying in abundance. It must be borne in mind also that every crop taken off the land removes a certain amount of all the "essential ingredients," so that, under continuous cropping, it is necessary to return what has been carried away, and probably the heaviest drain from this source falls upon the potash and nitrogen. These results should also serve as an indication to the manufacturers of commercial fertilizers that a greater variety is needed in their composition than now exists, to correspond with the requirements of different localities. The great majority at present are highly phosphatic, and contain comparatively small proportions of potash and nitrogen; whereas, it is clearly shown that the soil of our blue-grass region is already well supplied with phosphates.

NITROGEN AND NITROGEN-GATHERERS.

While on this subject, a few words in regard to nitrogen in fertilizers will not be out of place. As remarked above, this is the most costly constituent of commercial fertilizers; and, in many instances, the increased cost of the fertilizer will balance or even exceed the increase in the proceeds from the crop, due to the nitrogen. Fortunately, we are not obliged to rely entirely upon commercial fertilizers for our supply of nitrogen to enrich our soils. Recent investigations have proved that the class of plants called "leguminous plants," to which the clovers, peas, beans, &c., belong, have the power of deriving from the air a part of the nitrogen required in their growth. For this reason they are sometimes called "*nitrogen-gatherers.*" This fact helps to explain why clover is so valuable in restoring and enriching poor soils. If we fertilize our crop of clover liberally with potash and moderately with phosphates, we have there the means of enriching our soil in all these "essential ingredients" of fertilizers. This is a very important principle in the use of fertilizers, and is in accordance with long established practice.

THE COMPOSITION OF FERTILIZERS.

The best way of determining the second point above is by chemical analysis of the fertilizers.

Fertilizer Law.—Our State law provides that every commercial fertilizer selling for more than $10 per ton shall be analyzed at the Experiment Station, and that each sack or other package offered for sale shall bear a copy of this analysis over the Director's signature. This analysis then becomes the standard of quality and the guide by which the purchaser is to judge what he is getting. The analyses made this year, up to the present date, are printed in this Bulletin. As an additional means of keeping the quality of the fertilizers up to the standard, the law also provides that any farmer purchasing a fertilizer may take a sample for analysis, according to the rules and regulations prescribed by the Director, and may have the analysis made at the Station free of cost. The law, as revised by the last Legislature, is printed in full in the Appendix, together with suggestions to purchasers, rules and regulations, and directions for taking samples for analysis.

HOW TO APPLY FERTILIZERS.

In regard to the manner of applying fertilizers, it is generally best to sow broadcast, or drill and work well into the soil before planting. When a small quantity of fertilizer is applied to each hill or row at planting time, it acts mainly as a stimulant to produce an early and vigorous start, which is considered necessary for the tobacco crop, but often renders the crop more sensitive to drouth. *In any case care should be taken to mix the fertilizer with the soil, so that it will not come in contact with the seeds or plants. Most fertilizers, and especially those containing much nitrogen, soluble phosphoric acid or potash, will injure or destroy young plants if brought directly in contact with them.*

EXPLANATIONS IN REGARD TO THE TABLES.

The farmers should study carefully the table of analyses in this Bulletin before purchasing commercial fertilizers. It will be noticed that there is given in the tables the amount of *phos-*

phoric acid, in its *soluble, reverted* and *insoluble form, nitrogen*, and its eqivalent in ammonia, and *potash* for each brand. Now the selling value of a commercial fertilizer should depend upon the amount of the various forms of phosphoric acid, the nitrogen and the potash it contains ; for, as has been said, it is to supply the plants with *phosphoric acid, nitrogen and potash* that the fertilizer is mainly applied to the soil. As regards phosphoric acid, the *soluble and reverted* forms should be particularly noted. They are the forms capable of being readily taken up as a food for the plant, while the *insoluble phosphoric acid* does not, in all probability, serve as food to the plant at once, and probably not for a year or more. For this reason this form of phosphoric acid is not as valuable to the farmer as the other forms. It is also the cheapest form of phosphoric acid in the market. Nitrogen is another element of great importance and value as a fertilizer, and is needed in most every soil where fertilizers are applied with benefit. Potash is the cheapest essential ingredient of a commercial fertilizer, but in all crops, and especially tobacco and potatoes, it is a very important element.

The Estimated Value.—In the last column of the table is given the value in dollars and cents of a ton of each fertilizer. These values are estimated from the essential ingredients contained in the fertilizers, and the forms in which they exist. In other words, they express the *commercial value*, or about the price the ingredients could be bought for on the open market, mixed and put upon the market as fertilizers. These values are not intended to express the *agricultural value* of the fertilizers, or the profit they will give the farmer by their use. They are intended rather to notify him, if he intends to purchase fertilizers, that from quotations this year of the essential ingredients of these fertilizers, he should be able to purchase the chemicals to furnish them, in the quantities shown by the analysis, for about the estimated price given in the table. Another, and perhaps the most important use of these estimated values, is to assist the farmer in determining which is the cheapest fertilizer for him to purchase. In choosing between several fertilizers of the same kind—that is, containing the same essential ingredients in about the same proportion, the one that has the highest "estimated value per ton" in the table of analyses would be preferable at the same cost. Or, if the "estimated value per ton" is about the same in all, the one that sells for the least is to be preferred. Take, for example, a supposable case: A farmer desires to purchase ten tons of some commercial fertilizer for his tobacco crop. His land is poor, and he concludes to purchase a fertilizer containing all three of the essential ingredients, namely, phosphoric acid, potash and nitrogen. He goes to his merchant, and finds that he has two brands for sale. No. 1 is priced at $40 per ton, and No. 2 at $30. The farmer refers to the table in this Bulletin, and finds the two brands relatively alike as to the essential ingredients. No. 1 is estimated at $40, and No. 2 at $25. It is evident, from the estimated values, that he should purchase the higher priced fertilizer, for if he paid $40 for this brand, he should pay but $25 instead of $30 for the cheaper one.

The Analyses.—But the analyses printed on the tags signed by the Director, attached to each sack or package of fertilizer, or in the tables of this Bulletin, should be carefully considered as well as the estimated value, *for the estimated value is not a sufficient guide to determine which of two or more fertilizers to purchase.* To illustrate the importance of considering the analyses as well as the estimated value, let us take an example. Suppose a farmer desires to purchase a fertilizer for his corn crop. He goes to his merchant, and is offered either of two brands at the same price. The price, fortunately, does not help him to decide in this case. He next looks at the tags attached to the sacks, and finds that the Director has estimated each fertilizer at $30.60 per ton. He next looks at the analyses, and finds fertilizer No. 1 to contain:

Soluble Phosphoric Acid	11 per cent.
Reverted " "	7 per cent.
Potash	None.
Nitrogen	None.

And fertilizer No. 2 to contain:

Soluble Phosphoric Acid, } Reverted " " }	7.5 per cent.
Nitrogen	3.0 per cent.
Potash	4.2 per cent.

He is now able to judge quickly which of the two fertilizers to purchase. If his soil needs phosphoric acid, he will quickly decide on No. 1, for he will get twice as much for the same money, while did he purchass No. 2 he would have paid $12.75 for the phosphoric acid which he needed; and $17.85 for the nitrogen and potash which he did not need. But should he be in doubt whether his land needed one or all the elements of a fertilizer, he would be wise in purchasing No. 2 For should his soil need potash or nitrogen, or all three of the essential elements, to produce a large corn crop, and should he have purchased No. 1, it is doubtful whether he would have received any benefit from it.

Concentrated Fertilizers the More Economical. — Another matter of relative cost may be properly considered here. Other things being equal, the cost per pound of the essential ingredients in a concentrated fertilizer is usually less than in one where the percentages are lower, on account of the increased cost for freight and handling in the latter case. Suppose, for example, our farmer is offered fertilizer No. 2 at $30.00 per ton on the cars, and another containing just twice the percentages of essential ingredients, in equally available form, at $60.00 on the cars. It is evident that the second would be really cheaper, because in one ton he would get as much phosphoric acid, potash and nitrogen as in two tons of No. 2, and would save freight, cost of sacks and handing on one ton of fertilizer. This is an extreme case, but the principle holds good where the extremes are not so great.

In applying a very concentrated fertilizer it is often well to mix it with dry earth, road dust, etc., for convenience in sowing, and to prevent injury to plants.

On account of the differences in soils, no rule can be given by which to tell what fertilizer is the best for any particular crop, and this question must be decided by actual trial, systematically and carefully made. Some such trials are made at the Station each year, and the Director will be glad to furnish a plan for similar experiments to any one who desires to test the effect of fertilizers on his land.

MATERIALS OF WHICH COMMERCIAL FERTILIZERS ARE MADE

For further explanation relative to the materials of which commercial fertilizers are made, and the chemical terms used in speaking of them, we refer to Bulletin 41 and other issues on commercial fertilizers, copies of which will be furnished on application.

VALUES USED.

The following are the values used for the essential ingredients in calculating the estimated value per ton: Phosphoric acid soluble in water, 8½ cents; "reverted" phosphoric acid, 8½ cents; insoluble phosphoric acid, 3 cents; phosphoric acid in fine bone, 4½ cents, in medium bone, 4 cents per lb.; potash from muriate, 5½ cents; from sulphate, 7 cents, and nitrogen, 20 cents per lb.

Fine bone is all that passes through a sieve with meshes 1-25 inch square. Medium bone passes through a sieve with meshes 1-6 inch square, but does not include fine bone.

FERTILIZERS ANALYZED.

For the year 1893, up to August 1st, 24 manufacturers have had 93 different fertilizers analyzed in compliance with the law, and 114,500 tags have been issued. These analyses are printed in the following tables:

TABLE 1.—RAW BONE MANURES.

Station Number	Name and Address of Manufacturer	Name of Brand.	Pounds in the Hundred. Phosphoric Acid. In Fine Bone.	Phosphoric Acid. In Medium Bone.	Phosphoric Acid. Total	Equivalent to Bone Phosphate	Nitrogen	Equivalent to Ammonia	Estimated Value Per Ton
2220	A. D. Adair & McCarty Bros., Atlanta, Ga.	Adair's Pure Raw Bone Meal	12.13	11.84	23.97	52 36	4.03	4.89	$36 51
2200	Armour & Co, Chicago, Ill.	Bone Meal	21.10	5.28	26 38	57.61	2 42	2 94	32 89
2192	Cincinnati Desiccating Co, Cincinnati, Ohio	Pure Raw Bone Meal	17.51	7.08	24 59	53 70	3.50	4.25	35 42
2278	Same	Fine Ground Bone	12.13	9.08	21 21	46.32	3.36	4.08	31 62
2177	Currie Fert. Co., L uisville, Ky.	Currie's Raw Bone Meal	10.73	10.43	21.16	46 21	4.17	5.06	34 68
2232	Dunn & Backer, Troy, Ind.	Clover Leaf Brand Pure Raw Bone Meal	22.11	2.32	24.43	53.37	4.08	4 95	37 98
2283	Globe Fert. Co, Louisville, Ky.	Globe Bone Meal	11.33	10.92	22.75	49.68	3.98	4.83	35 31
2097	J. B. Jones, Louisville, Ky.	Pure Raw Bone Meal	7.96	14.45	22.41	48.95	4.05	4.92	34 92
2098	Same	Pure Ammoniated Bone Meal	14.71	2.56	17.27	37 72	2.66	3.23	25 93
2237	A. B. Mayer Manufacturing Co, St. Louis, Mo.	Anchor Brand Pure Bone Meal	12 66	9.75	22.41	48.95	3 75	4.55	34 19
2169	North-Western Fertilizing Co., Chicago, Ill.	Horse Shoe Brand Fine Raw Bone	23.92	. . .	23.92	52 25	3.68	4.47	36 25
2161	Same	Horse Shoe Brand Ralston's Bone Meal	14 55	4 23	18.78	41.02	2.64	3.20	27 04
2171	Same	Horse Sh. Br'd Pure Ground Bone	14.03	3.80	17.83	38.95	3.44	4 18	29 43
2172	Same	Horse Shoe Brand Chicago Raw Bone Meal	18.24	1 80	20.04	43.76	2.17	2.63	26 56
2186	Wm. Skene & Co., Louisville, Ky.	Skene's Pure R'w B'e Dust or Meal	11.87	11 13	23.00	50.24	3.97	4.82	35 46

2267	Standard Guano & Chemical Manufact'ng Co., New Orleans, La.	Pure Ground Bone	14.20	7.09	21.29	46.49	3 91	4 75	34 09
2119	Thompson & Edwards Fertilizer Co., Chicago, Ill.	World-of-Good R B. Corn Grower	15 68	2.97	18.65	40.74	4.16	5 05	*35 87
2294	National Fertilizer Co., Nashville, Tenn.	Bone Meal	12.61	12.62	25.23	55.10	3.93	4.77	37 17
2299	Nolte & Dolch Fertilizer Co, St. Louis, Mo.	Pure Raw Bone Meal	18.54	1.70	20 24	44.20	4 42	5 37	35 73
2300	Ohio Valley Fertilizing Co, Owensboro. Ky.	Bone Meal	12.82	11.59	24 41	53.31	3.07	3.73	33 09
2290	J. F. & W. H. Singer, Nashville, Tenn.	Raw Bone Meal	12.96	10 48	23.44	51 19	3.68	4 47	34 76

* Potash from Muriate, 0.42 per cent.; from Sulphate 1 59 per cent.

TABLE 2.—COMPLETE FERTILIZERS, SUPERPHOSPHATES, ETC.

