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Experiments with Crimson Clover and Hairy Vetch.

J. F. DUGGAR.

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Experiments With Crimson Clover and Hairy Vetch.

BY J. F. DUGGAR.

SUMMARY.

Clover, vetch and similar leguminous plants are able to draw much of their nitrogen from the air when enlargements called tubercules or nodules are found on their roots. They are unable to do this, or to store up fertility, when tubercules are absent.

In order for tubercules to develop, specific germs or bacteria must be present in the soil or seed, or come in contact with the young rootlets. In the regions where the clovers, vetch, alfalfa, etc., are extensively grown, these germs become generally distributed in the soil of the entire region. In a number of localities in Alabama, where these legumes are not grown to any great extent, these germs are absent from some soils or present in insufficient numbers.

Inoculation is the process of supplying these germs, either by scattering on a field some of the germ-laden soil from a field where these rarely grown legumes have borne tubercles, or by the use of the prepared material called Nitragin.

Nitragin is a concentrated germ fertilizer containing myriads of germs which are able to cause the growth of tubercles on the roots of certain leguminous or soil improving plants. Both Nitragin and germ-laden earth were very profitably used in our experinents.

Crimson clover inoculated with clover Nitragin afforded a crop of 4,057 pounds of hay per acre, while ordinary or untreated seed gave (including many accidently inoculated

plants) only 761 pounds of hay. This is a gain of at least 3,296 pounds of hay per acre as the result of inoculation.

Seed of hairy vetch inoculated with vetch Nitragen produced hay at the rate of 3,270 pounds per acre, against 564 pounds with ordinary or untreated seed. This is an increase of 2,706 pounds of hay per acre as the result of inoculation.

The cost of inoculation, using Nitragin as above, was at the rate of $2.25 per acre, leaving a large profit.

In an earlier experiment here hairy vetch was inoculated with soil from an old vetch field, wihout expense except a small item for labor. This home grown inoculating material effected an increase of 2,308 pounds of hay per acre.

A field once inoculated, whether naturally or artificially, remains inoculated for years.

As a general rule, each division or genus of leguminous plant has its own specific or adapted germ.

Nitragin is very perishable especially in warm weather and this may cause frequent failure in using it.

Natural agencies are constantly at work spreading root tubercle bacteria and inoculating soils. If given sufficient time (several years) most legumes will probably develop tubercles without help from man. Artificial inoculation brings quicker success in the culture of rarely grown legumes.

Inoculated hairy vetch yielded slightly less dry material in the above-ground portion and a considerably smaller weight of roots than nearly mature rye.

However the inoculated vetch contained in both tops and roots a much higher percentage of the valuable element, nitrogen, than did rye, and also more than did non-inoculated vetch plants.

The crop on one acre contained in tops, stubble and roots 105.5 pounds of nitrogen in the case of inoculated hairy vetch, only 26 pounds in the case of rye, and still less in non-inoculated vetch plants. This excess of 79.5 pounds of nitrogen stored up by vetch explains the superior fertilizer and food value of hairy vetch over rye.

Of the total nitrogen in healthy plants of crimson clover and hairy vetch, less than one-fifth was contained in the roots and short stubble. The roots and stubble alone of hairy vetch contained about four-fifths as much nitrogen as the entire rye plant.

Both heavy and light applications of non-nitrogenous fertilizers were profitably applied to hairy vetch.

Soil Improving Plants and Root Tubercles.

In several experiments described in Bulletin No. 95 of this station the land was left in a much more fertile condition by plowing under a crop of cowpea vines than by turning under a growth of crabgrass and weeds. The cowpeas had stored up fertility, the other plants had not.

Examination of the roots of the plants shows that cowpea roots have many roundish enlargements, while roots of crab grass, most weeds, cotton, corn, etc., are free from swellings of this character.

The name tubercle or nodule is applied to these enlargements, which may be found on all thrifty cowpea plants, clover plants, etc. If these tubercles are present the plant bearing them is a renovating or soil-improving plant. All plants on which these nodules can grow belong to the class of leguminous plants or legumes.

Leguminous plants, unlike others, are able to obtain from the air a large proportion of the nitrogen required for growth. This power to collect or "fix" atmospheric nitrogen resides, not in the flowering plant itself, but in the tubercles attached to its roots.

Each of these enlargements, nodules, or tubercles, is filled with myriads of miscroscopic germs or bacteria, which feed on the gaseous nitrogen found in limitless amounts in the atmosphere. Air, and consequently free or gaseous nitrogen, circulates in all cultivated soils and comes in contact with root tubercles. The germs within these nodules seize this nitrogen, which flowering plants cannot directly utilize, and change it into a form suitable for nourishing these higher plants. The nitrogenous food thus prepared in the tubercle enters into the circulation in the root to which the nodule is attached, and thence is carried in the sap to build up all parts of the leguminous plant.

INOCULATION OF SOIL OR SEED.

Every plant suitable for the growth of root tubercles ought to have an abundant supply of them. The writer has never found a cowpea plant of suitable age and grown under normal conditions which was free from tubercles.

