SOME EFFECTS OF DRYING AND ULTRA-VIOLET LIGHT ON SOILS

by

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INTRODUCTION

The drying of the soil by exposure to intense sunlight or by heat to improve its productiveness has been used in certain arid regions of India, and its beneficial effects have been noted in other countries. Since the drying of the soil seems to have a stimulating effect on crop growth in arid regions it is possible that the same might hold true for the more humid regions as well, and that the degree or intensity of drying would bear some relation to increased growth. In studying this relation it was thought necessary to consider certain changes in the physical, chemical, and biological conditions of the soil.

The physical condition due to drying of a soil is largely manifested through the colloidal fraction. Drying increases granulation and this increased granulation is to a great extent due to the flocculation and shrinkage of the colloidal material.

The changes in the chemical composition due to drying has been studied largely from the amount of plant food recovered in a water extract. Considerable increases in the amount of soluble materials has been observed when a soil has been previously dried. This would tend to show that drying of soils in the field may be an important factor in maintaining soil fertility in that it may greatly influence the amount of soluble compounds.

Since drying of a soil has been considered as partial sterilization the biological factor must be studied in connection with the chemical changes produced.

Ultra-violet light is also a powerful sterilizing agent and the question arises as to whether or not the effect of ultra-violet radiation would not produce partial sterilization in soils which might give conditions for increased yield.

The purpose of this study was to determine the effect of drying and ultra-violet light on some of the physical, chemical, and biological changes taking place in the soil.

ACKNOWLEDGMENT

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REVIEW OF LITERATURE

King (13) in his investigations in regard to the amount of plant food recoverable from a fresh soil, soil air-dried, and soil dried in the oven at 110°C. found more nitrates, phosphates, sulfates, bicarbonates, and silica, but less chlorides from an oven-dried than from the fresh sample. He ascribes this increase largely to what he calls the "fixing" power of soil grains, causing a concentraion near the surface of the soil particles which when dried are covered with the residues of evaporation, and allow a greater solution than in the fresh soil. He further states that the granular condition of the soil will allow a larger amount of water to be carried within the granules, the subsequent drying bringing the salts to the surface thus making them accessable of solution.

Warington (35), Kelley and McGeorge (14), Leather (17), Gustafson (8), Steenkamp (31), and others have shown that on the average, the drying of soils and heating to 100°C. has increased to a marked extent the water soluble constituents of the soil. They ascribe the results largely to physical causes, namely, the dehydration of the soil colloids.

Puri and Keene (22) concluded from their work that the influence of electrolytes on soil suspension is not a sharp flocculation or deflocculation but a gradual and progressive action, as the concentration is increased. The volume of dispersive medium is important.

Jones (11, 12) and his co-workers have shown that ions in solution possess hydrating powers, and that the ions with the highest valance are the strongest hydrate formers. They have also shown that ions with high hydrating power, when mixed with ions of low hydrating power dehydrate the latter, and that ions in dilute solution hold more water of hydration than ions in concentrated solutions.

Burton (2) has shown colloidal particles possess a charge several thousand times greater than that possessed by a single ion.

From this Wheeting (33) concludes that the ion manifestly could not act as a nucleus for the condensation of colloidal particles, and valence must be effective in some other manner than through electrical neutralization, and in this regard has shown a correlation to exist between hydration effects and flocculation effects. Further work conducted by Wheeting shows that colloidal particles in a dispersed condition hold more combined water than when flocculated. There is a critical point in the degree of hydration of colloids, below which they are unstable, and above which they are stable. Flocculation may be brought about by any treatment which will reduce below the critical point the water of hydration held by the colloid. Stabilization results from increases in the hydrate content. He states that "it is therefore evident, at least, in the case of negatively charged colloids, dispersed in water, the state of dispersion or flocculation is governed by the quantity of water of hydration held by the particles.

Dayhuff and Hoagland (4) have shown that colloidal clay remains negatively charged at all concentrations which they used; pH 2.1 - 12.7. The nature and concentration of the cations in the medium were the main factors influencing the stability of the suspension.

Whitney (34) explains flocculation by means of surface tension by stating that if the potential of the surface particles of water is less than that of a particle in the interior of the mass of liquid there will be surface tension, and the two grains will not come together, because they would enlarge the surface area and increase the number of surface particles of the liquid. If on the other hand, the potential of the particle on the surface of the liquid is greater than the potential of a particle in the interior of the liquid mass, the surface will tend to enlarge and the grains of clay may come close together and be held there with some force as their close contact increases the number of surface particles in the liquid around them.

Pickering (20) has shown an increase in the soluble organic materials in soils heated to 30°, 60° and 80°C. and then exposed to the sun for two months at summer temperature and watered occasionally. At higher temperatures a decrease was obtained.

Russell and Hutchinson (25) in studying the effects of partial sterilization found an increased availability of plant food and an increased plant growth. This they believe is related to a change in the bacterial flora, the larger phagocytic organisms being killed and the beneficial bacteria allowed to increase.

Howard (10) recognized the increased fertility of soils exposed to the intense sunlight of India, and believe that this may be due to an inhibiting effect of partial sterilization on the protozoa as reported by Russell and Hutchinson.

Russell (23) recognizes the observations made by Howard and believes that soils exposed to sunlight may be dried and heated sufficiently to remove the factor which limits the productiveness of the soil.

Klein (16), Russell and Petherbridge (27) observed that a reduction in moisture content previous to planting had a beneficial effect on plant growth.

Pickering (21) found that the heating of soils inhibited germination of certain seeds, and that the alteration of the soil begun at temperatures as low as 30°C. No appreciable destruction of the detrimental substance occurred when the soil was kept for several months in a moderately dry condition.

Russell and Darbishire (28) concluded from their work that after a soil had been partially sterilized there is an increase in the amount of oxygen absorbed in the soil, presumably by micro-organisms on the assumption of increased activity of the new micro-flora which results in increased decomposition of organized plant food into humus and mineral substances, the formation of ammonia and the fixation of nitrogen while the additional carbon dioxide evolved assists in the solution of mineral matter.

Greg-Smith (9) has shown that bacteriotoxins are destroyed at 94°C. He holds that upon remoistening the soil the more resistant bacteria multiply and become more numerous because of the absence of bacteriotoxins. Sunlight and air-drying the soils destroy the toxins.