Station Number	Name and Address of Manufacturer.	Name of Brand.	Pounds in the Hundred. Phosphoric Acid. Soluble	Phosphoric Acid. Reverted	Phosphoric Acid. Insoluble	Nitrogen	Equiv. to Ammonia	Potash. From Sulphate	Potash. From Muriate	Estimated Value Per Ton.
2199	Armour & Co., Chicago, Ill.	Bone and Blood	. .	5.38	8.39	5.60	6 80	. . .	. . .	$36 58
2201	Same	Dissolved Bone	0.54	8.18	4.78	1 33	1.61	. . .	. . .	23 01
2113	Cincinnati Desiccating Co., Cincinnati, O.	Kentucky and Tenn. Tobacco Grower	2.44	6.39	3.81	1.98	2.40	. . .	3.27	28 82
2194	Same	Acidulated Bone	3 20	7.64	8.12	3 61	4.38	. . .	. . .	37 74
2195	Same	Gilead Phospha e	3.22	5.84	3.96	2.58	3.13	. . .	2.12	30 43
2196	Same	Ohio Valley Phosphate	2.98	5.80	4.31	1.62	1.97	. . .	1.89	26 08
2197	Same	Phœnix Phosphate	2.98	4.41	3.25	1.94	2.36	. . .	1.14	23 52
2198	Same	Tobacco and Potato Fertilizer	3.66	4 47	3.90	4.17	5.06	5.10	. . .	39 98
2187	Cleveland Dryer Co., Cleveland, O.	White Burley Tobacco Fertilizer	8.44	2.11	3.01	2.23	2 71	. . .	3.72	32 76
2188	Same	Buckeye Phosphate	5.46	5.22	3.01	2 45	2.97	. . .	. . .	29 77
2189	Same	Ohio Seed Maker	5.67	5 23	3.33	1.74	2.11	. . .	. . .	27 49
2190	Same	Ammoniated Dissolved Bone	7.42	3.64	2.46	1.69	2.05	. . .	. . .	27 04
2191	Same	Square Bone	4.03	6.94	9.63	1.95	2.37	. . .	. .	32 23
2120	Crocker Fertilizer & Chemical Co, Buffalo, N. Y.	Kentucky Tobacco Phosphate	8.29	1.39	1.30	2 92	3.54	. . .	4.51	33 88
2158	Same	Crocker's New Rival Ammoniated Superphosphate	6.65	3.22	2 39	1.39	1.69	. . .	2 02	25 99
2178	Currie Fert. Co., Louisville, Ky.	Currie's Dissolved Bone	6.87	1.34	0.49	1.19	1.44	4.30	. .	25 03
2179	Same	Currie's Corn Grower	5.50	2 61	3.44	2.90	3.52	1.04	0.96	30 01
2180	Same	Currie's Falls City Bone Meal	4.80	4.29	7.11	1.32	1.60	. . .	2.39	27 93
2181	Same	Currie's Falls City Phosphate	5.54	2.50	3.26	2.70	3.28	1 24	0 72	28 97
2182	Same	Currie's Wheat Grower	5.67	2.68	3.28	2.74	3.33	1.00	1.10	29 74
2183	Same	Currie's Guano	6.72	1.43	0.60	1.20	1.46	4.24	. . .	24 96
2184	Same	Currie's Black Diamond Phosphate	7.62	1.20	0.84	0.68	0.83	2.00	. . .	21 01

2183	Same	Currie's Guano	6.72	1.43	0.60	1.20	1.46	4.24	. . .	24 96
2184	Same	Currie's Black Diamond Phosphate	7.62	1.20	0.84	0.68	0.83	2.00	. . .	21 01
2205	Same	Currie's Tobacco Grower	5.45	2.59	3 35	2.83	3.44	. . .	2.95	30 25
2245	Excelsior Guano Co., Baltimore, Maryland	Ammoniated Bone Superphosphate	6.24	2.25	4.46	1.72	2.09	. . .	1 68	25 83
2217	Furman Farm Improvement Co., Atlanta, Ga.	Buffalo Bone Fertilizer	6.03	3.35	1.97	2.28	2.77	. . .	2.00	28 45
2219	Same	Farish Furman Formula	13.38	2.01	1.46	. . .	. . .	. . .	3.64	31 04
2257	Same	Furman High Grade Fertilizer	8.09	1.41	1.46	2.24	2 72	. . .	2.83	29 10
2258	Same	Furman Soluble Bone with Ammonia and Potash	9.11	1.53	1.39	1.25	1.52	. . .	1 62	25 70
2259	Same	Farish Furman Formula	9.63	1.98	0.56	. .		. .	3.21	23 60
2121	Globe Fert. Co., Louisville, Ky	Golden Harvest Bone Meal	6 74	3.62	8.19	2.37	2.88	. . .	. . .	32 00
2122	Same	Eagle Fertilizer	5.99	1 69	3 35	2.72	3.30	0.47	1.28	28 02
2123	Same	Progress Phosphate	7.60	1.25	2 48	1 90	2.31	0.99	. . .	25 53
2124	Same	Globe Bone Dust	7 24	1.19	2.61	1.45	1 76	0.99		23 09
2125	Same	Kentucky Standard Tobacco Grower	5.55	1.91	4.17	3 25	3.95	. . .	3.80	32 36
2126	Same	Globe Wheat Grower	6.03	1.98	3.21	2 69	3.27	0.44	1.42	28 49
2099	J. B. Jones, Louisville, Ky.	Corn Grower	3.62	4.11	5.14	3 06	3.71	. . .		28 46
2280	Same	Bromophyte	0.54	2.34	1.15	1.28	1.55	. . .	0.29	11 03
2063	Loudenback Fert. Co., Urbana, O.	Urbana Acid Phosphate	12.74	2.79	0.56	. . .	. . .	. . .	. . .	26 74
2064	Same	Urbana Sweepstakes Bone Phosphate	7 37	1.98	1.55	2.21	2.68	. . .	3 30	29 30
2065	Same	Urbana Bone Meal	2.93	8.93	5.59	2 53	3.07	. . .	3.53	37 51
2066	Same	Urbana Superphosphate and Potash	7 74	2.46	1.10	1.96	2.38	. . .	2.55	28 65
2067	Same	Urbana Ammoniated Dissolved Bone	10.81	1 15	0.59	2.45	2.97	. . .	3.58	34 42
2091	P. B. Mathiason & Co., St. Louis, Missouri	Increscent Brand Tobacco Grower	1.89	4 98	5 19	3.50	4.25	4.28	. . .	34 78
2238	A. B. Mayer Mf'g Co., St. Louis, Missouri	Anchor Brand Complete Fertilizer	1.25	3.55	5.88	2.97	3 61	. . .	3.34	27 24
2239	Same	Anchor Brand Wheat Grower	. . .	6 90	10.26	4 51	5.48	. . .	0 46	36 44
2240	Michigan Carbon Works, Detroit, Michigan	Homestead Tobacco Grower	9 27	0.43	0 74	3 60	4.37	. . .	5.14	36 98
2242	Same	Homestead Potato Grower	9.12	0.51	0.77	3.44	4 18	. . .	5.10	36 20
2243	Same	Jarves Tobacco Fertilizer	5 25	0.96	1.11	2.29	2.78	2.70	. . .	24 16
2244	Same	Jarves Drill Phosphate	5.11	3.41	1.29	1 28	1.55	. . .	. . .	20 38
2262	Same	Homestead Corn and Wheat Grower	7 80	1.24	1 51	2.32	2.82	. . .	2.13	27 90
2279	Mobile Phosphate & Chemical Co., Mobile, Ala.	Mobile Standard Guano	9.39	1.11	2.00	1.77	2.15		1.24	27 49
2234	National Fert. Co., Nash., Tenn	Tennessee Guano	6 14	1 42	0 87	1.84	2.23	. . .	1.21	22 06

TABLE II.—COMPLETE FERTILIZER, SUPERPHOSPHATES, ETC.—Continued.

Station Number	Name and Address of Manufacturer.	Name of Brand.	Pounds in the Hundred. Phosphoric Acid. Soluble	Phosphoric Acid. Reverted	Phosphoric Acid. Insoluble	Nitrogen	Equivalent to Ammonia	Potash. From Sulphate	Potash. From Muriate.	Estimated Value Per Ton.
2235	National Fert. Co., Nashville, Tenn.	Tobacco Grower	6 24	1.37	0.88	1.83	2.22	. . .	1.30	$22 22
2236	Same	National Dissolved Bone	7.50	2 08	1.61	1.21	1.47	. . .	1.32	23 55
2162	North Western Fertilizing Co., Chicago Ill	Horse Shoe Brand Tobacco Grower	3.26	4.20	4.32	2.44	2.96	0.77	. . .	26 11
2163	Same	Horse Shoe Brand Challenge Corn Gro'er.	3.33	4 83	3.34	2.13	2 59	0.65	. . .	25 30
2164	Same	Horse Shoe Brand Twenty-six Dollar Phosphate	2.65	4.19	2 78	1.96	2.38	. . .	. . .	21 14
2165	Same	Horse Shoe Brand Prairie Phosphate	2.62	4.06	2.85	2.00	2.43	. . .	. . .	21 07
2166	Same	Horse Shoe Brand Kentucky Corn and Tobacco Grower	2.67	4 05	2.81	1.96	2.38	0 35	. . .	21 44
2167	Same	Horse Shoe Brand Potato Grower	3.29	4.03	4 45	2.39	2 90	0 76	. . .	25 73
2168	Same	Horse Shoe Brand Ky.-Ana Phosphate	3 42	2.90	4.06	1.17	1.42	. . .	. . .	17 76
2169	Same	Horse Shoe Brand Superphosphate and Raw Bone Mixture	2.35	5.85	7.33	2.70	3.28	0.51	. .	29 85
2170	Same	Horse Shoe Brand National Bo e Dust.	3.34	5.03	3.48	2.19	2.66	0.65	. . .	25 99
2173	Same	Horse Shoe Brand High Grade Truck Manure	1.91	5.57	5.94	3.33	4.04	1.98	. . .	32 37
2176	Pottstown Iron Co., Pottstown, Pennsylvania	Odorless Phosphate	. . .	8.05	10.55	. . .	. . .		. . .	20 02
2251	J. S. Reese & Co., Baltimore, Md	Excellenza Soluble Guano	6.05	3.21	0.95	2.37	2.88	1.01	0.96	28 26
2252	Same	Reese's Pacific Guano	6.13	3 02	0.97	2.46	2 99	0.96	0.96	28 38
2253	Same	Kentucky Tobacco and Corn Producer	5.49	6.58	0.53	0.83	1.01	. . .	0.47	24 67
2254	Same	Monarch Guano	6.19	3.26	0.90	2.32	2.82	1.12	0.96	28 50

2253	Same	Kentucky Tobacco and Corn Producer .	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2254	Same	Monarch Guano.	6.19	3.26	0.90	2.32	2.82	1.12	0.96	28 50
2281	Same	Crown Bone Phosphate and Potash . .	11.25	1.74	1.29	. . .	. . .	. . .	2.31	25 39
2185	Wm. Skene & Co., Louisville, Ky.	Skene's Ky. Bone Meal and Potash . .	2.25	3.74	3.76	1.86	2.26	. . .	5.30	25 71
2221	Same	Skene's Perfect Tobacco and Potato Grower	5.09	4.12	0.92	3.34	4.05	12.98	. . .	47 74
2270	Springfield Fert. Co., Springfield, Ohio	Atlas Bone Phosphate	4.99	3.24	1.77	1.63	1.98	. . .	2.46	24 28
2271	Same	Soluble Bone Phosphate	3.98	2 66	1.37	0.99	1.20	. . .	2 92	19 28
2274	Same	Globe Bone Phosphate	4.09	4.75	2.55	2.03	2.46	. . .	2.19	27 09
2268	Standard Guano & Chemical Manufacturing Co., New Orleans, La.	Di solved Bone	14 05	1.67	1 60	. . .	. . .	. . .	. . .	27 68
2288	Chesapeake Guano Co., Baltimore, Maryland	Dissolved Bone Phosphate	13.07	1.47	1.34	. . .	. . .	. . .	. . .	25 52
2286	Goulding Fertilizer Co., Limited, Pensacola, Fla	Goulding's Bone Compound.	5.99	2.91	1.96	1 68	2.04	. . .	1.15	24 30
2292	Jas. McCallum & Co., Dayton, O .	Ammoniated Dissolved Bone	6.54	2.72	2 16	2 98	3.62	. .	3.09	32 36
2293	Same	Spot Cash Fertilizer	4.58	3.57	2.14	2 50	3.04		2.81	28 23
2298	Meridian Fert. Factory, Meridian, Mississippi.	Standard Home Mixture Guano. . . .	8.42	1.74	1.87	1.90	2.31	. . .	1.90	28 08

1893.

M. A. SCOVELL, *Director*.

APPENDIX.

CHAPTER 62.

AN ACT Concerning Fertilizers.

Be it enacted by the General Assembly of the Commonwealth of Kentucky: § 1. On or before the first day of May in each year, before any person shall sell, offer, or expose for sale in this State, any commercial fertilizer whose retail price is more than ten dollars per ton, said person shall furnish to the Director of the Agricultural Experiment Station, inaugurated by the Agricultural and Mechanical College of Kentucky (which station is hereby recognized as the "Kentucky Agricultural Experiment Station"), a quantity of such commercial fertilizer, not less than one pound, sufficient for analysis, accompanied by an affidavit that the substance so furnished is a fair and true sample of a commercial fertilizer which the said person desires to sell within this State.

§ 2. It shall be the duty of the Director of the Kentucky Agricultural Experiment Station to make, or cause to be made, a chemical analysis of every sample of commercial fertilizer so furnished to him, and he shall print the result of such analysis in the form of a label; such label shall set forth the name of the manufacturer, the place of manufacture, the brand of the fertilizer, and the essential ingredients contained in said fertilizer, expressed in terms and manner approved by said Director, together with a certificate from the Director, setting forth that said analysis is a true and complete analysis of the sample furnished him of such brand of fertilizer, and he shall also place upon each label the money value of such fertilizer, computed from its composition, as he may determine. The Director shall furnish such labels in quantities of five hundred, or multiple thereof, to any person desiring to sell, offer or expose for sale, any commercial fertilizer in this State.

§ 3. Every box, barrel, keg, or other package or quantity of any commercial fertilizer (the retail price of which is over ten dollars per ton), in any shape or form whatever, sold or offered for sale in this State, shall have attached to it in a conspicuous place, a label bearing a certified analysis of a sample of such fertilizer from the Director of the Kentucky Agricultural Experiment Station, as provided in the foregoing sections of this law.

§ 4. Any manufacturer or vender of any commercial fertilizer, or any person who shall, offer or expose for sale any fertilizer without having previously complied with the provisions of this chapter shall be fined not less than one hundred nor more than five hundred dollars for each violation or evasion of this law.

§ 5. The Director of the Kentucky Agricultural Experiment Station shall receive for analyzing a fertilizer, and affixing his certificate thereto, the sum of fifteen dollars; and for labels furnished, one dollar per hundred.

§ 6. The Director of said Kentucky Agricultural Experiment Station shall pay all such fees received by him into the Treasury of the Agricultural and Mechanical College of Kentucky, the authorities of which shall expend the same in meeting the legitimate expenses of the Station, in making analysis of fertilizers in experimental tests of same, and in such other experimental work and purchases as shall inure to the benefit of the farmers of this Commonwealth. The Director shall, within two months of the biennial meeting of the General Assembly, present to the Commissioner of Agriculture a report of the work done by him, together with an itemized statement of receipts and expenditures for the two years preceding, under the operations of this law.