Yet some plants that can form tubercles are sometimes found to have none. The writer has examined hundreds of individual clover and vetch plants on which there were no tubercles. For such plants the farmer has no use. They are no more doing the work they should do than is a barren stalk of corn.

Why do leguminous plants under some conditions fail to form tubercles? It is because the proper germ ("seed," so to speak) is absent from the particular soil in which legumes grow without root nodules. In order for tubercles to form on a given leguminous plants a specific germ must be present. For clover this must be a germ or bacterium of that particular strain or stock which is accustomed to grow in clover tubercles; for vetch it should be the kind of germ which is accustomed to grow in vetch tubercles; and so for other plants.

Inoculation consists in placing a supply of these germs in such position that the young roots of the leguminous plants will come in contact with them. We may inoculate either the soil or the seed.

Individual tubercles are short-lived, and when one decays it distributes in the surrounding soil a great multitude of germs or root-tubercle bacteria which serve the purpose of seed for the next crop of tubercles. Thus in an old clover field are myriads of clover germs, in an old vetch field multitudes of vetch germs, and so for other legumes. Hence when clover follows clover or when it is sown in a locality where the growth of clover is general and clover germs generally distributed, artificial inoculation is unnecessary.

It was not suspected until recent years that any soils stood in need of being artificially supplied with root-nodule bacteria. Salfeld and others found that "moor soils," a small and peculiar class of peaty soils found in Europe, were benefited by artificial inoculation for certain legumes. No account of large areas of American soils needing inoculation had been published so far as could be learned prior to Bulletin 87 of this station. That bulletin pointed out the fact that in many portions of Alabama the frequent failure of clover, alfalfa, and other rarely grown legumes was due to the absence or insufficiency of the corresponding root-nodule bacteria in the soil.

Since soil of an old clover field contains abundant clover germs, since these are necessary to the abundant growth of clover, and since they are wholly or in part absent from some soils, it follows that soil from an old clover field should be added to soils thus deficient and hence unsuitable for clover.

Quite recently a German firm whose American agents are Victor Koechl & Co., 79 Murray St., New York, have placed on the market a preparation called Nitragin. The several brands of Nitragin contain in concentrated form the same kinds of germs that are found in old fields of clover, vetch, alfalfa, etc.

Either this prepared material or the soils containing the requisite root-nodule bacteria may be used as an inoculating material. Both have been separately used in our experiments and both have been highly beneficial.

Crimson Clover and Hairy Vetch.

Before describing in detail our experiments in which there was an enormous increase in the yield of crimson clover and hairy vetch, brief notes regarding these two plants are in order.

Crimson clover is an annual leguminous plant making its growth between October and May. Making all of its growth in the cooler, moister portion of the year, it escapes with less injury than does red clover from dry weather in summer. It has a head which is two or three times as long as that of red clover and which is of a crimson or scarlet color. The plant grows 16 to 28 inches high, makes good pasturage, and excellent hay if cut in time. Its chief value in the South will doubtless be as a green manure for improving the soil of old cotton and corn fields.

It can be sown among the standing cotton stalks in October and covered with a V-harrow or cultivator, and can be plowed under the following April in time for summer crops. Sown here as late as November 6 among cotton stalks it attained a height of 14 to 26 inches. The amount of cleaned seed required to seed an acre is 15 to 20 pounds, and the cost is usually 5 cents per pound, the seed for an acre costing 75 cents to $1.00.

Hairy vetch is also an annual leguminous plant, making its growth during the same period as crimson clover and useful for the same purposes. It is a vine-like growth, and for support should be sown with some erect plant, as one of the grains. For sowing with vetch Myer's turf oat has been highly recommended by the Mississippi Experiment Station. Here this mixture, one to two pecks of vetch seed per acre and one to one and one-half bushels of oats, has been successful on rich spots, but on poor land an earlier ripening variety of oats is needed.

Europeans recommend rye as an excellent plant to sow with hairy vetch, but in our experiments common Southern rye ripened too early.

If vetch is sown alone for hay one bushel per acre is required. With the small grains vetch can be combined in any proportion desired. The cost of seed is about three dollars per bushel.

Both crimson clover and hairy vetch should be sown in the period between September 1 and November 1, usually October 1. Earlier sowing is permissible on land not very subject to drought.

Inoculation Experiments with Crimson Clover.

It is almost certain that crimson clover has failed more frequently and more completely than any other plant ever tested in Alabama. The cause is now revealed, and the cure for such failures in indicated by the results recently obtained in experiments conducted at this Station.

Four plots, each one-twentieth acre in area, were used for an inoculation experiment with crimson clover in November, 1897. The soil was a clay loam, by no means fertile. The four plots used were all in the same terrace, and all were prepared alike and at the same time. So far as could be learned no clover had previously been grown in this field nor in adjoining fields. Each plot was fertilized with 15 pounds acid phosphate and 2 pounds of muriate of potash. This is at the uniform rate of 300 pounds of acid phosphate and 40 pounds of muriate of potash per acre on all plots. No nitrogenous fertilizer was used on any plot.