Fisher (7) believes that more depends on the chemical composition than on the bacterial activity. Oxidation must be the principal factor as the nitrates are increased on drying, yet the nitrifying organisms are killed. He holds that colloids and surface tension must play an important part as a factor in this induced oxidation.

Salter (30) has pointed out that the changes in soil colloids are associated with drying and wetting, freezing and thawing. The removal of water from a colloidal system results in a concentration of soils which produce a progressive decrease in dispersion. When soluble electrolytes are present, loss of water may cause an increase in the concentration resulting in precipitation.

Nordensen (19) has shown in his work that light exerts upon metal colloids a slow coagulating influence which is similar to that of weak electrolytes. Ultraviolet light and B rays act equally well on positive and negative particles. In all cases the light coagulation is accompanied by a decrease in the total charge of the colloid.

Vitins (32) in studying the importance of calcium sulfate in agriculture states that rich crops are obtained especially after severe winters, when the soil gets frozen through, or in dry summers. He came to the conclusion that the coagulating capacity of divalent cations must be increased by the frost and by the dryness.

Russell and Smith (24) found that nitrifying organisms can be easily killed by an insufficient amount of moisture or by drying at 100°C.

Russell and Hutchinson (26) in studying the changes taking place in partially sterilized soils came to the conclusion that changes were largely biologic in nature. The number of bacteria increase with ammonia production and therefore associates the increased ammonia production with increased numbers of bacteria. They came to the conclusion that the larger organisms, namely, protozoa, infusoria, ameoba, and ciliata constitute the factor, or one of the factors limiting bacterial activity and therefore the fertility of untreated soils.

Kelley (15) found that an increase in vigor of the millet plant to be correlated with an increase in temperature at which the soil was sterilized, while the effect on onions was just the opposite. In the case of cowpeas, the increase in temperature at which the soils were sterilized resulted in a steady decrease in vigor. In conclusion he states that the results clearly show the intimate relationship between leguminous plants and bacterial life in the soil.

Duley and Metzger (5) from unpublished data, grew wheat seedlings in a soil which had been oven-dried and obtained increases in total dry matter of 174 percent.

Waksman and Starkey (36) in studying the effects of partial sterilization of soil in relation to microbiological activities ans soil fertility found that the protozoa were not destroyed by the process of air-drying, the flagellates were as abundant as in the untreated soil, while the ciliates and ameoba disappeared temporarily; however, when the air-dry soil was inoculated with only 0.5 percent of fresh soil, the ameoba were also abundant soon after moistening. They came to the conclusion that the destruction of protozoa could not account for the stimulating effect upon bacterial activities, but rather to the improved physical condition of the soil and making the organic matter more available as a source of energy to the growth of micro-organisms.

Heating the soil decreased the number of bacteria and fungi, followed by an increase. Protozoa did not reappear in appreciable numbers for 28 days.

Nitrates were increased at the start, this was followed by a drop accompanying the increase in the number of microorganisms, but as the bacterial numbers dropped nitrates began to increase.

Albreicht (1) in determining the viability of Pseudomonas radicicola found that the soil dried in the sun and that dried in the dark, and a dried soil stored for 30 months produced nodules on alfalfa and red clover as well as the untreated fresh soil, hence came to the conclusion that direct sunlight and desiccation are not as destructive to this organism in its native habitat as has been commonly supposed.

Rahn (28) obtained greatest differences in heavy soils than in light soils, the differences were particularly marked in garden soils. This would tend to indicate that the stimulating effect of drying has to do with the modification of the organic matter in the soil.

Lebedjantsev (17) concluded from experimental data that the change in fertility by drying is conditioned by the removal of water by evaporation, and by the heating of the soils by the sun's rays; and draws the final conclusion that the process of drying is a powerful factor determining to a large extent the fertility of the soil under natural conditions.

With regard to the individual factors in the drying of soil, he found that the removal of water, and the increase in temperature, gave a positive effect, whereas the effect of oxidation with oxygen, with the aid and influence of light is negative. In one case the removal of water acts more strongly than the increase in temperature, whereas, in another the action of temperature is stronger than the increase in dehydration.

The effect on crop yield was also determined and it was found that the drying of the soil was accompanied by an increase in yield. The greatest response was obtained with plants which under natural conditions thrive in soils not subjected to the drying influence in tilling operations; the least response, on the contrary, was obtained with cultivated plants exposed to the greatest artificial drying caused by cultivation in the row. He also found that the drying caused only a small change in the solubility of mineral substances; a large increase of organic substances, nitrogen, and phosphorus; and an extremely large increase in ammonia nitrogen.

A positive influence of drying is evident only with cultivated soils reaching a 6 percent moisture content, and with uncultivated soils reaching 14 percent. With smaller degrees no increase was observed.

Ellis and Wells (4) in summarizing the effect of ultraviolet rays on bacteria, state the following facts: (1) The active rays are those which are absorbed by the body acted upon. The total effect is a function of the intensity of the radiation and of the time during which it acts. (2) The action is exerted, chiefly if not entirely on the protein constituents of the bodies of the organisms. Within the protein molecules, there is strong reason to believe that it is the aromatic amino-acids that are specifically attacked. (3) The action is a direct one of the rays upon the bodies of the bacteria, and is not due to the formation of germicidal substances, such as hydrogen peroxide.

Other factors that may effect plant growth and the bacterial flora of the soil might be mentioned the effects of electricity and radio-active substances. It appears, however, that normal atmospheric or air-earth current has but slight effect. The soil being made up essentially of disintegrated rock materials contain measurable amounts of radium and thorium. Moreover, potassium compounds are radio active emmitting B-rays. What effect these radio-active substances may have on soil organisms is not known.

PRELIMINARY INVESTIGATIONS

Some preliminary work was done during 1927-'28 to determine what type of measurements would afford the best index for measuring the effects of ultra-violet light.

The preliminary work consisted principally of treating the soil with the ultra-violet light, no account being taken of the effects of drying and heating while under the lamp. Soils were treated for varying lengths of time and measurements made on ammonia and nitrate production and bacterial counts. These measurements showed that in general the ammonia increased at the start while nitrates and bacterial numbers decreased followed by a rapid rise upon remoistening. Later water soluble calcium and sulfate and pH determinations were made, but it was found that these determinations, except in the case of calcium, showed little or no correlation with the various treatments. The sulfate and pH determinations were therefore discontinued.

MATERIALS AND METHODS

The soils used throughout the work reported in this paper was a cultivated soil of a fine sandy loam type belonging to the Laurel series. The soil was collected on September 25, 1928. The surface soil was scraped off and only the moist soil taken to a depth of seven inches was used.