§ 7. The Director of said Experiment Station is hereby authorized, in person or by deputy, to take samples for analysis from any lot or package of any commercial fertilizer which may be in the possession of any dealer in this State; and is authorized to prescribe and enforce such rules and regulations as he may deem necessary to carry fully into effect the true intent and meaning of this law. And any agriculturist, a purchaser of any commercial fertilizer in this State, may take a sample of the same, under the rules and regulations of the Director of the said Experiment Station, and forward the same to the Experiment Station for analysis, which analysis shall be made free of charge.

§ 8. If the Director of the Experiment Station shall believe, after having made an analysis of any fertilizer, that the same is of no practical value, he shall refuse to furnish any labels to be placed on such fertilizer.

Approved June 20, 1892.

RULES AND REGULATIONS.

By authority of section 7 of the fertilizer law the Director makes the following Rules and Regulations concerning the sale of fertilizers in this State:

1. The seller is responsible for affixing the *official* label to the fertilizer packages, unless the manufacturer has provided and attached them.

2. All labels, to be official, must emanate from the Director of the Kentucky Agricultural Experiment Station. Persons attaching other than official labels, for official labels, are evading the law, and are subject to the penalties thereof.

3. Official labels are issued only to persons guaranteeing by affidavit that the fertilizer to which they are to be attached is true to the sample on which the results of the analysis and commercial value are determined. Persons attaching labels to goods misrepresenting the fertilizers, or the sample for which they are issued, are subject to the penalties of the law for each offense.

TO PURCHASERS OF FERTILIZERS.

It is of vast importance to the State that the fertilizers sold should be of the quality as represented. To this end the Director would advise farmers purchasing fertilizers:

1. To purchase with a guarantee that the fertilizer is as represented by the official tag attached.

2. Take a sample, especially if purchasing in large quantities, and send it to the Director for analysis to see whether the fertilizer is as represented by the seller.

3. To have nothing to do with fertilizers which are not labeled with a tag bearing an analysis, and certified to and signed by

the Director. Manufacturers of genuine goods are always willing to comply with a law which protects them as well as the purchaser, and their goods will be found labeled as required by law. It is generally those who offer adulterated or inferior goods that do not desire the quality of their goods to be known.

In order to obtain a fair sample for this purpose, the following directions should be observed:

HOW TO TAKE SAMPLES.

a. Select at least two average sacks of the fertilizer, preserving the labels to send with sample. Open these sacks and mix well together the contents of each, down to one-half its depth, emptying out upon a clean floor, if necessary, and crushing any soft, moist lumps, in order to facilitate mixture, but leaving hard, dry lumps unbroken, so that the sample shall exhibit the texture and mechanical condition of the fertilizer.

b. Take out five equal cupsful from different parts of the mixed portions of each package. Pour them (ten in all) one over another upon a paper; intermix again thoroughly, but quickly, to avoid loss or gain of moisture; fill a can or jar from this mixture; inclose labels taken from the sacks; seal; label plainly, giving name also of sender, and send by express, *charges prepaid*, to M. A. SCOVELL, *Director*,
Lexington, Ky.

Unless these directions are strictly complied with, it will be useless to send samples for free analysis.

BULLETIN No. 47.

1. *THE PESTS OF SHADE AND ORNAMENTAL TREES.*

BY H. GARMAN, ENTOMOLOGIST AND BOTANIST.

Trees are subject to many different injuries from insect enemies, from parasitic fungi, from unfavorable conditions of surroundings, from severe droughts, sudden lowering of the temperature, etc., and require, like other plants, some care and attention in order that they may grow well. They need this attention, especially when grown about dwellings for shade, since the exposure to weather, and the facility with which their enemies can concentrate on them and spread from tree to tree, makes them more liable to injury than when scattered and growing in a state of nature. Often several causes leading to the decline and ultimate destruction of shade trees are at work at one and the same time, and it becomes then a matter of some difficulty to discover the primary cause and to check the injury. It may be that the soil was not suited to the needs of the trees planted, and that they exhausted the available supply of nutriment, then suffered from starvation, if I may use the word, in which condition plants are well known to be much more liable to the attacks of fungus and insect enemies than when in perfect health. In such cases, however, the insects are liable to get the blame for the injury; and while there is no doubt that they increase the injury, and may insure the ultimate death of trees which would not otherwise succumb completely, it is evident that their removal will not entirely answer the requirements of the case. The proper thing to do for trees suspected to be in need of nourishing material at the roots is, of course, to supply the food in the form of a fertilizer. The material taken from the earth by thrifty trees is very considerable, as may be known from the fact that other plants of vigorous growth and large size will not grow well near them. In the forest and thicket they get this nourishing material from the decay of fallen trees and leaves and from the annual growth of surface vegetation. Along the streets of a city and on a well-groomed lawn the supply from sources such as these amounts to but little, and it is, therefore, the part of wisdom to supply the deficiency by artificial means.

Considerations of this sort come strictly within the domain of practical horticulture rather than in that of economic entomology and botany, yet it is not possible to separate by hard and fast lines these different lines of work and study, so intimately are they bound up with each other. Inquiries sometimes reach the Experiment Station concerning "diseased" shade or fruit trees which it is evident are suffering from a period of neglect on the part of the owners. It requires heroic measures to rescue trees which have exhausted the nutriment within reach of their roots, which are besides bored through by the larvæ of beetles, and whose leaves are gnawed by web-worms, and it may be also infested with aphides and parasitic fungi; and while, for advanced cases of disease of this sort, it is only to be recommended that the trees be cut down and burned as promptly as possible to prevent further spread of the insect and fungus pests, this is a measure people are very reluctant to take, and it is one, consequently, an entomologist does not like to recommend (though it may be evident to him that in the long run this would be economy both to the owner and his neighbors). Until the State enforces by law the destruction of such infested trees, we can not, therefore, hope for the prompt and drastic measures often needful for stamping out the pests to which vegetation is subject.

INJURIES SHOULD BE CHECKED AT THEIR INCEPTION AND PRECAUTIONARY MEASURES SHOULD BE ADOPTED.

It is sometimes possible to prevent the increase of an injurious insect with but slight trouble if we know exactly what it is, and when our work may be most profitably done. The cutting away and burning of an infested branch, the removal and destruction of an entire tree, sometimes even the removal of a single insect, may save the trees of a whole village from severe injury. Always dead portions of trees either on the trees or lying on the ground are to be removed and disposed of. Weeds and rubbish calculated to afford lurking places for insects ought always to be removed, and loose dead bark on the trunks should not be allowed to remain. Though to many people a whitewashed tree trunk is an unsightly object, there can be no question as to the value of such treatment for some injuries, and the wash may be made even more effective by adding to it London purple or Paris green, when the "tombstone effect" of which some people complain will be done away with.

It is a matter of common observation that the man who attends to these things is much less troubled by injury to trees than one who neglects his grounds. Still there is a class of injuries which no one can be accused of encouraging, and which it is very desirable to control if possible. Sudden frosts after the sap begins to flow in spring may result in injuries not in themselves very serious, but which open the way to attacks by insects. Sleet and wind storms may occasion injuries which in the nature of things cannot be avoided. Droughts when prolonged often weaken trees which are not very vigorous, or are badly situated, and then insects, when encouraged by very favorable weather, will overrun a place in spite of all the ordinary precautions that may be taken, attacking in such cases the more thrifty trees, as well as the enfeebled ones.

SUNSTROKE OF TREES.

In considering the nature of injuries suffered by shade and ornamental trees, we must not omit mention of an injury which is very common in Kentucky, and often very destructive. I refer to that sudden blighting of trees with rather succulent foliage, which occurs in hot weather in July. Trees seemingly in perfect health, with splendid growths of leaves, receive a check which, in its suddenness and effects, can only be likened to sunstroke. The crisp green leaves wither on most of the branches in a day, and ultimately blacken and dry up as if the tree were utterly killed. After a time such trees partially or wholly recover and put out a new growth of leaves before fall, still, however, by their enfeebled condition showing that the shock was a severe one. When I first observed this trouble among trees, I supposed it might be due to attacks from some one of those minute organisms known as bacteria. The dying leaves show no trace of ordinary parasitic fungi such as occasion the mildew of grape vines and the scab of apple. But careful examination of the tissues when first affected shows no bacterial or other organisms present that could possibly occasion such

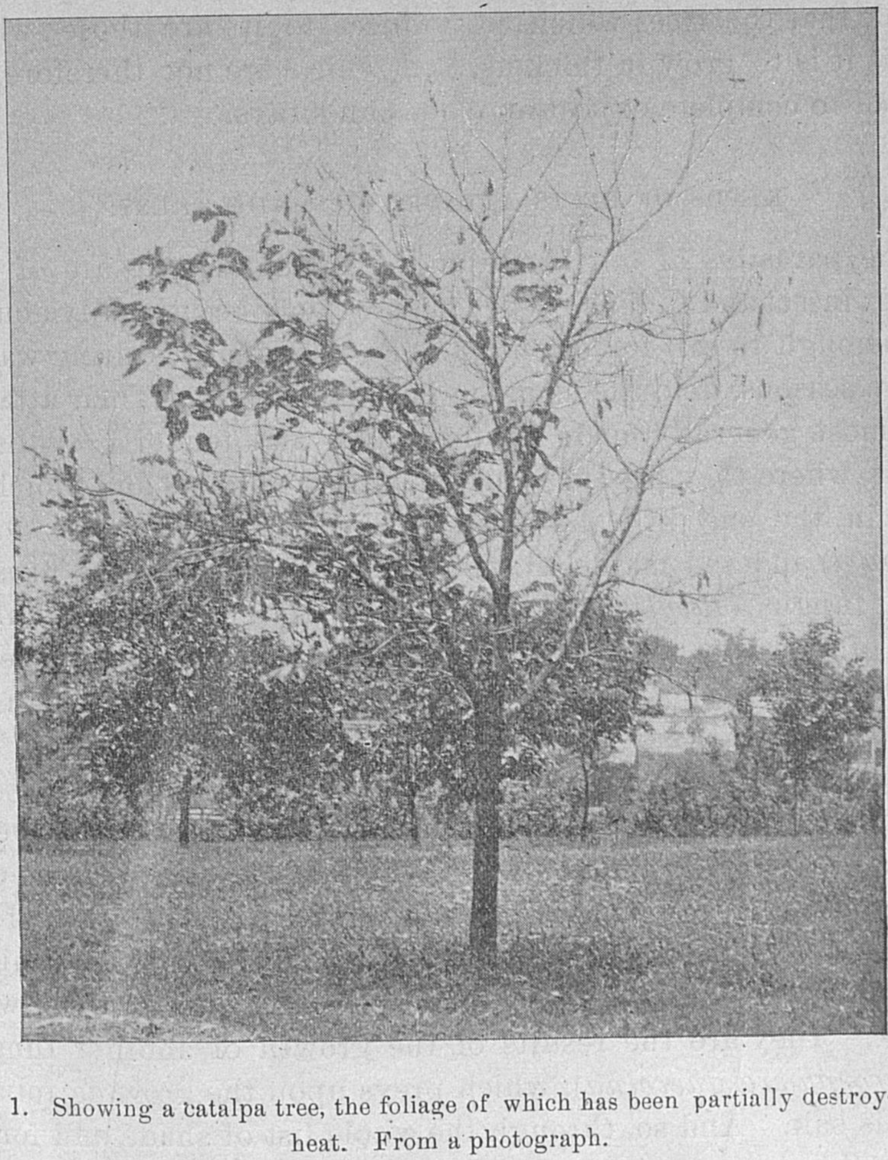


Fig. 1. Showing a catalpa tree, the foliage of which has been partially destroyed by heat. From a photograph.

sudden and extensive injury, and after repeated attempts to induce the disease by inoculation, I am forced to believe that conditions of weather, such as showers followed by extreme heat, occasionally kill the foliage of some of our shade trees.

The tree which has suffered most in this neighborhood during the past three years is the Catalpa, and I present herewith a figure of one of these trees as it appeared soon after it became affected. One of my purposes in calling attention to this trouble is to point it out as an affection not due to insects, and not very easy to guard against. Inquiry has reached me occasionally with reference to it. I do not know any thing likely to prevent its occurrence except shade; and I am disposed to think that the trees which are subject to it are those whose habit it is to grow in thickets, and which are not therefore adjusted to complete exposure to the sun's rays.

KINDS OF PESTS ATTACKING SHADE TREES.

The parasites of our shade and ornamental trees are of two sorts: insect and fungus. The latter are only occasionally abundant enough to call for attention. But they may, during warm, damp seasons, do quite as much harm as insects. Their attacks are most generally made on the leaves and tender growths of twigs, where they produce variously colored spots and blotches, and in the end kill the tissue. The soft maple (*Acer dasycarpum*) and red maple (*A. rubrum*) are subject to the attacks of a fungus (*Rhytisma acerinum*) in the Mississippi Valley that often works much injury to the leaves. It produces a dense black spot varying from .25 to .50 inch in diameter, with its upper surface coarsely wrinkled and slightly convex. The leaves of the yellow poplar (tulip-tree) are also subject to the attacks of a fungus, producing small black dots and spots eventually resulting in extensive discolorations. The black oak (*Quercus coccinea*) sometimes bears on the upper surface of its leaves numerous ash-gray blotches of irregular size, which, when closely examined, are found to be minutely speckled with black. They are the results of the growth of another fungus (*Microsphæra quercina*), which preys upon the growing foliage of this oak. And so, through the whole list of shade and forest trees, there are very few species that are not subject to one or more of these fungus parasites. The elms, the basswoods, the hickories, the walnuts, all have their peculiar species.

With such numbers of enemies, insect and fungus to drain them of sap and destroy their foliage, it might seem that trees would more frequently be destroyed. This result would probably be witnessed more often were it not for the fact that the

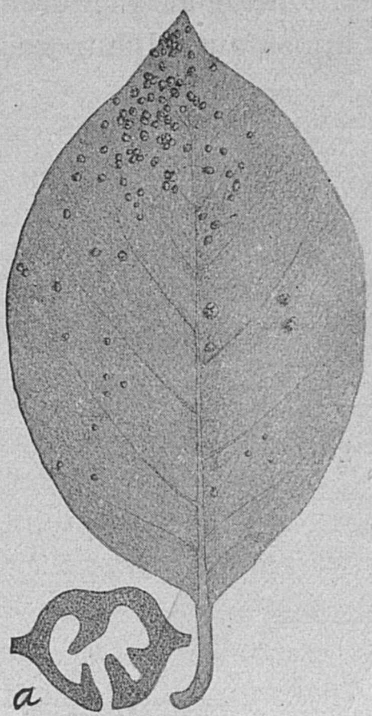


Fig. 2. Showing leaf of black gum galled by minute mites; *a*, section through one of the galls. Soft maples show a similar injury.

leaf-eating insects are most common, as a rule, during dry seasons (this does not appear to be true of insects which live in the interior of plants), while the fungus enemies are most injurious when the rainfall is greatest. Their prevalence being thus alternating to some extent, the trees do not so often suffer from attacks of both at one and the same time.