One pint of seed of crimson clover was sown on each plot; this is at the rate of ten quarts of seeds per acre. On account of dry weather seed was not sown until November 5, 1897, which was a month later than the preferred season.

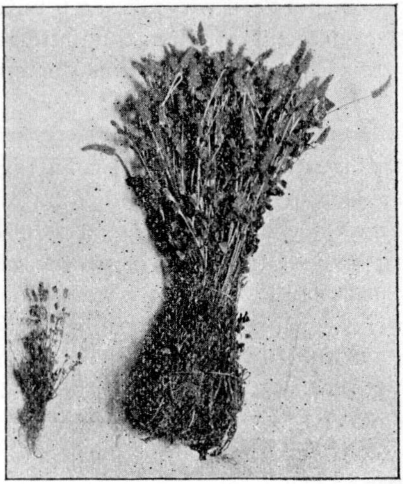
The seed for Plots 1 and 3 was inoculated, that is supplied with clover germs, as follows:

The seed was moistened with water to which had been added about two teaspoonsful of clover Nitragin. This is a material imported from Germany, and containing myriads of the germs such as are found on the little enlargements or tubercles that grow on thrifty clover plants. By this means the individual seeds for Plots 1 and 3 were brought in contact with clover germs, or just such germs as the seed would come in contact with if sown on a field where clover had previously grown successfully. The seed of Plots 2 and 4 was not moistened, but sown in the usual way.

As soon as seed was sown on all four plots, a harrow was run over all plots to cover seed.

On account of late sowing, crimson clover plants on all plots made very little growth and all plots appeared alike until March, 1898. By this time the plots sown with inoculated seed presented a greener appearance, and on examination of the plants on the inoculated plots, enlargements or tubercles could be found on the roots. These tubercles were not present on the plots sown in the ordinary way, except on plants growing along a depression or water-furrow and in other spots near the edges of the plots and adjacent to the inoculated plots. These spots were greener than the other portions of the non-inoculated plots, and their location (in depression and along the border of the non-inoculated plots adjacent to the inoculated plots) indicated that the plants in these green spots had become inoculated by seed dragged from adjacent plots, or by the drainage water from the inoculated plots. This accidental inoculation of a part of the plots to which no clover germs were intentionally applied must be kept in mind when noting the yields.

During all of March and April the plants on Plots 1 and 3 grew luxuriantly. The plots not inoculated made almost no growth in March (except on the spots accidently inoculated



CRIMSON CLOVER.
18 Non-inoculated plants. 18 Inoculated plants.

as above) and acquired a decided yellowish color. In April some of the non-inoculated plants, then not over two inches high, died, apparently from nitrogen starvation. Others had barely sufficient vitality to throw up seed stems 4 to 7 inches high, capped by a very small bloom. Still others did not bloom, but remained stationary at a height of 2 to 4 inches. Late in April and during the first few days in May the contrast between the inoculated and non-inoculated plants drew forth expressions of astonishment from numerous visitors to whom the field was shown.

Plots 1 and 3 were ready to be cut May 1, but for the benefit of visitors harvesting was postponed for more than a week. When cut the plants on the inoculated plots were 22 to 26 inches high and well branched. The deep green foliage was surmounted by the brilliant crimson of the blooms, the whole presenting a very attractive appearance.

On plots 2 and 4 there were spots covering one-fifth to one-eighth of their area on which spots the plants presented the same luxuriant appearance as on the inoculated plots. Elsewhere on the non-inoculated plots the plants were yellowish, the blooms few, small, and near the ground, and the plants too small to be cut with either mower or scythe. These small plants were carefully cut with a small sickle to avoid any possible waste.

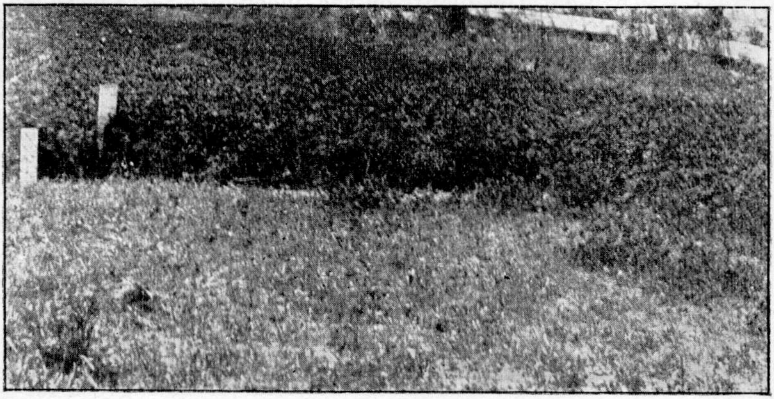
In the table below are given the yields of both green forage and hay. These figures, however, fail to do justice to the increase effected by inoculation, for most of the material on the non-inoculated plots consisted of the luxuriant plants growing on accidentally inoculated spots, as before explained.

Yields of crimson clover from inoculated and non-inoculated seed.