The soil was brought into the laboratory and thoroughly mixed, after which it was passed through a 10 mesh screen and again mixed. The soil was then divided into four lots and placed in glass containers, being covered with wrapping paper.

The untreated soil, and the moist soil to be treated with ultra-violet light and the sample to be dried in the oven was stored in a dark cool place. Nothing more was done to these samples until October 23, except the addition of water to keep them at approximately the same moisture content that obtained in the field at the time the samples were collected, which was 20 percent.

The rest of the soil was divided into equal portions, and spread out on brown wrapping paper in a thin layer to dry. As soon as the samples had dried sufficiently they were passed through a 20 mesh screen in order to remove the coarser particles. One portion of the soil was dried in the shade, another in the greenhouse, and the other in the sun. These soils were stirred and rolled about on the paper occasionally to insure more complete drying and exposure. On cloudy, rainy, and windy days, the soils were put into glass containers and covered with paper. The ones dried in the greenhouse and sun were stored in the greenhouse and the one dried in the shade was stored in the shade.

These soils were exposed for a period of 100 sunlight hours or they were kept in the air-dry state for a period of 25 days. The temperature of the air and soil was taken at 2:00 p.m. The average temperature in degrees Centegrade for the period at which the soils were exposed were as follows:

Average Temperature of air		Average Temperature of soil		Highest Temperature of soil
Shade	25.5	Shade	22.0	28.8
Greenhouse	32.7	Greenhouse	37.4	47.5
Sun	28.9	Sun	35.2	53.0

On October 23, 1928, 1800 gram portions were taken from the jars containing the soils dried under the various conditions as well as from the moist soil and given a three hour treatment under the mercury vapor lamp. The apparatus consisted of a transparent quartz tube, a 70 volt d.c. quartz mercury-vapor arc lamp. The tube was placed 10 inches above the surface of the soil. The soil was spread out on an oil cloth in a square such that the depth of the soil was one inch. At intervals of one minute the top soil was raked to one side. In this way a new surface was exposed at intervals of one minute. This was continued until all of the soil had been raked to one side. It was then thoroughly mixed by rolling it about on the oil cloth and the process repeated, being continued for three hours. The moist soil was prevented from drying out while under the lamp by spraying on water by means of an atomizer. In the meantime an 1800 gram sample was dried in the oven at 105° C. for a period of 20 hours. No light treatment was given this sample.

As soon as possible after treatment samples were taken for nitrate, ammonia, and calcium determination and bacteria counts, as well as for determining the rate of settling. Moisture determinations were made on separate samples. Duplicate samples of 25 grams each were weighed in porcelain crucibles and placed in an electric oven at about 105° C. for eight hours to determine total moisture.

The percentage of moisture in the fresh soil was calculated on the oven dry basis. Five hundred c.c. of distilled water was used with 100 grams of water-free soil. The soil was shaken by hand for five minutes and allowed to stand for an additional five minutes after which it was filtered by suction on a Buckner funnel. Five gram samples were used for bacteriological counts.

As soon as possible after the first determinations for nitrates, ammonia, calcium, and bacterial numbers were made the soil was weighed out into glass tumblers. One hundred and five grams of soil based on oven-dry weight was weighed out into each of seven jelly tumblers, the number used for each set of treatments, making a total of 63. The rest of the soil from the various treatments was also weighed out into glass tumblers for determining the effect on the growth of alfalfa and red clover. The glass tumblers in this case were coated on the outside with lamp black in order to shut out the light.

RESULTS

Rate of Settling

The object of this experiment was to study the effect of drying and of ultra-violet light on the rate of settling of the colloidal material. The equivalent of 70 grams of dry soil was weighed out and 350 c.c. of distilled water was added to it. The dispersion was obtained according to the method of Bouyoucos with a milk mixing machine. The time of stirring being limited to three minutes after which the solution was poured into hydrometer tubes all of which were approximately of the same size and diameter. The tubes were then sealed and set aside where they would not be disturbed. Measurements were made every day. The results are shown graphically in figures 1, 2, and 3 which were plotted

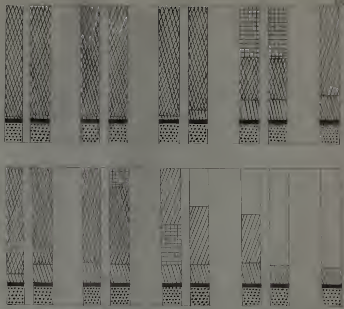

Fig. 4. Effect of drying and ultra-violet light on rate of settling [illegible] at end of 4 [illegible]

Treatment

1. [illegible]
2. [illegible] and ultra-violet light
3. [illegible]
4. [illegible] and ultra-violet light
5. [illegible]
6. [illegible] and ultra-violet light
7. [illegible]
8. [illegible] and ultra-violet light
9. [illegible]

Legend

[illegible]

[illegible]

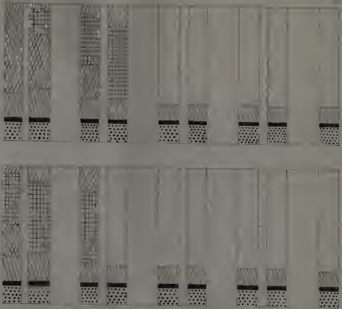

Fig. 2. Effect of dry and ultra-violet light on rate of settling of soils at end of [illegible] and [illegible] days.

Treatment	Legend
1. Moist soil - untreated	Clear
2. Moist soil and ultra-violet light	Edge of column just visible
3. Dried in shade	Smooth bands on walls just visible
4. Dried in shade and ultra-violet light	Opaque
5. Dried in greenhouse	Colloidal material
6. Dried in greenhouse and ultra-violet light	Organic colloids
7. Dried in sun	Sand and silt
8. Dried in sun and ultra-violet light	
9. Dried in oven	

Scale 1 cm. = 1 cm.

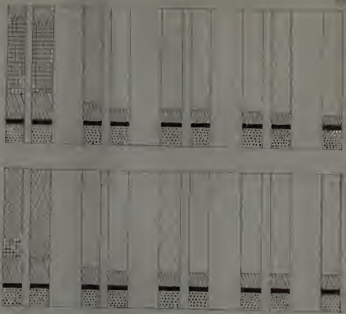

Fig. 2. Effect of drying and ultra-violet light on rate of swelling in soils at end of [illegible] and [illegible] days.