The insect pests are the more frequently destructive, and at times so completely strip the leaves from elms, maples and other trees as to threaten their extermination. They may be divided roughly into three groups, according to the part of the tree they attack, as follows: (1) Leaf insects, (2) trunk and branch-mining insects, and (3) roof-infesting insects.

The first group of the three includes most of the species which attract general attention, though it cannot be said that they are the most destructive. To it belong the fall web-worm, the walnut-worm, and the elm leaf-beetle, so destructive in the eastern States. To it also belongs the Gypsy-moth, for the destruction of which the State of Massachusetts during the three years ending December 31, 1893, expended $175,000. Such insects attract attention at once from the nature of their injury, the unsightly appearance due to gnawed leaves, webbing

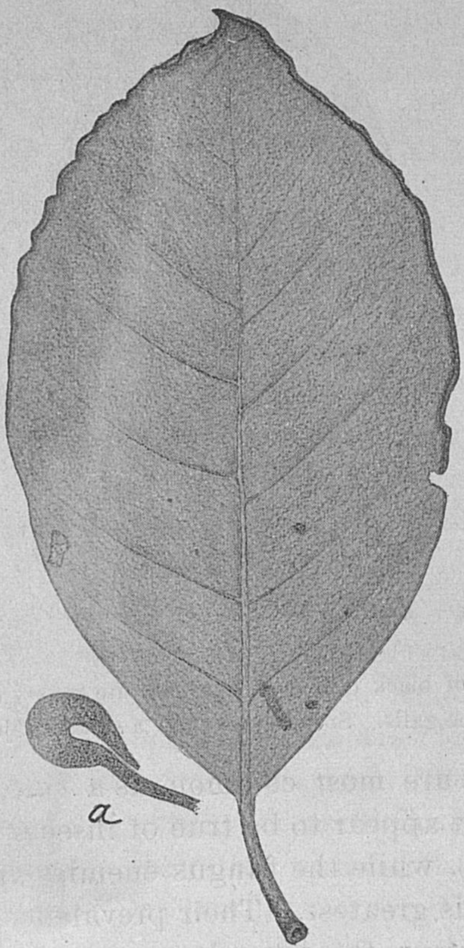


Fig. 3. Showing a marginal gall produced by mites on black gum.

and refuse, taking away at once from trees their practical value as shade, and their esthetic value as ornament.

While their injuries are not at first so apparent, the work of the boring and mining species is not less injurious, and is the more to be feared because its results are not seen until the mischief under the bark is at an advanced stage. The locust borer and the elm bark-beetle are members of this group, both species being common and injurious in Kentucky. The pine bark-beetles and the fruit bark-beetles, now becoming injurious in this State, may also be placed here. The greater number of species which attack the trunk are the grubs of beetles. A few are caterpillars (larvæ) of moths. The branches and twigs are injured by a host of small species, some of which girdle them, others mine them; still other species do serious mischief by placing their eggs in them, while some of the true bugs simply puncture and abstract their sap.

Doubtless the number of insects which feed on the roots of shade trees is large, but the unavoidable difficulties in the way of studying their habits has prevented a very full knowledge of this group. Among the better known is the seventeen year cicada (*Cicada septendecim*), which, in its immature condition, lives in the earth, where it doubtless punctures the roots of oaks and other trees. A few root-feeding beetles are also known to attack trees, but our knowledge concerning their habits is much too scanty. The insects belong in great part to the following orders, which I have arranged according to their importance as enemies of trees. The moths are placed first with some question, since the beetles are often locally the more destructive, and are especially injurious to cone-bearing trees, upon which the moths do relatively little mischief.

Moths and Butterflies (Order Lepidoptera). This group includes all the caterpillars, such as the canker-worms, walnut-worms and the like, with well-developed heads and legs. Their bodies are often hairy. They live exposed on the leaves or construct webs, while some of the small species mine the leaves or twigs. A few bore the trunks. The adult moths are not in any way injurious.

Beetles (Order Coleoptera). The insects of this order injure trees both in their immature and mature stages. The adults are hard bodied insects, well known under such names as June-bug and potato-bug, while their young are known as grubs, those attacking trees having well-developed heads, but often no legs. Their bodies are generally thick and stout, and are more or less U-shaped in many cases. They attack roots, trunk and leaves.

True Bugs (Order Hemiptera). A large number of this group of insects attack the foliage and tender growths of twigs, and a few such species as the 17-year locust (cicada) suck the sap from the roots of trees. All such insects are provided with a piercing proboscis, and feed at all stages of their growth upon the sap of plants. The order includes, besides the 17-year locust, such species as the plant-lice (aphides), the bark lice, the various tree and leaf hoppers, and the plant-bugs (Capsidæ), the latter sometimes very destructive to young fruit trees.

Sawflies and Bees (Order Hymenoptera). In the grub state, some of these insects gnaw away the leaves of trees and other plants, while other small species gall the twigs and leaves. The sawflies, including the elm saw-fly, the currant-worm, and the like, are our most destructive species. The adults do little mischief of any sort, and many species are beneficial by helping to fertilize flowers of useful plants.

Flies (Order Diptera). In their adult state these are two-winged insects, such as the house fly, mosquito and buffalo-gnat. When not mature they are known as grubs, maggots and wrigglers. Though sometimes very annoying to man and the domestic animals, the winged adults do no harm to vegetation. The grubs of a few small flies and gnats live in galls or mines in the leaves and twigs of trees, while a few others mine seed-pods, and other kinds of fruit. The grubs may be known from all other kinds which infest trees by the absence of legs and of a head.

Katydids and Grasshoppers (Order Orthoptera). We have a number of katydids (though all do not have the well known note that has given rise to the name) and tree-crickets in Kentucky that spend most of their time among the foliage of trees. They are, however, usually so scattered that but little apparent harm results from their presence. Some of them, such as the true katydid, are strictly tree-dwellers. The members of this order have no grub state, but have the adult shape when hatched, and change subsequently only in size, and by acquiring wings.

TREES LEAST INJURED BY INSECTS.

It is evident to every one accustomed to notice trees closely that the species differ considerably in their susceptibility to insect attacks. Some, like the black locust, the walnut, the apple and the soft maple, are generally infested with a larger or smaller number of injurious insects, without regard to locality, while others, such as the buckeyes and hard maple, are relatively but little injured. And while it is true that as a general thing insects attack by preference such vegetation as is most nutritious and edible, and consequently likely to prove useful to us, this fact is mainly of importance in considering plants which bear flowers or fruits of value, and has not the same importance in considering shade trees. A tree may present a fine appearance, and yet its leaves and fruit be noxious. It does not follow though because a tree is not injured that it is in any way noxious to man. Some of our very finest native trees would come under condemnation if this were true. I have never heard of anything hurtful in the leaves of the tulip-tree, sweet gum, or sugar maple, all good trees for planting.

The central fact to be noted in this connection is, that certain of our trees are less subject to insect injury than others, and that it is possible by selecting judiciously to have, much of the time, trees with clean, whole leaves without resorting to the use of insecticides and fungicides.

TREES MOST SUBJECT TO INSECT INJURY.

As to trees most subject to injury, we may mention for this locality the poplars, box-elder and black locust, all of which are very badly denuded of their leaves at times by caterpillars. The box-elder, while a rapid grower, is not as valuable for shade as are many other trees, and can perhaps be spared. Some of the poplars are very handsome, especially when young, and something should be done to protect them. The black locust, with its fragrant blossoms, is so pleasantly associated with spring that it seems ungracious to say any thing against it; yet the plain truth is, that it is not remarkable either for beauty or shade, and its leaves are attacked by a small army of insects that give it a draggled and unpleasant appearance in the latter part of summer. Its trunk, too, is mined by several destructive borers. If ash, elm or hard maple had been planted in place of most of the black locusts in the State, the appearance of our country homes and roads would be greatly improved.

METHODS OF TREATING SHADE TREES.

For all insects that gnaw the leaves it is possible to apply mixtures which will serve to defend trees very effectively from injury. The chief difficulty comes from the labor required and the cost of apparatus. If trees threatened with injury from tent-caterpillars, fall web-worms, walnut-worms, elm leaf-beetles, or any one of the score of leaf-eating pests known to us, are thoroughly sprayed with water containing Paris green or London purple, their leaves are rendered proof against any very serious injury, and when it is possible to employ a suitable spraying pump this treatment is to be strongly recommended for all such enemies of trees. With young trees there need be no difficulty. These can be easily sprayed from the ground, or by mounting a barrel or tank, with force pump attached, on a wagon or cart.

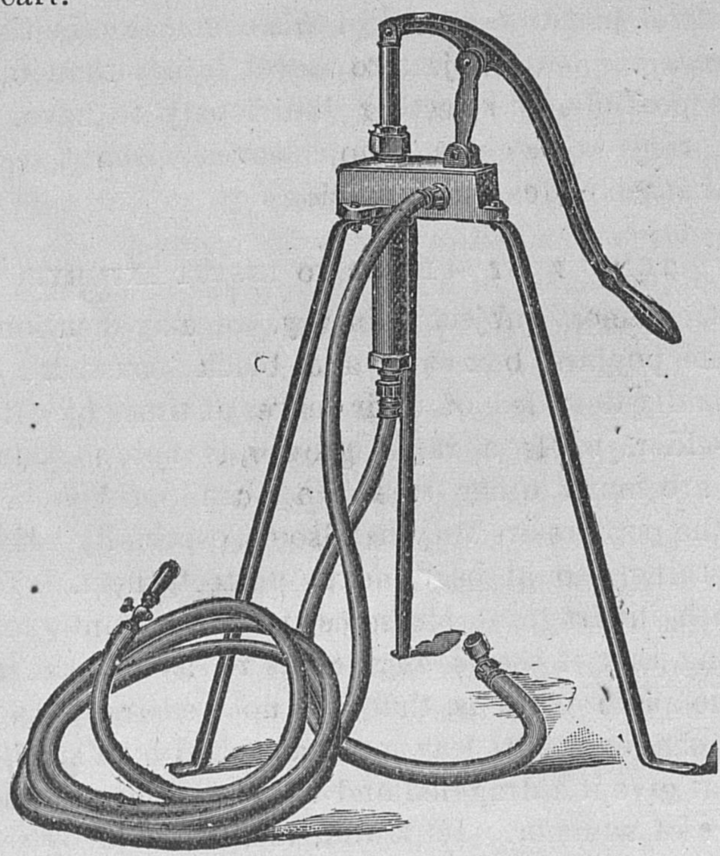


Fig. 4. The improved Nixon Climax pump, for spraying.

The outfit for spraying orchards commonly used, answers very well also for this purpose. When large trees are to be sprayed, strong pumps must be used, together with a sufficient length of hose, and some means of elevating the distributing nozzle. It is a common practice to employ long poles for this latter purpose, simply attaching the nozzle to one end by wrapping it with twine. A large bamboo rod with the septa burned out to permit the hose to be passed up through it, has been recommended for this same purpose, and has advantages of lightness and convenience in its favor. For exceptionally tall trees it is necessary to employ besides, a ladder, and occasionally it may be necessary to throw a solid stream of the fluids used, trusting to the friction against the atmosphere to break it into a spray. Some of the nozzles sold for this work are so constructed that the cap concerned in producing the spray can be removed, thus permitting a single stream to issue, which is thrown to a greater distance. The spray itself may be thrown horizontally by means of some of these pumps and nozzles a distance of 25 feet. Thrown vertically, or nearly so, it would not go so far, hence the occasional necessity of the other method for reaching the leaves.

The quantity of poison to be used varies with the kind of trees to be sprayed. For apple trees, it is customary to use one pound of either London purple or Paris green in from 160 to 200 gallons of water. We have used the former proportion (one pound to 160 gallons) at the Experiment Station, with little or no injury to the leaves. To avoid the danger of damaging the leaves, it is well to experiment on a branch, or, at most, a single tree, before doing more extensive spraying, remembering, however, that the poisons may not show their destructive effects on either leaves or insects until several days have elapsed. These poisons lose none of their effectiveness as insecticides when mixed with wheat flour, and the addition of the flour renders the mixture more adhesive and less injurious to the leaves, hence, it is well to use the two in combination where possible. For spraying the leaves of elm trees Dr. C. V. Riley recommends, after some experience in spraying these trees about the city of Washington, London purple, one-half pound, flour three quarts, water forty gallons. He considers one-half to three-quarters of a pound of the poison in forty gallons (one barrel) of water about the maximum strength to be used with safety.

Insects which puncture the leaves of trees can not be destroyed with mixtures of London purple or Paris green. It is true that these poisons, when applied to the bodies of some insects, have a destructive effect; but used in quantities sufficient for this purpose, they are liable to injure foliage. For bark-lice, plant-lice and leaf hoppers, all of which puncture and suck the sap of plants instead of gnawing away and eating the substance, it is, therefore, necessary to use other preparations. These must kill when brought in contact with the body of an

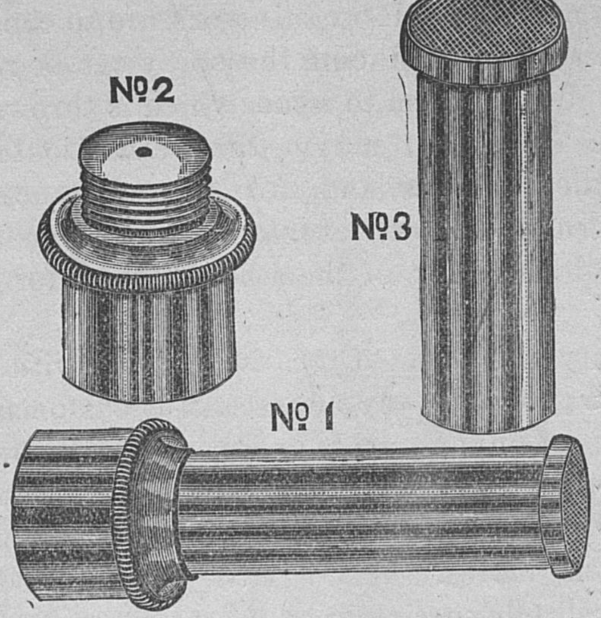


Fig. 5. A good form of nozzle. No. 1, the complete nozzle. No. 2, the nipple, unscrewed so as to show small opening for escape of fluid. No. 3, the cap with wire screen at end for breaking fluid into a spray.

insect, and, moreover, must do this without injuring the leaves. Among substances employed for this purpose coal oil (kerosene), Persian insect powder (pyrethrum), buhach, and white hellebore, are well known for their effectiveness. A "resin compound," more recently recognized as useful, is now used successfully for scale insects on orange trees, in the West, and is highly recommended by some of our best authorities on the treatment of such pests. The methods of preparing and using such insecticides have been so frequently considered in Station reports that it is not necessary to go into detail here. Those especially interested in these matters will find a condensed account of the insecticides and fungicides in common use, in Circular No. 3, of this Experiment Station. As a matter of convenience I will, however, give the formulæ for making the two preparations best calculated, by virtue of their cheapness and effectiveness, for use on trees.