Plot No.	SEED	YIELD PER ACRE	
		Green forage	Cured hay
		Lbs.	*Lbs.*
1	Inoculated	16746	4781
2	Not inoculated	1277	464
3	Inoculated	11333	3333
4	Not inoculated	3310	1059
Av.	Inoculated	**14039**	**4057**
Av	Not inoculated	**2293**	**761**

In this experiment the average yield of green clover was 14,039 pounds per acre with inoculation, and only 2,292 pounds without inoculation. Of cured hay the average was 4,057 pounds per acre with inoculation, and only 761 pounds without, an increase of 3,296 pounds per acre.

In regard to the cost of this beneficial treatment, Nitragin is quoted at 62 cents per bottle in Germany, but costs us $1.25, plus express from New York. One bottle is sufficient



CRIMSON CLOVER.
Inoculated plants shown in upper part of picture, non-inoculated plants in foreground.

for five-eighths of an acre, so that, including express from New York, the cost of inoculation with Nitragin is about $2.25 per acre.

But material obtained at home without cost can be used instead of costly Nitragin. The soil from a field where any true clover (red, crimson, white or creeping clover, etc.) has made a luxuriant growth and formed tubercles can be used to inoculate clover seed, or soil from an old vetch field may be used as inoculation material for vetch. In the following experiment, first published in Alabama Station Bulletin No. 87, such inexpensive inoculating material was used.

Hairy Vetch Inoculated with Vetch Earth.

Seed of hairy vetch was sown October 17, 1896, all plots being fertilized alike with acid phosphate and sulphate of potash. Before sowing, one lot of seed was dipped into water, into which there had been stirred and allowed to settle earth from a lawn, once a garden spot, where common vetch (*Vicia sativa*) had for several years in succession made a luxuriant growth and formed tubercles.

The plants from inoculated seed formed numerous branches, most of which were about three feet long; those from ordinary untreated seed made but few branches, and these were only about eight inches long. The inoculated plants had large clusters of tubercles on the roots; the others had no tubercles.

The weight of cured hay was 2,540 pounds per acre from inoculated seed, and only 232 pounds from non-inoculated seed, a gain of 2,308 pounds, obtained at no other expense than that of the labor necessary to obtain the soil from the lawn where vetch had grown.

Inoculation Experiment with Hairy Vetch.

An experiment similar to the above was begun November 4, 1897, except that, instead of vetch earth, there was used some of the imported material prepared especially for this plant and known as vetch Nitragin. The field used was remarkably uniform in fertility, as shown by the nearly uniform yields of corn on all plots in 1897. Seed of hairy vetch was sown on one-twelfth acre plots November 4, 1897, at the rate of 30 quarts per acre. On two untreated plots seed was sown in the ordinary way. On the other plots the seed was dipped in a solution of vetch Nitragin.

The plants grew off slowly on all plots and the soil contained sufficient nitrogen to keep the non-inoculated plants abreast of the others until spring. Then differences appeared: the non-inoculated plants being in large part reddish or brownish. The inoculated plants had a healthy green foliage, branched much more freely than the others, and attained a length of vine several times greater than did the plants on the untreated plots.

On the inoculated plots large clusters of tubercles were found on the roots of plants, while on the plants grown from untreated seed tubercles were absent. About May 1 hairy vetch was ready to be cut for hay. It was cut May 9, the

HAIRY VETCH.
Four inoculated plants. Four non-inoculated plants.

growth on only one of the non-inoculated plots being cut, the other being plowed under as part of another experiment. The growth on the two non-inoculated plots was about equal, the plants on both being reddish to brownish and having branches, most of which were only about 6 to 12 inches long. The marked differences between the inoculated and noninooulated plots were easily observed by visitors, even when standing at a considerable distance away.

Yield per acre of hairy vetch from inoculated and non-inoculated seed.

Plot No.	SEED.	YIELD PER ACRE.	
		Green Forage.	Cured Hay.
		Lbs.	*Lbs.*
10	Inoculated	8460	3180
12	Inoculated	11520	3360
Av.	Inoculated	**9990**	**3270**
Av.	Not inoculated	**1560**	**564**

In this experiment the average yield of cured hay per

HAIRY VETCH PLOTS.
Inoculated plants shown in upper part of picture; non-inoculated plants in lower part or foreground.

acre was 3270 pounds with inoculated seed and only 564 pounds with ordinary seed. This is an increase of 2706 pounds of hay per acre as the result of inoculation.

Inoculation Practicable.

The cost of Nitragin, about $2.25 per acre, the risk of finding that it has spoiled while in transit or before use, and the dislike of many farmers to undertake some unusual operation, are influences which will prevent most farmers from employing this method of inoculation.

There is a cheaper, simpler and more practicable method of inoculation. This consists in using, instead of Nitragin, the earth from about the roots of tubercle-bearing leguminous plants. He who already has even a small area of clover growing in his fields, pastures or lawn can practice inoculation at practically no expense. He can use this clover dirt in inoculating any true clover. If he has a plot of vetch he can use the soil from the vetch plot as inoculating material for vetch seed, or he can doubtless use effectively on vetch the earth from a part of his garden where English peas have recently grown and formed tubercles.