Treatment

1. Moist soil - untreated
2. Moist soil and ultra-violet light
3. Dried in shade
4. Dried in shade and ultra-violet light
5. Dried in greenhouse
6. Dried in greenhouse and ultra-violet light
7. Dried in sun
8. Dried in sun and ultra-violet light
9. Dried in oven

Legend

Scale: 1 mm. = 1 cm.

at intervals of four days. Pl te 1 shows the degree to which the colloid l material had settled out at the end of 23 days.

The sand and silt settled out in a few hours time, the organic colloids shown in black, settled out in all tubes at about the same rate. It will be observed that the settling out of the colloidal material and the clarification of the solution is in proportion to the severity of treatment that is the more severe the treatment of drying or ultra-violet light, the more rapid has been the rate of settling. It will also be noted that the differences in the rate of settling between the untreated soil and the moist soil receiving the ultra-violet light is slight. Greater differences in this regard were observed in the samples that had been dried; the ultra-violet light treatment in every case showed an increase in the rate at which the colloidal material settled out. Evidently the ultra-violet light had a greater effect on the colloidal fraction of the soils that had been subjected to the drying condition than that which had been kept moist from the start.

It would seem from the work of others and from the work reported in this paper that the influence of drying and heating and ultra-violet light is largely the result of physical causes. According to certain physical conceptions

1 2 3 4 5 6 7 8 9

Plate 1

Treatment: 1. Moist soil untreated

2. Moist soil and ultra-violet light

3. Dried in shade

4. Dried in shade and ultra-violet light

5. Dried in greenhouse

6. Dried in greenhouse and ultra-violet light

7. Dried in sun

8. Dried in sun and ultra-violet light

9. Dried in oven

the moisture distributes itself as a thin film around the particle or possibly within the particle itself and is held by an enormous pressure. Under such conditions the concentration of the film water with reference to mineral matter should be much greater than that of free capillary water in the soil.

Upon heating the soil to 100° C. alterations in the films would take place through evaporation and partial dehydration of the colloids thus destroying the pressure by which the film was previously held around the particles. During the course of evaporation the concentration of the soil moisture would increase to the saturation point after which the mineral matter would be deposited on the film as evaporation went on.

Since ultra-violet light has the effect of reducing the charge carried by the particles on which it acts, a slow coagulation would take place which would increase the rate of precipitation and any increase in the mineral constituents would favor this precipitation. It has long been recognized that ionic adsorption is highly specific in regard to colloids. Cations are more effective as precipitants when added in the smallest concentrations than are the anions. The results obtained are in harmony with these views.

Ammonification

The purpose of this experiment was to determine the effect of drying and ultra-violet light treatment on ammonification in soils.

The ammonia was determined colorimetrically by the use of Nessler's reagent.

The results are shown in Table I and figures 4, 5, 6, 7, and 8. It will be observed that the amount of ammonia produced increased with the severity of the treatments. The samples receiving the ultra-violet light treatment were higher in ammonia at the start in every case. As nitrification set in the ammonia rapidly disappeared until only mere traces were present at the end of the experiment. The ammonia in the soils receiving the light treatment disappeared more rapidly and was always lower toward the end of the experiment than those not receiving this treatment. Figure 8 shows the effect of oven-drying on ammonia production. A slight increase was obtained at the start, followed by a more rapid increase, the maximum being obtained at the end of 28 days. This was followed by a rapid decrease as nitrification became more vigorous.

Drying, heating, and ultra-violet light treatment is equivalent to partial sterilization of soils which is

Table I. Ammonia production in parts per million of dry soil

Sample number	Treatment	Time -- days 0	2	7	14	28	57	97	Ave.	Increase due to u.v. light
1	Untreated	1.6	1.4	4.0	tr.	3.6	tr.	tr.	1.5	
2	Moist soil and u.v. light	1.0	2.9	5.0	"	3.0	"	"	1.7	0.2
3	Dried in shade	5.0	3.3	3.9	"	2.8	"	"	2.1	
4	Dried in shade and u.v. light	5.3	4.7	3.3	"	3.0	"	"	2.4	0.3
5	Dried in green-house	6.6	8.0	3.4	"	2.4	"	"	2.9	
6	Dried in green-house and u.v. light	6.6	9.5	3.4	"	2.3	"	"	3.1	0.2
7	Dried in sun	5.3	8.7	7.5	"	2.2	"	"	3.4	
8	Dried in sun and u.v. light	6.0	9.5	7.2	"	2.4	"	"	3.6	0.2
9	Dried in oven	8.0	8.7	18.5	28.2	50.0	37.5	9.5	21.6	

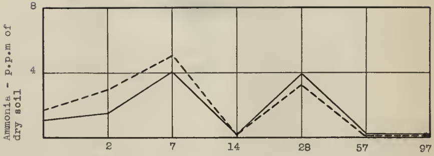

Fig. 4. Time -- (days)

______ Untreated -- moist soil

------ Moist soil and ultra-violet light

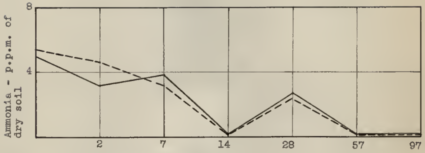

Fig. 5. Time (days)

_______ Dried in shade

------- Dried in shade and ultra-violet light

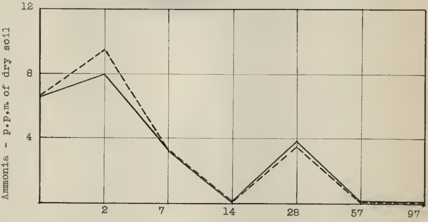

Fig. 6. Time (days)

_______ Dried in greenhouse

------- Dried in greenhouse and ultra-violet light

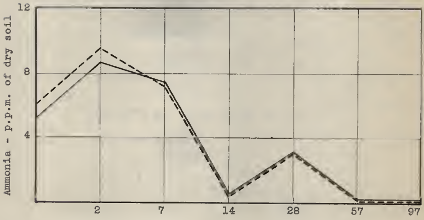

Fig. 7. Time (days)

______ Dried in sun

------ Dried in sun and ultra-violet light

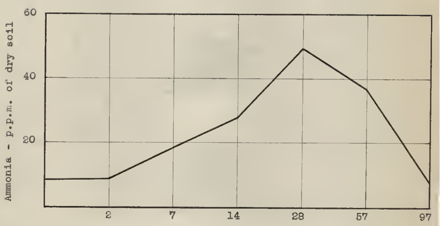

Fig. 8. Time (days)

Oven-dried

thought to bring about a chemical change in the organic matter of the soil, making it more available as a source of energy for microorganisms. The non-spore bearing bacteria are the first to become active, if the treatment has not been too severe, and multiply rapidly upon remoistening. In the absence of nitrifying bacteria the nitrogen accumulates as ammonia which is in this case a waste product.