Kerosene, or coal oil, is now everywhere applied to plants as an emulsion, which may be prepared as follows: Dissolve one-half pound of cheap soap in a gallon of hot water, then while still hot add to this two gallons of kerosene, and finally pass the whole through a pump, returning it with force to the vessel whence it is being pumped up. In a few minutes it will assume the appearance of cream, and if the churning has been thoroughly done it will retain this consistency and appearance. It is in fact an emulsion, and in this condition the oil may be mixed with water in any proportion. Herein consists its advantage over pure coal oil. It may be so diluted that it will do no injury to leaves, but still retains all its properties as an insecticide.

Mr. Koebele, who has perhaps had as much experience with the resin compound as any one, recommended a few years ago the following formula for its preparation:

Sal-soda, 3 lbs.
Resin, 4 lbs.
Water, 3 pints.

Dissolve the soda and resin in the water by heating. While boiling, add water slowly until the whole makes 36 pints. To use, add 8 parts of water to one part of the above. Stronger mixtures have been used, but may do injury when not carefully applied. Three pints of the compound to 4 of water is about the maximum to be used with safety.

Mr. Coquillett, an agent of the Division of Entomology at Washington, has also worked with this compound, and gives the following as the result of his experiments with one of the scale insects of fruit trees in California:

Caustic soda (70 per cent.), 9 pounds.
Resin, 30 pounds.
Fish oil, 4½ pounds.
Water enough to make one hundred gallons.

He advises the use of a kettle holding 30 gallons for making the compound. All the materials are placed in this, and after covering them to a depth of four or five inches with water, they are dissolved, and then boiled for two hours, or "until it will dilute evenly with water, like black coffee." At this stage the kettle is slowly filled with water, and when full may be emptied into a tank or barrel, where the remainder of the water can be added. Any sudden chilling of the preparation by the addition of large quantities of water is, he says, to be avoided. It would seem from Mr. Coquillett's work that the compound destroys the insects by forming a sort of varnish on their bodies, thus choking up their breathing pores and smothering them. The soda is useful, consequently, only by virtue of its action in the resin and oil, and no more should be employed of this ingredient than is necessary, because of injuries to foliage when the proportion used is large.

On our west coast the use of gas for destroying scale and other insects on fruit trees is considered by those who have worked with it the most efficacious treatment, and is now superceding the use of washes. When it is remembered that many of these scale insects are protected by a shell, not unlike a minute turtle's shell, all the limbs and other parts being small and concealed, and that the edges of this are commonly kept closely applied to the leaves or twigs, it will be understood that it is no easy matter to apply fluids by spraying so as to reach vulnerable parts of these insects. It is true, none the less, that the resin compounds and preparations of kerosene are very useful for this purpose, especially where the number of trees to be treated is small, and applications can thus be made repeatedly and thoroughly.

Gas, however, penetrating as it does every crevice about the trees, is calculated to destroy all insects it reaches, and experiment shows that it will destroy their eggs as well. In applying the gas it is, of course, essential that the trees be inclosed. For this purpose Mr. Coquillett recommends large octagonal sheets, made in great part of eight-ounce duck, the two middle breadths upon which the strain comes in handling being made of ten-ounce duck. These may be rendered gas-tight by painting with linseed oil, or a thin paint made of yellow ochre, and are placed over small trees by means of poles, or over large ones by means of a special derrick mounted on a wagon.

The hydrocyanic acid gas, now generally employed, is generated in an open earthen vessel, placed under the inclosing tent or sheet. The ingredients employed are: Undiluted commercial sulphuric acid, 1 fluid ounce; undissolved fused potassium cyanide, 1 ounce by weight; cold water, 3 fluid ounces. The water is poured into the vessel, then the acid follows, after which the vessel is placed on the ground in the tent, and the potassium cyanide is added, and the openings at the ground are closed. The materials for generating the gas must vary in quantity with the size of the tree and the thickness of its foliage. The time necessary to destroy insects ranges from fifteen to forty minutes. Mr. Coquillett thinks the best time to apply gas is at night, or during cool and cloudy days, when the life processes of the trees are least active.

It is not likely that this method of treating trees will soon be employed for large shade trees; for small ones, for nursery stock, and for some fruit trees, it is admirably adapted, and I have called attention to it here, because it will doubtless be found in special cases to be the most convenient means of checking injury. Those who may be especially interested in the process will find an excellent condensed account of it in Vol. VI, No. 2, p. 176 (1893) *Insect Life*, printed by the Department of Agriculture at Washington.

Many other ways of treating trees for injurious insects have been advocated, some good, others of no value whatever. Among the latter may be mentioned the plan of boring holes in the trunks of trees and filling them with sulphur. Tarred bands are sometimes employed to prevent the ascent or descent of injurious insects along the trunks. Whether the bands prove of value or not depends of course upon whether the insect has other means of getting to the leaves than by creeping up the trunk. They can be of little use in checking the injuries of such pests as fly to the leaves, though they have sometimes been recommended and used for such species. For the cankerworm, and some others which habitually creep up the trunk, the tarred bands can, in some cases, be used profitably, but even for these spraying, if practicable, is the better treatment. When bands are used, the tar must be kept from the trunks by strips of tin; otherwise, it may injure the trees. Bands of straw, old carpet, or other material, are sometimes used also as traps for insects, which leave trees for pupation among rubbish on the ground. Such larvæ often collect under these bands in large numbers, even those which let themselves down from the branches by means of their silken threads, returning in considerable numbers to the trunk to undergo their changes. This habit, it has been claimed, explains the fact that when several bands are used at different heights on the same tree, the lower generally harbors the most insects.

Some insects, as, for example, the elm leaf-beetle of the Eastern States, will not stop under bands, their habit being to undergo their changes under rubbish, or in the ground. A box with a cement bottom, inclosing the base of the tree, and a wide strip of tin covered with tar or other adhesive substance tacked to its upper edges, effectually confines such pests, and renders their destruction easy. The box is, I believe, a device first employed by the entomologist, Townend Glover.

In the special matter following, I have included only the notable insects which injure shade trees in Kentucky. Those mentioned do the greater part of the mischief from which our trees suffer during ordinary seasons. A large list could be given of other species which frequent shade trees for one purpose or another, some injurious in their tendency, some bene-

THE FALL WEB-WORM

(*Hyphantria cunea*).

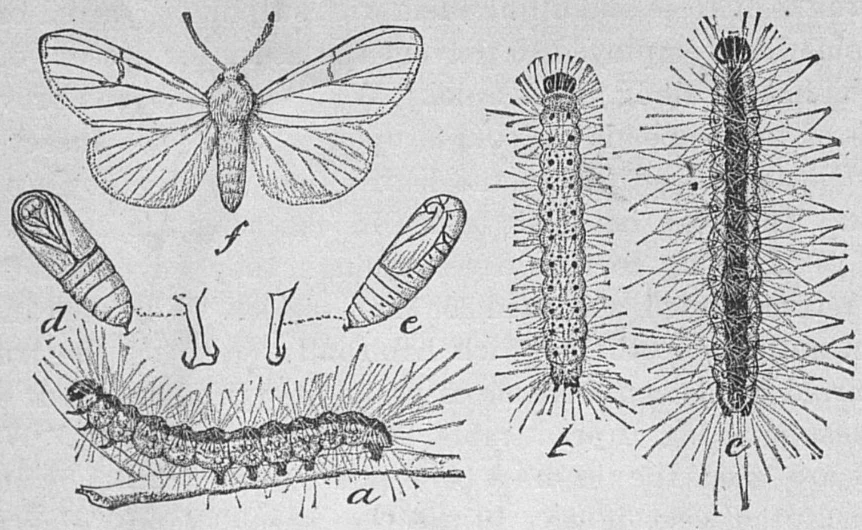


Fig. 6. Fall web-worm. *a*, side view; *b* and *c*, light and dark colored larvæ seen from above; *d* and *e*, different views of pupa; *f*, moth. (From the Division of Entomology at Washington).

ficial, some as far as we know neither one nor the other. It could only encumber a paper of the character of the present one to include these insects, which may, therefore, be left until they show themselves entitled to attention.

This insect is known everywhere by the webs made by the worms. These are placed in the smaller forks of branches or include the terminal twigs and leaves. They are especially common towards fall.

The web is a rather loose affair including many leaves and twigs eventually, in which the worms remain at all times, simply extending it and including fresh leaves when the supply already inclosed has been exhausted. In this habit of remaining in the web they differ from the tent-caterpillar of apple trees, with which they are sometimes confounded. The greater part of the mischief done to trees occurs in the latter part of summer and is the work of the second brood. An early brood which appears to be especially fond of osage-orange makes its appearance as soon as the leaves unfold. Examples kept by me in a box indoors, went into the ground to pass the winter during the latter part of September and first half of October, the last to change to a pupa being observed preparing for the change October 19. These examples began to appear as adult moths February 18, 1892, and continued to come out at intervals until April 2.

The species does not hibernate in all cases in the pupa state, some examples of the moth coming up from the ground in the fall and hibernating in this condition. During the season of 1893 examples which were noted as changing rapidly to pupæ on August 2, yielded two adults, one on the 13th and the other on the 16th of September, the remainder of the colony continuing in the pupa state.

The eggs of the brood are placed on the leaves as soon as the latter develop, and during June the webs may be found, though they seem never to become so common at this season as they do later.

The worms may be found in such webs until the first of July, when most of them leave to undergo the next change in the ground. Examples kept by me began to change on July 8, and the moths began to come out of the earth July 15. On the 28th of July the female moths were observed placing their eggs on leaves of elms for the second brood.

During the year 1890 this pest was especially abundant and injurious in Kentucky, as the following quotation from notes made by me on September 4, will show:

Very abundant on a variety of trees, including osage-orange, elm, maple, honey-locust, and black locust, and has done a good deal of damage during the dry spell just passed. Some of the smaller trees are completely stripped of leaves, not the slightest trace of green being visible. Most of the worms are fully grown and are leaving the trees for the ground, or for other vegetation, in the latter case taking to weeds and almost anything green. Near Providence to-day they were found to be badly affected with *Empusa grylli* (a parasitic fungus), probably 50 per cent. being attacked. These diseased worms collect on the terminal twigs of poke root, rag-weed, and on the ends and knots of rails, where they die, become swollen, rigid, and finally show the characteristic powdery coating indicating the presence of mature spores of the parasite on their skins. The disease will materially lessen the numbers of this insect for next year.

REMEDIAL TREATMENT.

The above prediction proved right, and the insect, thanks to the parasite, has not since been so common; yet it is still with us, and may at any time become abundant, hence the need of watchfulness. When the webs are within reach it is possible to destroy them and their occupants by simply applying burning paper. This does some little damage to the twigs, but the tree suffers less than it would from the worms, and further spread of the insects may be thus checked. When a pump is at hand the worms may be destroyed by spraying the infested branches with London purple mixed with wheat flour and water. The poison of this mixture remains for some time on the leaves, so that the destruction of the worms is only a matter of time.

THE BAG-WORM

(*Thyridopteryx ephemeræformis*).

This worm is the young (larva) of a moth. It lives in and carries about with it a case made of silk, on the outside of which it fastens bits of leaves, probably to render its detection less easy to birds and other enemies. One may see these cases all through the winter adhering to the naked twigs of both deciduous and evergreen trees, the worms having taken the precaution to fasten them there by wrapping the twigs with silk.

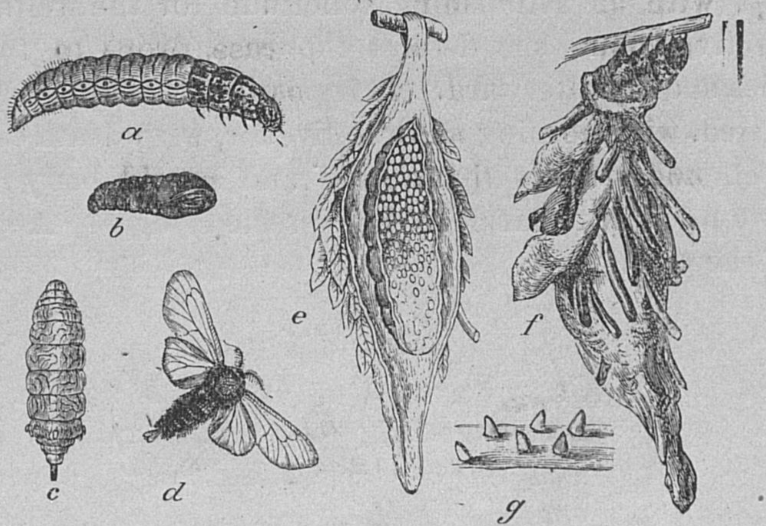


Fig. 7. The bag-worm. *a*, larva; *b*, pupa; *c*, adult female; *d*, adult male; *e*, bag containing eggs; *f*, bag containing larva; *g*, young larvæ, with conical cases. (From Riley.)

The case of a grown worm measures 1.75 inch in length and its greatest diameter is somewhat more than .50 inch. If cases are examined during the winter, a large number will be found empty, these being old ones which adhere to the twigs longer than one season, or else are those which produced males. In every one which produced a female the preceding summer will be found an oblong brown cylindrical object, tapering a little at one extremity, but blunt and with a ragged opening at the opposite end, through which the adult insect escaped; for these are the deserted pupal skins of the female. Each appears at first to be full of a powdery material, but on removing some of this the minute soft whitish eggs will be observed, packed closely so as to fill the greater part of the skin.