In using earth from the garden one should first make sure that the roots of plants growing in it are not infested with nematode worms. The nematode pest occurs in many localities in the Gulf States and is especially prevalent in gardens. Nematode injuries consist of enlargements on the roots of plants which might be confused with the beneficial root tubercles found on all thrifty leguminous plants. Although the two have no connection, they may exist on the roots of the same plant at the same time. They may be distinguished by the fact that generally the nematode worm causes the portion of the small root attacked to enlarge equally or nearly equally in all directions. In other words the nematode swelling and the small roots are practically concentric, the root having the appearance of growing through the swelling. The small tubercle, on the other hand, is attached to the side or surface of the root. Later stages of the nematode swellings are not so easily described.

The method of inoculating with soil that is usually recommended consists in scattering broadcast on the plowed ground about one ton per acre of soil from a field of clover, vetch, etc. This earth should be harrowed in promptly and thoroughly.

Another method which can be used when the supply of earth for inoculation is limited, consists in stirring the soil into water and dipping the seed in the liquid. It was this method which gave us here a tenfold increase in the yield of vetch sown in October, 1896. It would increase the chances of success to combine both methods, inoculating both seed and soil as just described.

The writer would not be understood as recommending that Nitragin be used on all the seed for large areas of clover, vetch, alfalfa, etc., sown in "cloverless" regions. Its cost and the risk of having it spoil before it is used almost prohibit its use on an extensive scale. But it is certain that Nitragin may be profitably used on the seed for a small area with a view to using the soil from the area thus inoculated for use as the inoculating material for large fields sown in subsequent years. In other words Nitragin finds its most appropriate use as a "starter," in somewhat the same sense that progressive dairy-men sometimes cause cream to sour by using a small quantity of sour milk from a creamery where the highest quality of butter is made, thus obtaining a stock of germs that are concerned in giving the highest flavor to butter. A bottle of Nitragin is sufficient for five-eighths of an acre, and the soil on that area is sufficient to inoculate the next year scores of acres.

Employed in this way, the Nitragin may be used with great profit. Of course, earth from an old clover field may also be used as a starter for clover on a small area, furnishing the next year material for use on many acres. Any farmer can strike a balance between the two methods, setting the cheapness of the inoculating earth over against the greater amount of labor of applying it. It has been claimed that the use of Nitragin affords more complete inoculation, or a more uniform distribution of the germs and of the resulting tubercles. We have made no experiments bearing on this last point.

Lespedeza Earth as Inoculating Material for Crimson Clover.

In October, 1896, an inoculation experiment was begun with crimson clover. As this was before the days of Nitragin, and as we had not at hand at that time a field of any one of the true clovers, it was decided to try the effect, as an inoculating material, of earth from a field of lespedeza or Japan clover. This earth was sown at the rate of 720 pounds per acre, broadcast, and harrowed in with the crimson clover seed. Although the earth employed was well supplied with the germs which cause the development of tubercles on lespedeza plants, the crimson clover plants growing on the plots where it was applied formed no tubercles and failed utterly, attaining a height of only about three inches.

Numerous experiments conducted by the writer accord with European experiments, which show that, with few exceptions, the inoculation of any leguminous plant can be affected only by the root-nodule bacteria from a plant belonging to the same genus. Thus the germs found in lespedeza tubercles have no power to originate tubercles on crimson, red or white clover; vetch germs have likewise no inoculating power toward the clovers, alfalfa, etc.

The first word in the botanical name of a leguminous plant generally gives the key by which to determine whether its root-nodule bacteria are capable of inoculating any other given leguminous plant. The general rule is this: If the first word (generic name) of any two legumes is identical, the root-tubercle bacteria on either are capable of causing tubercles to grow on the other. Examples to illustrate this principle follow: (a) Crimson clover (*Trifolium incarnatum*), red clover (*Trifolium pratense*), white or creeping clover (*Trifolium repens*), inoculated with the same material; (b) alfalfa (*Medicago sativa*), bur clover (*Medicago maculata*), inoculated with the same material.

The above rule does not cover all cases; for example, the root-nodule bacteria of the garden pea is capable of inoculating vetch, in spite of the fact that the first or generic names of the two plants are not identical.

Natural Methods of Inoculation.

The fact that clovers and clover-like plants have inhabited the earth for ages and have regularly formed tubercles without artificial inoculation will cause many persons to be skeptical regarding the value of inoculation. The fact that usually wild and cultivated legumes are naturally inoculated does not indicate that inoculation of certain rarely grown plants is unnecessary under all conditions. It would be just as logical to argue against plowing as a preparation for hay grasses on the ground that the grasses grow luxuriantly in their wild state without any preparation of the land.

Natural methods of inoculating legumes, or of bringing the appropriate root-tubercle bacteria in contact with the roots of young legumes are as follows:

(1) Decay of tubercles, on old legume roots, thus freeing thousands of bacteria in the soil where the seed will be dropped and where the next generation of legumes will grow.