In the case of the samples heated in the oven it seems reasonable to assume that all but the more resistant spore forming organisms were killed. This assumption is borne out by the fact that the bacterial numbers were greatly reduced at the start and no ammonia accumulation occurred until they again became active. This increase in ammonia persists until after nitrification sets in after which it disappears rapidly.

Nitrification

The object of this experiment was to determine the effect of drying and ultra-violet light treatment on nitrate production in soils. The nitrate was determined by the phenol-di-sulfonic acid method. The results are shown in Table II and figures 9, 10, 11, 12 and 13. By inspection of these graphs it may be seen from figure 9 that on

Table II. Nitrate production in parts per million of dry soil

Sample number	Treatment	Time -- days 0	2	7	14	28	57	97	Ave.	Increase due to u.v.
1	Untreated	34.7	40.0	41.5	44.7	52.6	90.9	100.0	44.1	
2	Moist soil and u.v. light	38.0	42.0	47.5	62.7	58.8	88.8	108.1	63.7	19.6
3	Dried in shade	20.0	39.0	90.2	111.0	117.6	137.9	153.8	95.6	
4	Dried in shade and u.v. light	16.6	42.0	110.0	111.0	123.1	160.0	177.7	105.6	10.0
5	Dried in green-house	12.7	22.2	85.0	114.2	140.3	186.0	210.5	110.1	
6	Dried in green-house and u.v. light	13.6	22.2	80.0	137.9	160.2	210.5	210.5	119.2	9.1
7	Dried in sun	13.6	16.3	41.2	135.6	170.2	222.2	251.6	121.5	
8	Dried in sun and u.v. light	12.8	17.3	40.0	160.0	177.8	250.0	235.3	127.6	6.1
9.	Dried in oven	27.9	26.6	30.2	23.5	28.5	57.9	296.3	55.7	

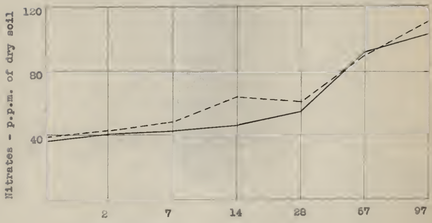

Fig. 9. Time (days)

_______ Untreated -- moist soil

------- Moist soil and ultra-violet light

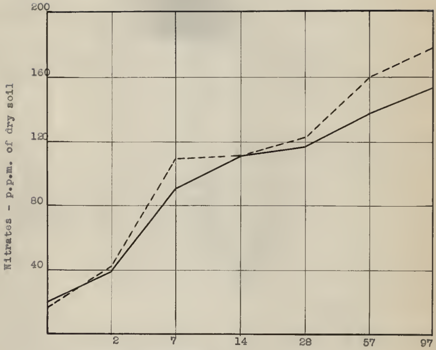

Fig. 10. Time (days)

______ Dried in shade

------- Dried in shade and ultra-violet light

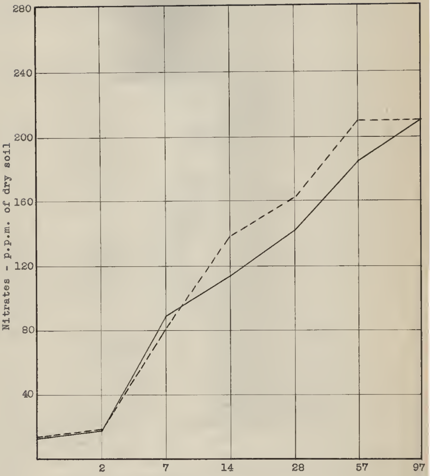

Fig. 11. Time (days)

______ Dried in greenhouse

------ Dried in greenhouse and ultra-violet light

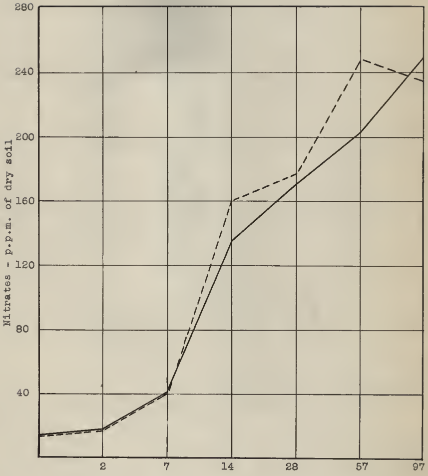

Fig. 12. Time (days)

———— Dried in sun

------- Dried in sun and ultra-violet light

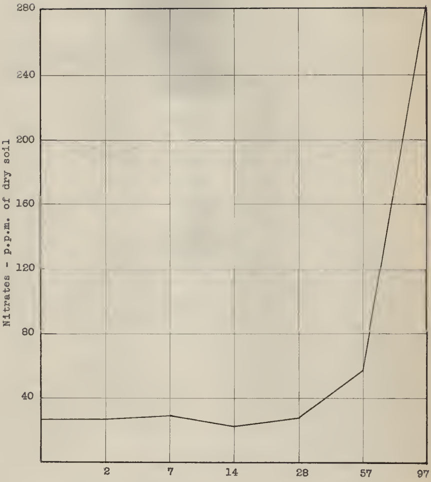

Fig. 13. Time (days)

Dried in oven

the moist soil ultra-violet light treatment has had more effect on nitrate production than on the samples that were air-dried. In the case of the air-dried soils the effect has also been to increase nitrate production, and the increases obtained bears some relation to the conditions under which the soil was dried as in the case of figure 9 the curves run more or less parallel. The samples receiving the ultra-violet light treatment being higher in every case in nitrates than those not receiving this treatment. Figure 13 shows the production of nitrates in the sample which had been oven-dried. A slight increase was obtained at the start followed by a slight decrease, until at the end of 57 days nitrification became very rapid. The time for maximum nitrification to take place was delayed as the severity of the treatments were increased.