The adult female of the bag-worm is a very singular creature, looking more like a worm than a moth, incapable of flight, having no rudiments of wings, and with only minute and functionless legs. The very scales of the greater part of her body are abortive, and are rubbed off to constitute the powdery material in which the eggs are packed. Being incapable of flight, the most she can do as to wriggle down to the opening at the lower end of her case where she meets the winged male, and then in the same manner wriggles back to her empty pupa case in which she carefully places her eggs for safe-keeping during the winter. Finally, with an astonishing solicitude for the welfare of her prospective young, she deserts the case, drops to the ground and dies shortly afterward. Is it possible that this pulpy mass, exhausted, with nothing more to live for, with death certain and at hand, understands that a dead and putrid body left in the case would work harm to her precious eggs? Anyway she leaves the case.

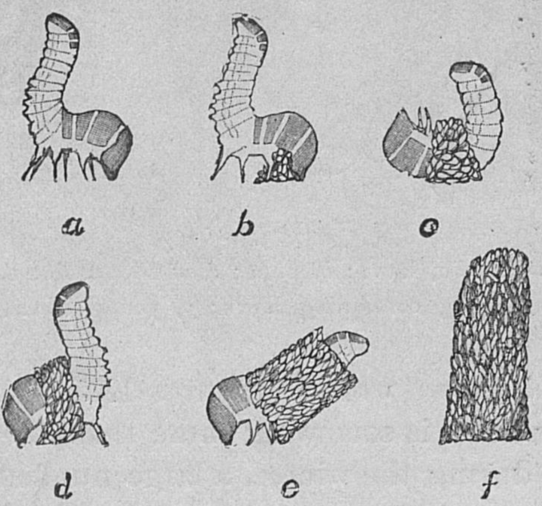


Fig. 8. The Bag-worm. Showing the recently hatched worm engaged in constructing its case. (From Division of Entomology at Washington).

The adult male of the bag-worm is a very ordinary but rather fussy little moth, with black body and four clear wings, with some black at the front and hind margins. When the wings are drawn out at the side they measure just about an inch from tip to tip of the front pair. The wings of the hind pair are much smaller. Its empty case may be known by the fact that it leaves the empty pupal skin partly protruding from the opening at the lower end.

LIFE-HISTORY FOR KENTUCKY.

The young bag-worms hatch from the eggs early in May, and before the end of June may become noticeable upon trees. They are especially fond of red cedar, and to a less extent of arbor vitæ, and may be found on such trees any season. When very abundant, they often denude these trees badly, and will then appear upon deciduous trees in the neighborhood, ultimately, when very abundant, as they were during the summer of 1893, occurring on most of our shade trees. No doubt they

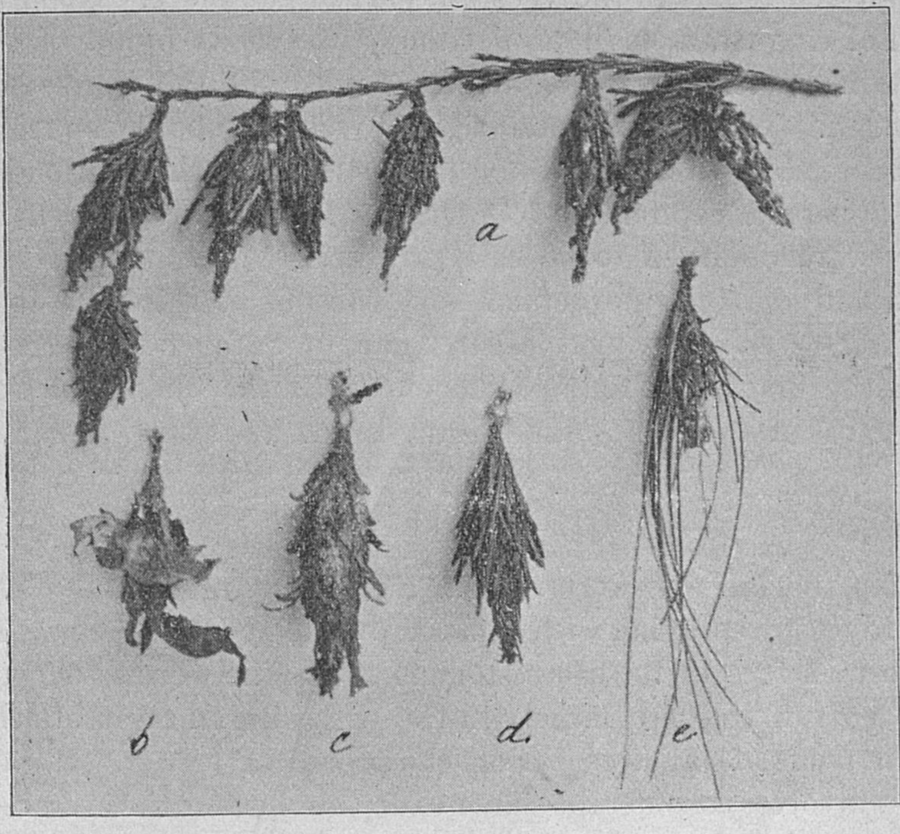


Fig. 9. The bag-worm. *a*, cases fastened to twig of red cedar, as seen when the worms have changed to pupæ; *b*, *c*, *d*, *e*, bags taken from different trees. *b*, from maple; *c*, from arbor vitæ; *d*, from spruce; *e*, from white pine. (From a photograph.)

are carried from tree to tree by winds, as they may often be seen suspended from the branches by their silken threads. But dispersal by this means is uncertain and slow; and from the fact that the worms could be found on isolated deciduous trees last summer, I incline to think they sometimes drop to the ground and creep from one tree to another. Burdened as they are with their cases, they are not very active in migrating, and during ordinary seasons remain pretty closely confined to evergreens. During the past summer, they were found to be common at Lexington on soft maple, elm, poplar, sycamore, black locust, red cedar, white pine, willow and linden. They occurred throughout the State in injurious numbers. Mr. E. A. Trout, of Trimble county, wrote July 26, that they were stripping black locust trees of their leaves in his neighborhood, while in August Mr. Denny P. Smith, of Cadiz, wrote that they were killing red cedars in the Western part of the State. About the 20th of August, a small proportion of the sacks found on trees contain pupæ, and by September 5 most of the worms have changed. The winged male begins to emerge about the middle of September, the first of those kept by us at the Station having appeared September 16. On the 25th of last September, they were observed to be emerging everywhere in large numbers, and the fully developed females were at this time found in their cases. During the early part of October the eggs are laid, the first being found October 8. By the middle of October, most of the adults have disappeared.

REMEDIAL TREATMENT.

Like the fall web-worm, this is a gnawing insect, and may be destroyed by spraying with London purple or Paris green. The important fact in its life-history is this: The worms which injure a given tree are largely in the egg state in cases attached to the twigs of this tree during the preceding winter. It sometimes involves considerable labor to do this, but for the evergreens (chiefly red cedar and arbor vitæ) from which this pest spreads it is not very difficult to remove and burn the cases. For other trees also this will generally prove the cheapest and most effective remedy, and it may be undertaken with the satisfaction of knowing that once the sacks are removed there is no immediate danger of the trees becoming infested to an injurious extent. Several small four-winged parasites attack the worms, but these emerge in the fall, as far as I have had an opportunity to observe, and hence there need be no hesitation in burning the cases during the winter.

THE CATALPA SPHINX

(*Sphinx catalpæ*).

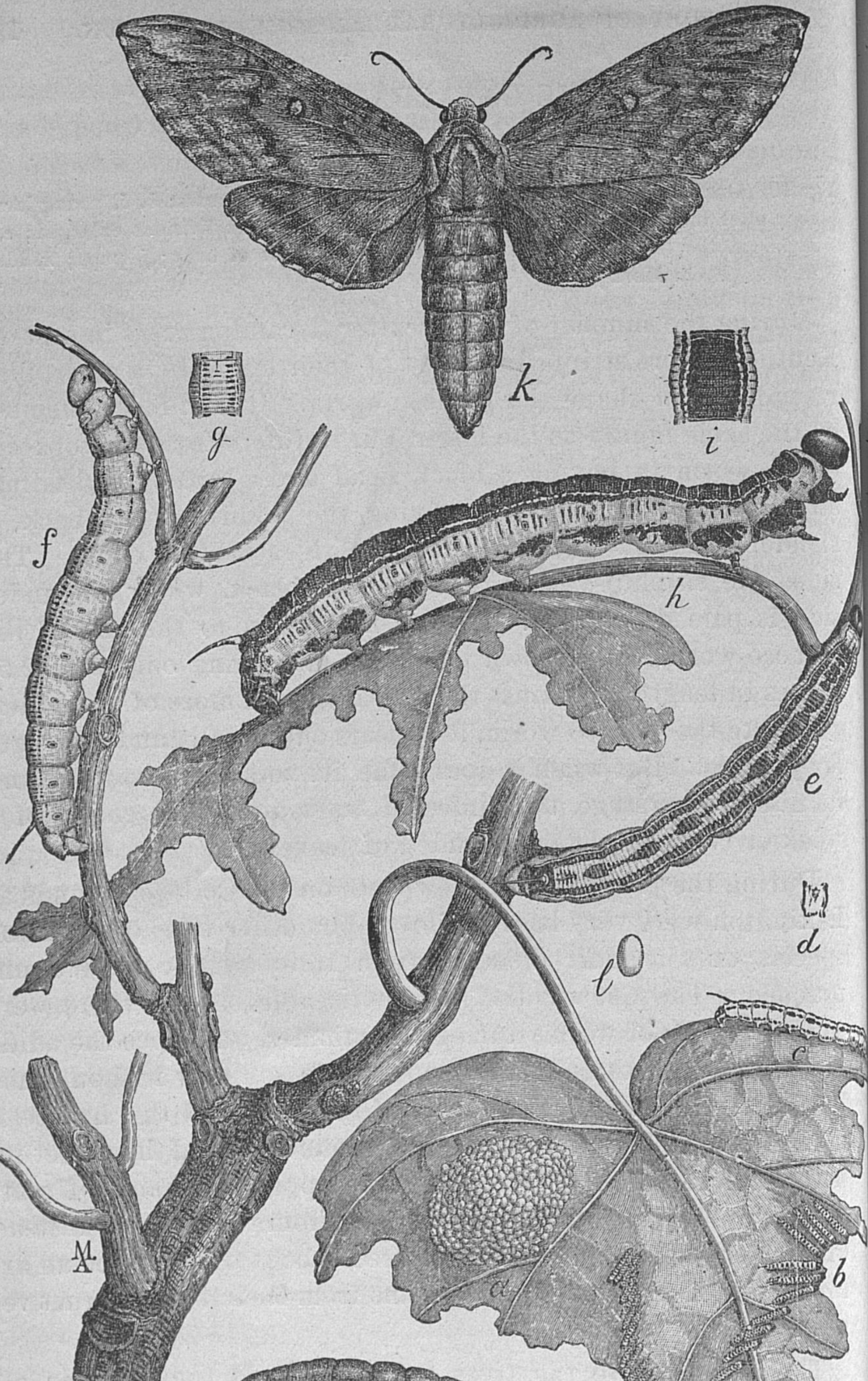
Fig. 10. (On following page.) The catalpa sphinx. *a*, egg mass; *b*, *b*, young larvæ soon after hatching; *c*, young larva; *d*, view of one of its divisions enlarged; *e*, *f*, *h*, larvæ, the last fully grown; *g*, *i*, views of divisions of body; *j*, pupa; *k*, adult moth. (From Marx.)

During the summer of 1893 scattered catalpa trees in eastern Kentucky were stripped of most of their leaves by a caterpillar resembling in shape the tobacco-worm. It is in fact a member of the same family as the latter, but it differs from the tobacco-eating worm in having a black head and a broad longitudinal stripe of velvety black occupying the middle of its back, a slender white line running parallel with each of its edges. The sides are sulphur-yellow, dotted with black, while the under side is pale dull green. It does not attain to the size of the tobacco-worm, fully grown examples measuring only 2.25–2.50 inches in length as against the 4.00 inches or more of the other.

Unlike the tobacco-worm, it appears only locally and at irregular periods. But when it does come, its voracity is so great and its numbers so large, that infested trees are in the course of a week or two completely denuded of leaves.

During the past summer a few trees on the College grounds at Lexington were very badly injured, but other trees of the same species only a short distance from those attacked were untouched. The fact was the more noticeable because there were several broods of worms during the summer, and since the adult moth flies, well there was no apparent reason why it should not have distributed its eggs on more of the trees. If this had been done, however, every tree on the grounds would have lost its leaves before fall, and hence we may suppose the habit of scattering over a wide area after emerging from the ground, instead of placing their eggs at once on trees about them, to be an arrangement for protecting the worms from their own destructiveness.

The worms leave the trees as suddenly as they appear, all going into the ground for pupation about the same time. The pupa closely resembles the brown objects with structure at one side like the handle of a pitcher which we find in gardens in


k
g
i
f
h
e
d
l
c
a
b
b
j
MA

spring. This latter is the pupa of the tobacco or tomato-worm. The pupa of the catalpa sphinx has the same general shape, but lacks the tongue-case. It varies in length from 1.28 to 1.56 inch. The color is bright fulvus (yellowish brown), with an obscure dark stripe along the middle of the back. The body tapers somewhat towards the extremities, terminating behind in a short spine, and in front being bluntly rounded. The surface is rather smooth and shining below, but above is minutely roughened, especially so on the head and thorax where it becomes opaque. On each side of the abdomen are three rather large slits on as many body divisions, and on each side near the front end is another similar opening. They resemble large breathing pores, but cannot have to do with respiration because true pores (spiracles) occur on the segments of the body bearing the clefts.