(2) Transportation of germs thus freed by means of winds, flowing water, etc.

(3) Inoculation of seeds before they fall by means of germ-laden soil settling upon them or spattering upon them during rains.

(4) Changes in the nature or food habits of the root-nodule bacteria by which it is claimed that these germs may in time so adapt themselves as to cause tubercles on any legume grown continuously on the same field for several years.

The writer is not in possession of very direct evidence on this latter point, made by European writers, but there is certainly some indirect evidence in its favor.

Wherever any of these agencies are active, inoculation is never absolutely necessary, and often superfluous.

When clover follows clover on the same land for several years in succession, we have an example of the first mentioned of these natural agencies. Of course in such a case artificial inoculation is unnecessary.

The case is similar when vetch is sown on land where closely related wild plants have previously grown, a class very common in uncultivated places, wood-lands, etc. In or near garden spots and around the residence vetch is often independent of artificial inoculation.

When clover is sown in a region where clovers are extensively grown and where the dust and surface drainage waters are laden with the corresponding germs, we have an example of the second agency. The uselessness of artificial inoculation of alfalfa in the West, where it is so universally grown, is also apparently to be explained in the same way. We have found the cow pea under all natural conditions to be independent of artificial inoculation in the South, doubtless because of the same agency.

The third agency is exemplified in the case of bur clover, the burs of which usually contain some of the soil on which they have grown. The writer's experiments indicate that this plant does not need artificial inoculation if the seed is planted without being hulled. Likewise we have found lespedeza to be independent of inoculation.

As perhaps illustrative of the change by which certain bacteria adapt themselves to plants on which they would not originally cause tubercles, we may refer to the fact that on land where vetch and clover during the first year develop few or no tubercles, after a few years of continuous growth of the same plant on the same land, tubercles are found in abundance. A case of this kind occurred here; hairy vetch, an annual plant, made a poor growth the first year, a fair growth the second year on the same plot, and a luxuriant development in subsequent years; and this, too, in spite of the fact that in the earlier years better seasons occurred and fertilization was heavier than in the later years. This particular case may also owe something to the agency of germs transported from an adjacent field where a closely related plant had been grown.

Let us admit that if grown continuously on the same land for a sufficient length of time, clover and vetch may reach the point of producing a normal supply of tubercles. Can the farmer living in a region where the appropriate root-tubercle bacteria are not abundant afford to wait on slow-acting natural agencies to inoculate his fields? Under such circumstances artificial inoculation must be regarded, not as in opposition to natural agencies, but as a means of hastening and increasing their activity.

Once inoculated, whether by natural or artificial means, a soil remains inoculated as long as the same legume is grown upon it. Indeed the growth of several non-leguminous crops (such as cotton, corn, oats, etc.,) does not cause the loss of the ability of this soil to produce tubercle-bearing plants of the original legume.

Cause of Frequent Failure of Nitragin.

The effects of Nitragin, given in a preceding paragraph, are sufficiently startling to convince the most conservative that inoculation comes as a new and revolutionary factor in the agriculture of the Gulf States. In view of the revealed ability to grow clovers, vetches, etc., on soils previously unfit for them, the possible benefits from inoculation can scarcely be overestimated.

But he who attempts to use Nitragin will, if he overlooks certain considerations, meet with some disappointments. The greatest obstacle to the general use of Nitragin in certain "cloverless" regions is the fact that this valuable material is perishable. It loses its inoculating property if long exposed to light, or if subjected to much heat, or if kept for more than two or three months. It endures longer in a cool than in a warm temperature. Nitragin shipped from Germany early enough to reach the Southern farmer in time for use on fall-sown seed runs great risk of being exposed to a temperature sufficiently high to cause fermentation, and consequent death, of the germs which it contains.

So many bottles of Nitragin ordered in time for use in our fall experiments have reached us in a worthless or dead condition that we would advise those who may wish to obtain a few bottles of Nitragin as a "starter," to order the shipment made from Germany about the first of February, so that the Nitragin will arrive in time for use on seed sown in March. While we have found to be dead some of the Nitragin imported in winter, the losses have been less at this season than with importations in the early fall.

In some cases this dead Nitragin had been used on seed sent out to farmers as "inoculated" before its worthless condition had been noted, thus causing failure and disappointment.

Co-operative Tests of Crimson Clover and Hairy Vetch.

More than fifty tests of crimson clover have been made by farmers in different parts of this State. The first tests were made entirely with untreated seed. Each party making the test was requested to send to the writer late in the spring three average plants for examination.

When untreated seed was used the plants were almost invariably small and either devoid of tubercles or supplied with only a limited number of very small tubercles.

The same was true with hairy vetch.

Our first supply of Nitragin was received January 6, 1897. It was an unsuitable time for sowing seed of any legume, but as soon as the weather permitted, seed of crimson clover and of other legumes were treated and sent through the mail for trial in different parts of the state. When used, the Nitragin was several months old and apparently too old to be of any value. At any rate the reports received indicated failure, the responsibility for which might be charged to either the unsuitable date of sowing or to the probable spoiling of the Nitragin. Moreover, there was delay in getting the seed into the ground.