Since nitrification is a biological process it seems only reasonable to conclude that due to the effect of partial sterilization the nitrifying organisms have been temporarily put out of action thus accounting for the decrease in nitrates. Upon remoistening conditions were made more favorable for the development of these organisms, so that after a short period of time nitrification became rapid which resulted in the disappearance of ammonia and the accumulation of nitrates in the soil.

In the oven-dried soil the nitrifying organisms would all be killed since these organisms do not produce spores. Nitrification in this case seems to have developed from contamination from outside sources.

It will be observed that the curves for nitrates are just opposite to those for ammonia and that the determination of the nitrate content preceded somewhat the increase in the numbers of microörganisms.

Soluble Calcium

The object of this experiment was to determine the effect of drying and ultra-violet light on the amount of calcium removed in a 1:5 water extract.

The calcium was determined by the turbidity method on duplicate samples of the water extract. The results are shown in Table III and figures 14, 15, 16, 17, and 18. The amount of water soluble calcium was always greater in the samples treated with the ultra-violet light and that the maximum amount was obtained on the seventh day after adjusting the moisture content to 20 percent.

After this a slight decrease was obtained until toward the end of the experiment when the amount of water soluble calcium again increased. Nitrific tion and the accumul-

Table III. Water soluble calcium in parts per million of dry soil

Sample number	Treatment	Time -- days 0	2	7	14	28	57	97	Ave.	Increase due to u.v. light
1	Untreated	27.9	34.5	41.5	26.0	42.7	24.3	32.5	32.8	
2	Moist soil and u.v. light	28.5	41.5	39.0	31.5	40.0	28.8	57.0	37.9	5.1
3	Dried in shade	35.5	48.5	50.5	36.5	53.5	31.2	60.0	45.1	
4	Dried in shade and u.v. light	39.0	53.0	62.5	38.0	58.5	33.9	61.5	49.5	4.4
5	Dried in greenhouse	38.0	50.5	65.0	46.8	70.5	39.0	63.0	53.2	
6	Dried in greenhouse and u.v. light	39.0	58.5	80.0	48.7	70.5	46.0	67.0	57.1	3.9
7	Dried in sun	43.0	53.0	73.0	45.0	68.0	52.0	80.5	59.2	
8	Dried in sun and u.v. light	63.0	58.5	97.5	48.9	70.5	55.5	83.5	63.9	4.7
9	Dried in oven	137.5	115.0	97.5	58.5	50.3	31.0	114.0	86.2	

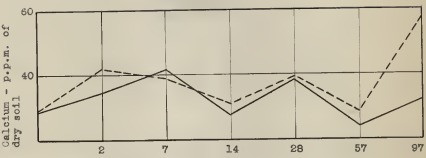

Fig. 14. Time (days)

——— Untreated -- moist soil

------- Moist soil and ultra-violet light

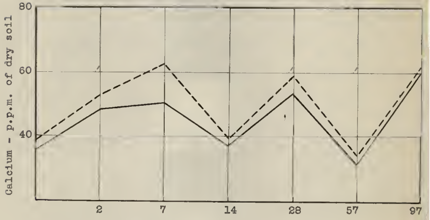

Fig. 15. Time (days)

______ Dried in shade

------- Dried in shade and ultra-violet light

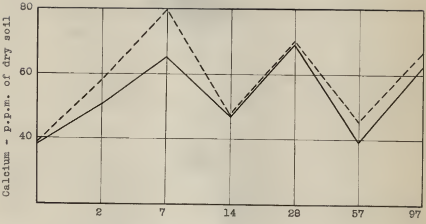

Fig. 16. Time (days)

______ Dried in greenhouse

------- Dried in greenhouse and ultra-violet light

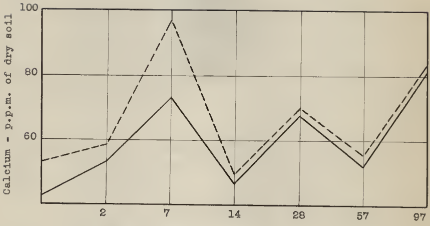

Fig. 17. Time (days)

_______ Dried in sun

------- Dried in sun and ultra-violet light

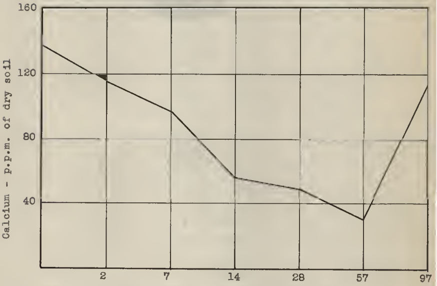

Fig. 18. Time (days)

Dried in oven

ation of nitrates evidently increased the water soluble calcium. Figure 18 shows the effect of oven-drying. A large increase was obtained at the start. This gradually decreased until toward the end of the experiment, when as nitrification became more vigorous, the amount of soluble calcium rapidly incr ased. King (11) has shown that reabsorption takes place if the water is left in contact with the soil for some time after shaking. This was undoubtedly what occurred in the soil after bringing the moisture content up to optimum and would explain at least in part, the disappearance of calcium as shown in the amount obtained in a water extract.

In regard to the effect of ultra-violet light on the solubility of calcium it may be stated, as previously mentioned, that the light reduces the charge carried by the calcium ion. In the humus fraction of the soil some of the calcium would exist in the form of calcium humate and a reduction in the char e would increase its solubility.

According to Helmholtz polar molecules may be orientated at the interface between th particle and the dispersing medium. This phenomenon will caus a difference of potential between the surface of the dispersed phase and the outer dispersing medium which would result in the formation of an electric double layer.

Negative ions present in the dispersing medium, as for example chlorine ions, would tend to combine with the positively charged calcium ions, since a reduction in the charge of the soil particle has taken place, thus giving conditions for its increased solubility.

Bacterial Numbers

The purpose of this experiment was to determine the effect of drying and ultra-violet light on the bacterial content of the soils.

The soil was thoroughly mixed with a clean spatula and give grams of it was weighed out into sterile flasks. Sterile tap water (100 c.c.) was added and the mixture shaken for five minutes. Further dilutions were made by adding one c.c. of the suspension to an exact amount of sterile tap water and shaken for one minute, such that the final suspension used for plating would develop from 25 to 200 colonies per plate.

The plates were prepared by inoculation with one c.c. of the final dilution. The results were based on the average of three plates.