The adult is one of the hawk-moths, such as are seen about flowers of summer evenings. The catalpa moth is more retiring than others of its family, and has never been captured as far as I know about flower-beds. I have not myself secured any examples except those carried through their changes in boxes. They are dull brownish gray in color, with obscure lines and spots of black. The more noticeable marks on the wings are: A spot on the front margin of the fore wing about a third the distance from the base to the apex; from it a line extends obliquely across the wing, and parallel and within the latter is another narrow line. The disk of the wing is uniformly brown, excepting for a whitish dot encircled with black. The outer third of the fore wing has a number of zig zag black lines extending across it, and a distinct black dash running from the apex obliquely inward. The hind wings show only two very obscure cross bands; the fringes are black, broken at intervals with white. The sides of the head and thorax are dark brownish black; above this the color is light gray, then come the black lines of the thorax, separating the light gray from the brownish gray of the middle part of the thorax. The abdomen presents three distinct longitudinal lines of black, one median, the others at each side, and consisting of a series of contiguous spots. Still farther down on each side is another very faint line likely to be overlooked. On the middle of the abdomen beneath are several small black dots. Large examples have a wing expanse of about 3 inches. The body measures about 1.25 inch in length.

LIFE-HISTORY.

The history of the worm for this region is as follows: The worms appear suddenly about the middle of June, hatching from eggs laid in a cluster on a leaf. On the 28th of June, in 1893, those observed were nearly ready to leave the trees, and all had done so and had changed to pupæ in the ground before July 10. The adults of this brood began to appear above ground July 17, and all were out before July 22, at which date one of the females in a box at the Station began to lay eggs for a second brood. On August 18, 1893, nearly grown worms of the second brood were obtained from trees at Lexington, and by August 21 these had gone into the ground for pupation. Four adult moths were obtained from these on September 13, 1893.

Now, either these moths hibernate and thus carry the species through the winter, or else they lay eggs for a third brood which passes the winter in the ground as pupæ. The latter method of hibernating seems the most probable in view of what we know of related worms, but my observations will not permit me to decide upon this point.

REMEDIAL TREATMENT.

Practically the question as to how these insects pass the winter is not of as much importance as in the case of some other injurious species. Spraying the leaves of infested trees with some of the well-known poisons mentioned above can be counted on as a safe remedy.

I found last summer that it was possible in the case of most catalpa trees to dislodge the nearly grown worms by jarring. By suddenly shaking a limb they could be make to drop like ripened fruit, and could then be quickly destroyed. In a few moments, on one occasion, I removed in this way every worm from a tree, to the number of not less than a hundred and fifty.

A CATALPA SPHINX PARASITE.

The worms are parasitized by a fly which places its eggs on their skins, giving rise to grubs which bore into and live upon their tissues. The adult flies emerge after the catalpa sphinx has pupated in the ground. The fly measures .31–.37 inch in length ; is gray, with black markings, of which the more conspicuous are four narrow longitudinal lines on the thorax, and cross bands occupying the hind portion of the divisions of the abdomen. The face is silvery, the eyes reddish brown, the legs black, excepting the outside of the front thighs, which are whitish. The whole body is protected by numerous strong black hairs, these being especially well developed on the head above and at the tip of the abdomen, where they form a sort of brush. It does not seem to be common enough to help greatly in keeping the worms from mischief, but, like other parasites, may serve a useful purpose when its hosts become extraordinarily abundant. From more than a hundred worms kept at the Station during the summer of 1893, only four examples of the parasitic fly were obtained. Two of these emerged July 17, another on July 18, and the other July 20.

THE WALNUT CATERPILLAR

(*Datana integerrima*).

Walnut trees, while not making the best of shade, are frequently spared when growing about sites selected for dwellings. Their value in this situation is greatly diminished here in Kentucky by the attacks of a caterpillar on the leaves. It is no uncommon thing to see large trees 50-60 feet in height almost completely deprived of foliage in the latter part of summer by these caterpillars. In addition to destroying the leaves, they make themselves very annoying by throwing down refuse, and by overrunning walks and buildings in the neighborhood when they descend from the trees to go into the ground.

The caterpillars, when grown, are black, without evident markings, and are loosely clothed with soft whitish hairs. When they come down from the trees, they measure about two inches in length. The young caterpillars are pale in color, and are distinctly striped with whitish. When they leave the trees, they have the singular habit of collecting on the trunks near the base in large masses of a hundred or more individuals. At Lexington, such masses have been observed as early as July 19, these probably representing an early brood; but the injury is at its worst during August, and the greater number of larvæ come from the trees during the last half of August and the first half of September. I have no record of adult moths observed between July 19 and September 1, but am disposed to think think there are two broods every summer.

The pupa is formed in the ground under the trees, and that of the late brood remains here over winter, the moth emerging during the first half of June of the following spring.

The moth is reddish brown in color, with a patch of deeper brown on the thorax. The front wings, which have an expanse of from 1.80 to 2.30 inches, are crossed with five dark lines, the first being nearest the base, the second at about the middle of the wing, and the remaining three being close together on the outer half. The fourth line is fainter than the others, and is very close to the fifth. The region between the first and second is darker than other parts of the surface, and bears a black dot near the front edge of the wing. The moth is much like that of the red-necked apple tree-caterpillar, but its wings are less uniform in color, and the cross lines are accompanied with rather wide but obscurely outlined pale bands.

Besides walnut, the species is said to attack willow, honey-locust, thorn and apple. For several years I have had a walnut tree in my yard, and among the many caterpillars and moths observed about it, I have never seen an example of the apple-infesting species. Nor have I seen the present species on any other trees besides walnut and hickory.

REMEDIAL TREATMENT.

The remedies to be recommended for injury by this caterpillar are spraying the leaves with poisonous mixtures, and trapping the worms as they descend from the tree. The great height of walnut trees makes thorough spraying rather difficult unless one is well equipped for such work. The greater number of worms descend along the trunks of the trees during the night, and should be destroyed whenever found collecting on the trunks. To prevent the escape of those which do not collect in this way I would advise the construction of a wooden frame about the infested trees, similar to that which has been used in the East for the elm leaf-beetle.

A square frame could be fitted closely about the trunk near the base, and the corners covered or filled to keep the caterpillars from going down this way. Then by tacking about its upper edges or along its outside a trough of tin to be filled with coal oil, their descent might be effectually prevented. Some of the worms drop to the ground from the leaves, hence the desirability of spraying the leaves when this is practicable.

LOCUST LEAF-MINERS

(*Lithocolletis robiniella, etc*).

Locust trees in Kentucky seem to be peculiarly subject to the attacks of several leaf-miners, the adults of which are small moths belonging to the same family as the common clothes moth. One or another species is to be found mining the leaves throughout the summer, from June to September, and often several may be found working together on the same tree. The moths themselves are rarely seen, because of their minute size. They place their lenticular eggs, usually one on a leaflet, and then disappear; but the flattened grubs hatching from these eggs bore into the leaf, eating away its substance and detaching at the same time the epidermis, thus producing blotches which at once attract attention. Towards fall one may see trees with most of the leaves rendered by these miners so brown that they give to the trees the appearance of having been killed. Examination of the leaves of locust trees at intervals during the summer will show the presence of four distinct species, three moths and one beetle, which may be recognized by the character of the mine. The grubs are so small as to be difficult of examination, except with a magnifier.

1. One of the most abundant of the moths places its eggs on the leaves early in June, and its young make a large mine occupying much of the leaflets immediately above the midrib. These mines usually have extensions or lobes from the sides, so that their outline becomes finally very irregular. Several broods appear each season. The technical name of this miner is *Gracillaria robiniella*.

2. The second species, also a moth (*Lithocolletis robiniella*), proves common in the latter part of summer, my first record of its appearance being August 5. The majority of the mines of this species are on the under side of leaflets, and are of a pure white color. They may be at the margin of the leaflet or elsewhere, and the ouline is generally not irregular. The grubs make for themselves small lenticular silken cocoons in the mines when ready to change, the moths emerging from them during the latter part of August, possibly to place eggs for another brood.

3. The remaining moth (*Lithocolletis ostensackenella*) produces a yellow blotch-mine placed anywhere on the upper side of the leaflets, and at first narrow and tortuous, but finally enlarging suddenly, and becoming more or less circular in outline. The mines begin to appear early in June (observed by me first, June 11), are empty by the first of August, the moths having matured, and a second lot begins to become noticeable about August 24.

4. The fourth and last miner is, when adult, a small beetle (*Odontota scutellaris*), with somewhat flattened body, measuring nearly .25 inch in length. It is black, with the exception of the thorax, and the sides of the wing-covers, these being tawny yellow. It is very injurious to black locust, and appears to attack apple leaves at times also. Mr. John W. Buck, of Midway, wrote me some time ago, enclosing specimens of the beetle, and stating that it was ruining the leaves of his apple trees. The adults become common on the leaves of locust trees about May 22, and the peculiar egg masses can be found by June 1. The masses consist of five or six discoid eggs, placed one behind another, with their flattened surfaces in contact. The young grubs, which are not very different from those of the moths, cut through the side of the eggs next the leaf, and bore down into the substance of the latter, all of those from an egg-mass living for a time in a single mine, but later scattering, and making each a mine of its own. When removed from their mines, they cut a slit in the leaf with their jaws, and work their way into the leaf again very rapidly, the whole length of the body being concealed in less than an hour. By June 30 the grubs begin to change to pupæ, some leaving the mines for this purpose, and shortly afterward the beetles appear.

REMEDIAL TREATMENT.

It has been stated that hand picking can be made to check the injuries of the small beetle last mentioned, but to any one who has witnessed its attacks in Eastern Kentucky this will seem incredible. The larger part of the leaves of all the trees of a neighborhood may be occupied by mines made by one or more of the above insects. Since they are ordinarily concealed within the leaves it might seem that it would be impossible to reach them by spraying, but when it is remembered that this method has proved very satisfactory in dealing with the codling moth, and that the adults of the beetles feed to some extent on the leaves, it will not appear impracticable. I am inclined to believe it can be made to answer the purpose if it is supplemented by raking up and burning the fallen leaves in the fall of the year, so as to catch the species which spend the winter among them.

THE LOCUST LEAF-SKELETONIZER

(*Gelechia pseudacaciella*).

This is another moth closely related with the three leaf-miners mentioned above, which, associated with them, or alone, has a very injurious effect on the trees. The young of this is larger than the others, cylindrical, with striped body, and lives between the leaflets, which it fastens together with silk, and then gnaws away the surface of the leaf, exposing the skeleton. It has proved most injurious during August and September.

The same treatment is to be recommended as for the preceding.

THE LOCUST SKIPPER

(*Eudamus tityrus*).

The skipper of the black locust is a brown butterfly with wing expanse of a trifle less than two inches, and is so called because of its jerky flight. It may be seen about the trees in summer placing its eggs on the leaves, and is a common visitor to many kinds of flowers, being especially fond of nectar from the heads of red clover. The species may be known from some fifteen other skipping butterflies occurring in Kentucky by its superior size, and by a large silvery white blotch on the under side of the hind wing. The front wings are marked by one large and several small blotches of brownish yellow. The mischief is done by the larva, a stout pale green worm, with large, globular, reddish brown head, to which a comical expression is given by two round yellow spots, very likely to be mistaken for eyes. The worms usually make their presence known by devouring the leaves. They feed largely at night, and during the day are concealed in little shelters which they construct by stretching bands of silk across from one leaflet to another, so as to draw them up and about their bodies. When a tree begins to lose its leaves one may, by close looking, find the culprits by these rolled leaves, between which they lie. Several broods are reared each summer, but the eggs appear to be deposited at intervals during a considerable period of time, very young larvæ occurring on the same tree with worms nearly grown. The change to a quiescent pupa takes place within the rolled leaves, which are lined with silk for the purpose. The last brood does most of the mischief from which the locust suffers. Many of the larvæ are about one-fourth grown at this latitude on August 20, and change rapidly to pupæ about September 15, remaining in this condition over winter. The injury is to be checked by spraying.

POPLAR DEFOLIATORS.

(*Icthyura inclusa*).

Several caterpillars and leaf-miners mar the poplar trees planted in Kentucky, of which perhaps the most destructive is the above. When actively injurious it is a worm, or caterpillar, reaching a length of about one inch, and may be known by the following characters: Head, jointed legs, a plate at hind extremity, and two double tubercles on the back, black. Four longitudinal yellow lines along the middle of back. Each side with faint yellow lines and two series or black dots.

The caterpillars are found during the day in leaves which they have rolled together and lined with silk, the petioles being fastened to the twigs with silk. Young Lombardy poplars are often seen with but little in the way of leaves besides those occupied by the caterpillars. They appear in June and again in

August, hatching from eggs of a pale lilac color placed in a single layer of from 114–134, on the under side of the leaf.

Fig. 11. Part of a Frankfort elm with bark removed so as to show work of the elm borers. (From a photograph).

The eggs (.02 inch in diameter) appear to be spherical, but really are only about two thirds of a sphere, the side attached to the leaf being flattened. The eggs are laid by an obscurely marked gray moth with wing expanse of about 1.12 inch.

Immediately after hatching, the worms are pale green with numerous black spots, the double tubercles being just visible. They live in a company on the upper side of the leaf, building over themselves a tent-like web, and gnawing away the upper layer of leaf substance so as to expose the skeleton. Eventually the leaf is drawn together so as to completely enclose them, but with openings through which they can pass in and out when feeding. Other species which also fold the leaves are sometimes associated with this species on the same tree. Since all injure the leaves in the same way, viz: by gnawing, it is not necessary to give a separate account of them at present.

They can be destroyed by spraying with Paris green.

THE ELM BORER

(*Saperda tridentata*).

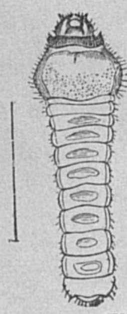


Fig. 12. The elm borer-grub. The line at the left of figure shows the natural size.

In the latter part of June, 1892, my attention was called to a diseased condition of elm trees about the streets of Frankfort, the nature of which was not apparent, though it was supposed to be due to the attacks of insects. On June 27 I made a visit to Frankfort for the purpose of examining the trees, and found that some valuable elms were dying, and that several others were already dead. The affected trees were among the largest and finest in the city. All those examined were American elms (*Ulmus americana*). The trouble was said to be new to the locality, but appeared to be making rapid headway. Examination of the dead and dying trees showed that their condition was not due to injury by leaf-eating insects, for the foliage remain untouched. An examination of affected trees, which still retained many green leaves, showed that the bark was unsound in places near the base of the trunk; but most of the insects under such bark were common species, known to feed on dead wood everywhere. From burrows under some of this bark, however, a borer was obtained, which belongs to the species, the name of which heads this paragraph. The number present did not seem to me sufficient to account for the death of the trees. In fact, on one of those almost dead, the inner bark, though discolored, was intact, and no trace of insects could be found about it. Such insects, however, may begin their attack on the branches and upper parts of the trunk, and an examination of these parts could not be made conveniently without cutting down the trees. When this was done in the fall I was enabled, through the kindness of the State Commissioner of Agriculture and his assistants, to examine the trees again. On the tenth of September my assistant, Mr. Terrill, went to Frankfort and brought back with him a portion of one of the trees for more careful examination at the Station. The elm-borer was then found to be abundant under the bark, always in the grub state. The inner bark of the greater part of the trunk was mined and eaten so that it could be detached in large pieces. The portion brought to Lexington was from one of the larger branches, and was cut out near the trunk. Several wood-boring grubs were found at work on it, but by far the larger number were the species which had been found mining the bark earlier in the season. It was, therefore, evident that the injury was done in part at least by the elm-borer. The decline of the trees may have been due primarily to something else, such as exhaustion of nourishing matter in the soil. A starved tree is always the prey of injurious insects and fungi, somewhat as a feeble man is more subject to disease than a strong and vigorous one; but there can be no question as to the activity of these insects in destroying the trees upon which, from whatever cause, they once secured a foothold.