In the second co-operative test the conditions were scarcely better. The very dry weather prevailing in the fall of 1897 made it inexpedient to treat the seed before November. One lot of seed was treated here November 10, another November 17, and still another November 27.

As this Nitragin had been shipped from Germany in September, at least some of the bottles had fermented before being used. The sample plants sent in again showed every evidence of failure and the general absence of an adequate supply of tubercles.

There was one instance where crimson clover plants from inoculated seed were strikingly better than those from ordinary seed.

At Eutaw, Mr. R. E. Kirksey received the seed within two days after they had been treated and sowed promptly, November 12. The following spring he reports as follows:

"Somc of the plants on the inoculated plot were dark green and a foot high, others not so high or green on the same plot. The plants on the other plot (seed not inoculated) were very small and yellow."

It is clear that Nitragin, kept here for some time in bottles, then opened, applied in solution to seed, and sent to farmers through the mails, has generally failed to inoculate the plants growing from the seed thus treated.

This failure of co-operative tests, in connection with our success in using fresh Nitragin, suggests that those who use Nitragin must themselves open the sealed bottles, use the material on the proper seed, and plant the seed promptly.

This general failure of Nitragin distributed with numerous delays as above, does not argue against the necessity of inoculation for crimson clover and hairy vetch in many parts of the state. The great number of plants found to be nearly or quite free from all tubercles or from those of proper size, indicates that effective inoculation would generally be beneficial to these plants.

These tests of crimson clover and hairy vetch made by farmers indicate, if taken as a whole, that these two plants cannot be successfully grown on most of the soils where they have been tried under our direction without effective artificial inoculation.

Relative Yields of Rye and Hairy Vetch.

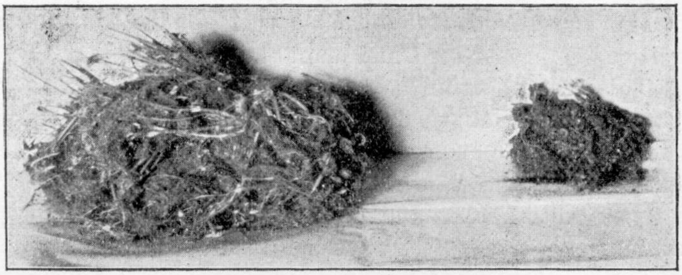
Rye and hairy vetch were grown under identical conditions on the sandy field sown November 4, 1897.

All plots were fertilized with like quantities of mineral fertilizer, using 36 quarts of seed per acre on the rye plot and 30 quarts per acre on the vetch plots.

One twelfth-acre plot of rye (Plot 1) was cut April 7, when in full bloom. The rye on the other (Plot 2) was turned under as a fertilizer for the succeeding crop. First, however, on May 7, 1898, the nearly mature rye on a carefully selected and average square yard of Plot 2 was harvested, as were similar areas of inoculated vetch and of non-inoculated vetch on adjacent plots.

The roots, to a depth of 6 inches below the surface and from an area of one square yard, were also separated from the soil by sifting, and then by repeated washing. Practically all the roots were found in the upper 6 inches.

Acre-yields of hay, calculated from such small areas are liable to considerable error, but in this case they agree rather closely with the figures obtained by weighing the entire pro



CRIMSON CLOVER.

Roots and stubble from one square yard of inoculated crimson clover

Roots and stubble from one square yard of non-inoculated crimsom clover.

duct of the one-twelfth-acre plots, indicating approximate correctness.*

The results follow, the weights being for air-dry material, or the natural dry condition of hay, straw, grain, etc:

*The variations between the acre-yields as calculated from the large and small plots is due to the fact that the yields on large plots included weeds, and in certain cases some accidentally inoculated plants. In the small areas, used for sampling, no accidentally inoculated plants were included and all weeds were separated.

Weight of air dry material of rye and hairy vetch; also weight of crimson clover.

PLOT NO.		ON 1 SQUARE YARD.		ON 1 ACRE.	
		Tops.	Roots.	Tops.	Roots.
(*Field M*)		*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*
1	Rye, cut in full bloom, Apr. 7	-- ---	---- --	1980	--- --
2	Rye, nearly mature	0.67	0.54	3243	2614
11	Hairy vetch, not inoculated	0.04	0.08	194	387
13	Hairy vetch, inoculated	0.63	0.30	3049	1452
(*Field T*)					
2	Crimson clover, not inoculated	0.02	0.05	106	266
1	Crimson clover, inoculated	1.00	0.30	4840	1452

The nearly mature rye on plot 2 yielded only a little greater weight of tops than did inoculated vetch. The roots of rye were much heavier than those of vetch, partly due, it is believed, to the greater amount of sand mixed with the finer rye roots.

Crimson clover, being in a different field, cannot be compared in yield with rye and vetch.

Nitrogen in Inoculated and Non-Inoculated Plants.

The thoroughly dried tops and roots from sample areas of one square yard each were analyzed by Dr. J. T. Anderson, associate chemist of this station.