Incubation of Plates and Counting

The plates were incubated for seven days at a temperature of 25° to 27°C. At the end of the incubation period all colonies were counted. It was convenient in all cases to count the colonies with the naked eye by marking them. The plates, however, were examined with a hand lens for possible colonies that might have escaped the previous counting.

Media used:

Lipmans and Browns synthetic agar media of the following composition:

Distilled water	1000 c.c.
Agar -- Difco Standard	20 grams
Peptone	.05 grams
Glucose	.10 grams
$MgSO_4$	.20 grams
K_2HPO_4	.50 grams

The results are shown in Table IV and figures 20, 21, 22, and 23. In general, the effects of drying and ultraviolet light was to reduce the numbers at the start followed by a rapid increase which gradually decreased, and tended to reach equilibrium toward the end of the experiment. Ultra violet light seems to have had little addition-

Table IV. Growth of bacteria in soils -- millions per gram of dry soil

Sample Number	Treatment	Time -- days 0	2	7	14	28	57	97	ve.
1	Untreated	5450000	6400000	6250000	6400000	3750000	4650000	4125000	5289285
2	Moist soil and u.v. light	3175000	2925000	4400000	8150000	5500000	825000	3525000	4071428
3	Dried in shade	600000	2800000	3500000	4650000	2750000	1925000	3632500	2[illegible]36785
4	Dried in shade and u.v. light	740000	3300000	2500000	3575000	2500000	2500000	358[illegible]500	2671071
5	Dried in greenhouse	617000	3550000	4925000	4400000	2500000	2825000	3062500	3125643
6	Dried in greenhouse and u.v. light	482500	2700000	4750000	3500000	2500000	1575000	3537500	2720643
7	Dried in sun	382500	3950000	43[illegible]5000	6000000	5050000	2425000	3590000	3674785
8	Dried in sun and u.v. light	400000	1275000	3750000	4575000	3925000	3500000	3182500	2943928
9	Dried in oven	440	370000	425000	33500000	16000000	14575000	12307500	11025420

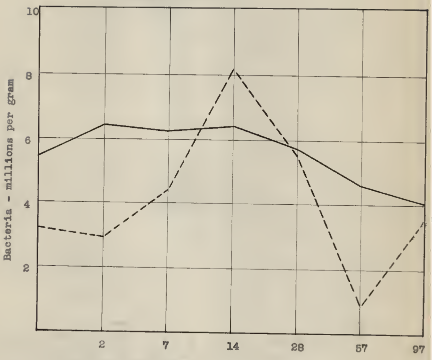

Fig. 19. Time (days)

——— Untreated - moist soil

------- Moist soil and ultra-violet light

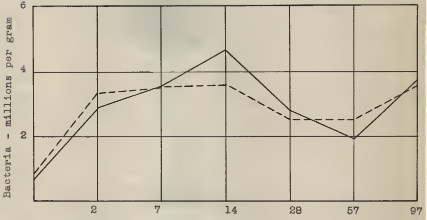

Fig. 20. Time (days)

_______ Dried in shade

------- Dried in shade and ultra-violet light

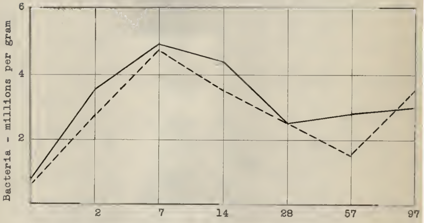

Fig. 21. Time (days)

______ Dried in greenhouse

------- Dried in greenhouse and ultra violet light

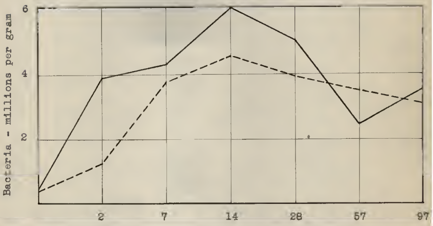

Fig. 22. Time (days)

_______ Dried in sun

------- Dried in sun and ultra-violet light

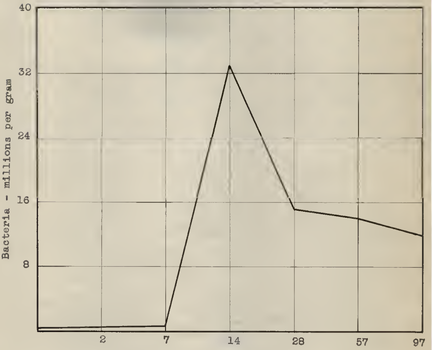

Fig. 23. Time (days)

Dried in oven

al effect over the drying.

Figure 23 shows the effect of oven-drying. Very little increase in total numbers was obtained until at the end of 14 days, after which a very rapid increase was obtained which gradually decreased toward the end of the experiment tending to reach the same level as obtained in the other samples.

Growth of Alfalfa and Red Clover

This part of the work was designed to determine the effect of drying and ultra-violet light on the growth and nodulation in alfalfa and red clover.

As soon as possible after the various treatments of the soil had been completed, 190 grams of soil, in the case of alfalfa, and 150 grams of soil, in the case of red clover, was weighed out into glass tumblers which had previously been coated with lamp black. The moisture content was made up to 20 percent with distilled water and the tumblers allowed to stand for some time to allow the water to distribute itself throughout, after which the soil was cultivated. Eight seeds were planted in each tumbler and later thinned to three plants. The tumblers were removed to the greenhouse and left uncovered, no precautions being taken against contamination.

Plates 2 and 3 show the plants after two weeks growth. An inspection of Tables V, V-A, VI, and VII shows the effects of drying and ultra-violet light on top and root growth of alfalfa and red clover. In Table V half of the alfalfa plants were harvested after a growth period of 68 days. It will be observed that the light treatment had given a small percentage decrease except in the case of the moist soil which showed a slight increase.

In the case of alfalfa the plants remained a bright green color and differences in growth were maintained throughout the growing period, while in the case of red clover a steady decrease in growth occurred and after about two weeks of growth the plants assumed a pale green color. This was probably due to the fact that the soil was not well inoculated with red clover. These results and conclusions are in harmony with those obtained by Kelley (13) and Duley and Metzger (5) who found little effect of ultra-violet light on wheat plants, but obtained marked increases on the oven-dried soil.