The insect is not a new one in this part of the world. It was known to the authorities of eastern cities many years ago as an enemy of the elm trees planted for shade along thoroughfares. Writing of his experience with it among trees on the Boston Common in 1847, Harris says: "The trees were found to have suffered terribly from the ravages of these insects. Several of them had already been cut down, as past recovery; others were in a dying state, and nearly all of them were more or less affected with disease or premature decay. Their bark was perforated, to the height of thirty feet from the ground, with numerous holes, through which insects had escaped; and large pieces had become so loose, by the undermining of the grubs, as to yield to slight efforts, and come off in flakes."

Somewhat later Dr. Asa Fitch observed the same insect about diseased elms in New York. The species attacked in this case was the slippery elm (*Ulmus fulva*), and he states that whenever portions of the bark of this tree has been stripped off for medicinal purposes "the remaining bark immediately becomes filled with these worms, by which all its inner layers are consumed in a few months and changed to worm-dust."

More recently still an outbreak of the pest occurred in Illinois, where I had an opportunity to observe it. Its work in this State was not confined to large trees, young ones twenty feet or less in height being also attacked. At the time of the outbreak Prof. Forbes, the State Entomologist, wrote: "The difficulty with the trees commonly commences to declare itself from the middle of summer to autumn, when the leaves, first upon the terminal twigs and then upon the larger branches, are seen to stop their growth, change their color and ultimately to fall." The first attack was sometimes made on the upper branches, these being killed, while the remainder continued to put forth new leaves until they were invaded.

The grub which mines the bark measures, when fully grown and extended, about one inch in length; is cylindrical in general shape, but becomes somewhat enlarged and flattened at the front end, like the round-headed apple tree-borer. The head is immersed in the succeeding division of the body, and hence seems smaller than it really is. It is of a dark brown color, and is provided with strong black jaws, usually more or less concealed by a membranous upper lip. The next division of the body is largest and widest, measuring about twice as wide as long; it is covered above with a rather firm, yellowish brown crust, forming a sort of shield, and bounded at each side by a short groove, the succeeding divisions becoming rapidly narrower to the fourth, from which the diameter changes but little to the last but one. The terminal division of the thirteen composing the body is small and conical. The grub has no legs. The winter is passed in the grub state, but the next spring the pupa stage is assumed in the burrows. Those obtained at

Frankfort are one-half inch long, rather slender, the abdomen being somewhat produced, but terminating bluntly; limbs and wing-pads folded against the body as usual in such pupæ; the antennæ extend around the femora of the two first pairs of legs, then turn forward so that the tips lie above the free mouth parts; on the head and thorax are a number of short black hairs arranged symmetrically, of which a series of four or five below the antenna of each side, and others along the front division of the thorax are conspicuous; divisions of the thorax with a median longitudinal channel above; abdomen distinctly segmented, margined, each division with tubercles with minute spines projecting backwards; tip of abdomen with a number of short hairs on each side. This stage lasts but a short time, when the final moult of the skin takes place and the adult beetle comes forth to lay eggs on the bark of trees for a fresh lot of grubs.

The beetle is a small slender insect, rather obscure in its colors, and so shy and retiring of habit that it is not often seen. It measures about 0.50 inch in length. Its color is brown with a grayish cast. It is marked with several black dots on the thorax and wing covers, and on the latter at each side is a marginal line of dull red, from which are given off three branches which project obliquely backward. The latter markings give the species its technical name *tridentata*.

Fig. 13. The adult of the elm borer.

Quite a number of parasites, small four-winged flies, were obtained trom wood from a diseased Frankfort elm, but since there were three other borers besides the one described above, at work on the wood it is not certain which species they were preying upon. The presumption is from the greater numbers in which the elm borer occurred that they come from it, and there is reason to hope that these friends of ours will greatly increase.

The adult beetles emerged at the Station during May and the first half of June. A single living example was taken from the boxes in which our infested wood was kept on July 21, hence the beetles are probably abroad during some portion of July also.

REMEDIAL TREATMENT.

It will be seen from the statements already made that the borers are in the bark of trees during the fall and winter months, and it is plain that if affected trees could be cut down and burned at this time large numbers of the insects would be destroyed. This practice is to be recommended for all trees which are plainly past saving. Burning during the spring and early summer could not serve a useful purpose, because the beetles are out of the bark during this part of the year.

To defend trees from attack it may be suggested that the trunks, and, if possible, the larger branches be coated with whitewash to which Paris green has been added in the proportion of ¼ pound to ten gallons of the wash. This poison is known to have a good effect in saving vegetation from attacks of insects by killing the young when they begin to bore into the tissues. Such a wash should be applied early in the spring before the beetles emerge, and should be renewed from time to time, as long as there is danger of beetles being about, i. e. until the middle of July.

A good many years ago a French authority on forestry recommended the scraping and cutting away of the bark of trees attacked by borers as one of the most satisfactory remedies known to him. His idea was that this treatment encouraged the flow of sap to the scored bark, so that the grubs were unable to mine it. It is well known that trees do defend themselves under some circumstances by filling up the burrows of insects as fast as these are made, and on some fruit trees one may find scores of burrows thus started and afterwards abandoned because of a gummy exudation which fills them. The experiments of the Frenchman, M. Robert, were made chiefly on elms, but with reference to beetles belonging to a different family from that of the American elm-borer. Both bore into the inner bark and sap wood, however, and it is probable, therefore, that the treatment he recommends will serve as well for our elms. He began by cutting out long strips of bark about 2–2.50 inches wide, extending from the ground to the branches. A new growth of bark was at once formed here, which projected as a longitudinal ridge in which the sap circulated so vigorously that the grubs in the immediate neighborhood were destroyed, and the tree itself showed an increase in general vigor. His next experiment was to remove from infested trees all the outer bark of the trunk, usually styled the corky layer. It was found that the grubs in the inner bark quickly perished, either from the increased flow of sap or from more complete exposure to the action of the sun. He claimed that this treatment stimulated the trees to renewed growth, that it improved their general condition, and that the new bark which replaces that which is removed is so smooth and thin that the beetles will not resort to it to deposit their eggs. The treatment, it is held, does no injury to the trees. M. Robert treated at one time over 2,000 trees along the boulevards and public roads of France with marked success. The same treatment serves, it is said, to invigorate apple trees which have ceased to bear, and has long been employed by fruit-growers in Normandy.

PINE BARK-BEETLES

(*Tomicus calligraphus, etc*).

Pine trees in cultivation sometimes suffer from the minings of small stout-bodied grubs which destroy the inner bark in much the same manner as the elm borer. Several different species of the same family (Scolytidæ) are often concerned in this work of destruction, but the one found abundantly on pines in this vicinity is the species named above.

The adult beetle is a small compact, cylindrical, brown object about 0.20 inch long, with short legs, and is to be known from beetles of other kinds by a singular excavation at the extremity of its body with toothed edges. It looks as if it had been mutilated by having the hind part of the wing covers gouged out. These beetles bore into the bark of trees making a channel of some length, which after the inner bark is reached, is made parallel with the surface. The eggs are placed at intervals along this channel, and the grubs hatching from these push into the adjacent bark, so that it becomes eventually completely destroyed by them.

The adults appear very early in the spring, being observed by us to be abundant under the bark of an Austrian pine at Lexington, February 29. At this date no larvæ or pupæ could be found, though the pupal skins were common in the burrows, showing that the beetles had recently matured. Beetles of this brood place their eggs in burrows under the bark during April and May, and then disappear. The grubs hatching from these mature during the summer and place eggs for another brood, which is in turn matured in the fall and winter months. The beetles found by us in February belonged to this brood, and were evidently only waiting for mild weather, when they would have escaped and deposited their eggs.

I am disposed to think that this beetle attacks trees only when their vitality is already low from the effects of drought, unfavorable situation, or the attacks of other pests. However this may be, it sometimes completes the destruction of valuable trees, suffering from what would otherwise have been only a temporary weakness. Trees in a dying condition from attacks of such borers should be promptly cut down and burned, care being taken to destroy all the bark and larger branches. Borers of this sort have been known to be disseminated among trees of a neighborhood from the lumber and logs about saw-mills. Dead and dying trees infested with borers are even more to be feared as centers of dissemination of pests. They can be burned to best advantage in winter, since the beetles are dormant at this season under the bark. During spring and in mid-summer they are abroad finding places to deposit their eggs, and hence burning at these times could not be expected to do so much good. Coating trees liable to attack with whitewash, to which some Paris green has been added, is a treatment I have sometimes recommended as a means of deterring the beetles from boring into the bark to place their eggs. To be effective, such treatment should be employed very early in spring before the beetles leave their winter quarters, and the application should be renewed from time to time during the summer.

Removing the outer bark to expose the grubs and stimulate the activities of the trees, as suggested in treating the elm-borer, may be found effective for the pine bark beetles also, as M. Robert's experiments were made with reference to checking the injuries of a closely related insect belonging to the same family.

THE MAPLE BARK-LOUSE

(*Pulvinaria innumerabilis*).

Fig. 14. Maple tree bark-louse. *a*, on the leaf; *b*, crowded together on a twig. (From Riley.)

This is the insect that may be seen forming white cottony tufts on the twigs of maple trees along our streets in early spring. It is one of the scale-insects, and does its mischief by puncturing the leaves and abstracting the sap of the trees. The species has already been treated in Bulletin 40 of the Station, to which those interested in the pest are referred. It is quite uniformly distributed among maple trees in Kentucky, and will bear watching.

II. AN EXPERIMENT ON PLUM ROT.

BY H. GARMAN.

Several plum trees standing near the house on the Experiment Farm have always been badly affected with the brown rot, due to the fungus parasite, known as *Monilia fructigena.* Last spring it was decided to treat one of these trees with Bordeaux mixture, leaving another standing beside it as a check. The former was sprayed on June 9, 1893, with Bordeaux mixture, about 2½ gallons being applied to the leaves and young fruit with a knapsack sprayer. The mixture was prepared by the formula employed for the apple experiments of 1892, and reported in Bulletin 44.

On July 5, the tree was sprayed again, about the same quantity of the mixture being applied.

The season was very unfavorable for fruit of all sorts, and neither the sprayed nor the check tree bore as full crops of fruit as usual. As far as it goes, however, the result is in favor of spraying. Some rotting fruit was observed at the time of picking on both trees, and a good many plums rotted and fell from both during the summer. On August 22, the plums were removed.

From the sprayed tree (No. 465) I took 477 plums, weighing 11½ pounds. These averaged a little smaller than those from the check tree, and the skins of some showed a peculiar roughness due either to a caustic action of the mixture, or else is simply a peculiarity of the tree. As the fruit of the trees have not before been compared, it is not safe to decide about this I have never witnessed any similar effect from spraying grapes and apples, though it may prove that plums are more sensitive to the copper and lime.

The unsprayed check tree (No. 466) yielded 254 plums, weighing 6 pounds and ½ ounce.

The difference in favor of spraying is thus about 5½ pounds in the weight of fruit. Or we may say the spraying increased the yield about 48 per cent.

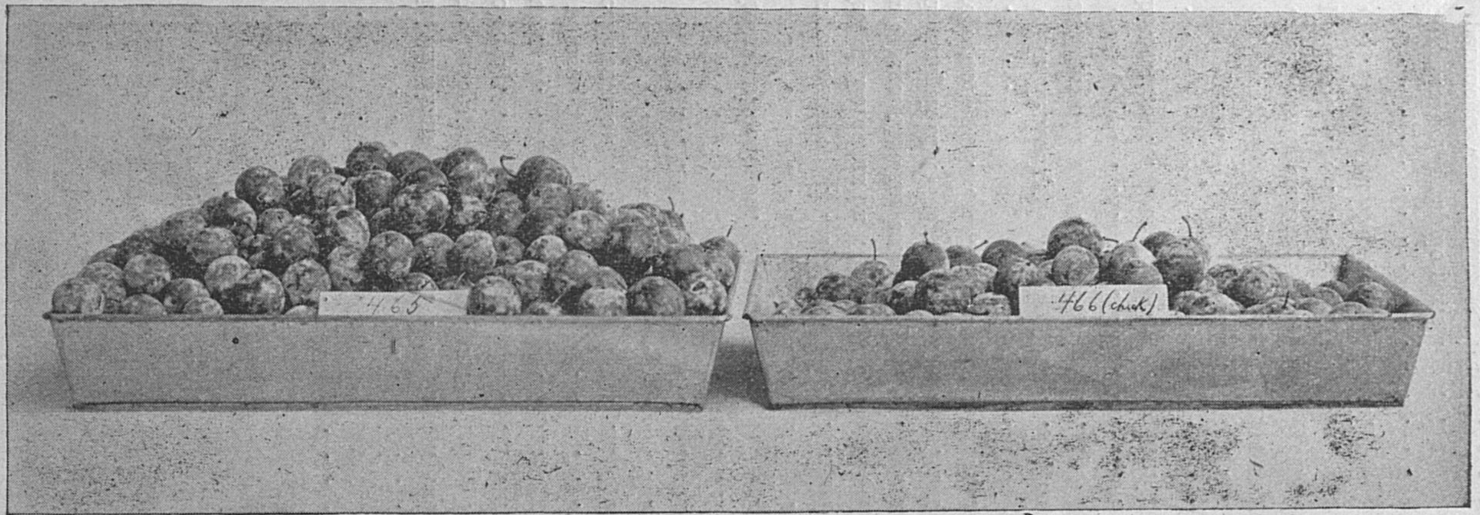


Fig. 15. 465, showing plums taken August 22, from sprayed tree; 466, showing plums taken from check tree.

INDEX.