His results,—which are averages of several determinations in each case,—and the figures derived from them, are given in the following table:

Percentage and amounts per acre of nitrogen in tops and in roots and stubble.

PLOT NO.		Percentage of nitrogen in air dry		Weight of nitrogen per acre in		
		Tops.	Roots and stub'le	Tops.	Roots and stub'le	Total product.
(*Field M*)		*Perct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*
2	Rye, nearly mature	0.52	0.35	16.9	9.1	26.
11	Hairy vetch, not inoculated	1.23	1.19	2.4	4.6	7.
13	Hairy vetch, inoculated	2.71	1.37	85.6	19.9	105.5
(*Field T*)						
2	Crimson clover, not inoculated	1.62	0.97	1.7	2.6	4.3
1	Crimson clover, inoculated	2 48	1.63	1.20	23 7	143.7

The quality as well as the quantity of the crop was very favorably influenced by inoculation, the percentage of nitrogen in the tops being practically doubled. The higher the percentage of nitrogen the greater is both the food value and the fertilizer value of a plant.

The tops of the rye, including the nearly mature grain and the straw, contained only 0.52 per cent. of the nitrogen, or less than one-fifth as much as was contained in the tops of inoculated vetch plants. The roots of rye contained only 0.35 per cent. of nitrogen, or about one-fourth as much as the roots of inoculated vetch plants.

Of intense practical interest are the figures showing the amount of nitrogen per acre contained in the several crops. Vetch on one acre contained in the entire plant 105.5 pounds of nitrogen, rye only 26 pounds, or about one-fourth as much, and the dwarfed vetch plants still less than rye.

We may get some measure of the superiority of inoculated vetch over rye as a fertilizer by noting the fact that the nitrogen in one acre of the former exceeded that in an equal area of rye by 79.5 pounds. This 79 5 pounds of nitrogen would represent approximately the amount of nitrogen assimulated by vetch *from the air*, if we should assume that vetch was able to obtain no more of its nitrogen from the soil than was rye; this assumption that rye can draw from the soil at least as much nitrogen as hairy vetch seems plausible, in view of the well known strong foraging habits of rye, as evidenced in its successful growth on poor soil.

If this assumption is correct, inoculated vetch plants have obtained practically three-fourths (105.5—26=79.5 pounds per acre) of their nitrogen *from the air.*

These figures seem to afford a rough measure of the fertilizing or renovating value of leguminous plants.

Of the total nitrogen in the entire plants the roots and stubble contained 19 per cent. in the case of inoculated vetch, 16 per cent. with inoculated crimson clover, and 35 per cent. with nearly mature rye. In all cases the stubble was shorter than the mower would leave it, being only about 2 inches long in the samples analyzed. It is doubtless safe to conclude that with stubble of ordinary length fully one-fifth, and possibly one-fourth, of the total nitrogen would be left in the soil after cutting the hay.

With short stubble there was left on the soil in the roots and stubble of vetch about four-fifths as much nitrogen as was afforded by plowing under the rye plants entire. In longer or ordinary stubble and in its roots vetch doubtless supplied as much nitrogen as both tops and roots of nearly mature rye.

Fertilizer Experiment With Hairy Vetch.

Three of the one twelfth-acre plots in the field sown with hairy vetch November 4, 1897, were used to ascertain the relative profits of fertilizers applied at two different rates. The land was sandy upland, liberally fertilized in recent years with commercial fertilizers.

Seed of hairy vetch, inoculated with Nitragin, was sown broadcast November 4, at the rate of 30 quarts per acre. The seed was worked in with a cultivator; the fertilizers were then spread broadcast and harrowed in.

Acid phosphate at the rate of 240 pounds per acre, together with muriate of potash at the rate of 40 ponnds per acre, and the same fertilizers in half the quantities named above, were employed. No nitrogenous fertilizer was applied to any plot. One plot received no fertilizer of any sort.

In the following table $10 per ton is assumed as the price of hay:

Fertilizer experiment with hairy vetch.

PLOT NO.	FERTILIZER PER ACRE.	HAY PER ACRE.		Cost of fertilizers.	Profit from fertilizers.
		Yield.	Increase over unfertilized plot.		
		Lbs.	*Lbs.*		
16	No fertilizer	2244			
15	120 lbs. acid phosphate 20 lbs. muriate of potash	2604	360	$1.25	$0.55
12	240 lbs acid phospate 40 lbs. muriate of potash	3360	1116	2.50	3.08

Although liberal amounts of commercial fertilizers had been used in this field for several years previous, mineral fertilizers were profitably applied to hairy vetch. The larger application of fertilizers was more profitable than the smaller.

It is believed that on average sandy land and in seasons of normal rainfall the effects of fertilizers wonld have been more pronounced.

Leguminous plants (such as vetch, clover, cowpeas, etc.,) when amply supplied with tubercles, need no nitrogenous fertilizers, but are highly responsive to acid phosphate and potash salts. These plants make heavy demands on the mineral plant food of the soil.