In Table V-A are shown the results of the other half which was harvested after a growth period of 85 days. It will be noted here that the results in top and root development are just opposite to those given in Table V. The percentages are also considerably greater. Table VI gives a

Plate 2

Treatment: 1. Moist soil untreated
2. Moist soil and ultra-violet light
3. Dried in shade
4. Dried in shade and ultra-viol t light
5. Dried in greenhouse
6. Dried in greenhouse and ultra-violet light
7. Dried in sun
8. Dried in sun and ultra-violet light
9. Dried in oven

Plate 3

Treatment: 1. Moist soil untreated
2. Moist soil and ultra-violet light
3. Dried in shade.
4. Dried in shade and ultra-violet light
5. Dried in greenhouse
6. Dried in greenhouse and ultra-violet light
7. Dried in sun
8. Dried in sun and ultra-violet light.

summary of V and V-A. It will be seen from this that drying and ultra-violet light has had little or no effect on production of nodules in a soil normally inoculated with these organisms. In the oven-dried sample the treatment has been severe enough to greatly decrease the number of nodules, and the few that did appear may have been due to contamination.

It will be noted in Table VII that neither drying nor ultra-violet light treatment had any appreciable effect on top and root development of red clover except in the case where the soil had been dried in the sun and given the light treatment in addition. A few nodules appeared on some of the plants but were likely due to contamination as the results would indicate that the soil was not normally inoculated with the organisms capable of producing nodules on the roots of red clover, as only one nodule was found in a total of 11 plants in the case of the check.

Table V. Effect of drying and ultra-violet light treatment of soil on growth of alfalfa

Treatment	No. of plants	Total no. of nodules	Ave. per plant	Dry wt. of tops	Dry wt. of roots	Percent increase in tops	Percent increase in roots
Untreated	6	93	15.5	0.67	0.29		
Moist soil and u. v. light	6	138	23.0	0.71	0.30	5.9	3.4
Dried in shade	5	158	31.6	0.78	0.35		
Dried in shade and u.v. light	6	145	24.1	0.75	0.34	-3.8	-3.8
Dried in green-house	6	120	20.0	0.74	0.31		
Dried in green-house and u.v. light	5	153	30.6	0.71	0.30	-4.0	-3.2
Dried in sun	6	131	21.8	0.72	0.31		
Dried in sun and u.v. light	6	119	19.8	0.70	0.24	-2.7	-22.5
Dried in oven	5	7	1.4	0.53	0.29		

Table V-A. Effect of drying and ultra-violet light treatment of soil on growth of alfalfa

Treatment	No. of plants	Total no. of nodules	Ave. per plant	Dry wt. of tops	Dry wt. of roots	Percent increase in tops	Percent increase in roots
Untreated	6	115	19.1	0.69	0.66		
Moist soil and u.v. light	5	134	26.8	0.55	0.55	-20.2	-19.1
Dried in shade	5	158	31.6	0.59	0.57		
Dried in shade and u.v. light	6	145	24.1	0.86	0.67	45.6	17.5
Dried in green-house	6	108	18.0	0.48	0.41		
Dried in green-house and u.v. light	6	148	24.8	0.57	0.53	18.7	29.2
Dried in sun	6	111	18.5	0.48	0.30		
Dried in sun and u.v. light	6	110	18.3	0.70	0.60	45.8	100
Dried in oven	6	44	7.3	0.33	0.57		

Summary Table VI. Effect of drying and ultra-violet light treatment of soil on growth of alfalfa

Treatment	No. of plants	Total no. of nodules	Ave. per plant	Dry wt. of tops	Dry wt. of roots	Percent increase in tops	Percent increase in roots
Untreated	12	186	15.5	1.56	0.95		
Moist soil and 3 hours u.v. light	10	240	24.0	1.26	0.85	-19.3	-12.3
Dried in shade	10	303	30.3	1.37	0.94		
Dried in shade and 3 hours u.v. light	12	273	22.7	1.61	1.01	17.5	7.4
Dried in green-house	12	228	19.0	1.19	0.69		
Dried in green-house and 3 hours u.v. light	12	281	23.4	1.31	0.83	10.2	20.3
Dried in sun	12	261	21.7	1.20	0.61		
Dried in sun and 3 hours u.v. light	11	208	18.9	1.40	0.84	16.6	37.7
Dried in oven	11	51	4.6	1.36	0.86		

Table VII. Effect of drying and ultra-violet light treatment of soil on growth of red clover

Treatment	No. of plants	Total no. of nodules	Ave. per plant	Dry wt. of tops	Dry wt. of roots	Percent decrease or increase due to light	
						Tops	Roots
Untreated	11	1	0.1	0.39	0.43		
Moist soil and u.v. light	12	29	2.4	0.45	0.42	15.3	-2.3
Dried in shade	11	5	0.5	0.73	0.70		
Dried in shade and u.v. light	10	16	1.6	0.81	0.63	10.9	-1.0
Dried in green-house	11	21	1.9	0.95	0.61		
Dried in green-house and u.v. light	8	1	0.1	0.96	0.64	1.0	4.9
Dried in sun	6	0	0	0.64	0.47		
Dried in sun and u.v. light	11	0	0	0.97	0.76	51.5	61.7
Dried in oven	11	0	0	1.01	0.95		

SUMMARY

1. Drying and ultra-violet light increase the rate of settling of soil colloidal material from an aqueous suspension. This effect is probably due to partial dehydration and a reduction in the charge carried by the colloidal particles.

2. The effect of drying and ultra-violet light has been to increase the amount of ammonia at the beginning. This rapidly disappeared upon remoistening the soil.

3. Drying and ultra-violet light decreased the nitrates at the beginning. This decrease was followed by a rapid increase as soon as conditions were made favorable for the development of nitrifying organisms.

4. The water soluble calcium showed a progressive increase in the amount recoverable in a water extract as the severity of treatment was increased. Ultra-violet light increased the amount recoverable in each case beyond that recovered from drying alone. This is probably also due to a decrease in the total charge carried by the calcium ions.

5. The bacterial content of the soils treated showed a marked decrease due to drying and ultra-violet light, followed by a rapid increase in numbers upon remoistening

the soil. The results would seem to indicate that drying had a greater effect than the light.

6. The effects of drying and ultra-violet light on the production of nodules in alfalfa seems to have had li tle or no effect when the soil was normally inoculated with these organisms. In the case of red clover, the treatment increased the growth for a short period, which was followed by a steady decrease in vigor and growth. Very few, and in most cases, no nodules were produced on the roots. This was probably due to the fact that the soil was not normally inoculated with these organisms.

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