

Graduating Thesis.

on the subject,

Underground Crop Production.

or

The Economic Relation of Micro-organic Life
in the soil, to Crops.

by

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Underground Crop Production.

or
The Economic Relation of Micro-organic Life in the
Soil, to Crops.

Analytic Synopsis.

A. Introduction.

B. The Farmers Business.

C. Micro-organic Life, — What it is.

I Shape.

II Size.

III Life History.

IV Habitat.

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D. Analogy of food of man, and of plants.

I Necessity of Nitrifying processes.

II How the plant feeds.

III Knowledge of plant food.

1. Nitrogen and its sources.

2. Nitrates and their peculiarities.

E. Ferments.

I. Analogy or comparison with yeast.

II. Requirements;

1. Moisture, darkness and warmth.

2. Presence of decaying organic matter.

III Kinds,

Three.

1. Freeing Ammonia.

2. Nitrous or Transitory.

3 Nitric.

IV Individual bacterium.

1. Shape- spherical.

2. Exceedingly small.

3. Found in first three feet of earth.

4. Power of penetration modified by the subsurface.

5. Necessary temperatures, and damage by drought.

6. Necessity of abundant moisture.

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F. Benefits from Cultivation.

- I. Stirring the soil redistributes the germs.
- II. Aerates the soil
- III. Every cultivation as good as a coat of fertilizer, even the application of nitrates of sodium.
- IV. Improved, common sense cultivation will double the productivity of the soil.

Underground Crop Production.

or

The Economic Relations of Micro-organic life in the
Soil, & Crops.

The subject of Crop Production is one of almost unlimited importance, we might even say, supremely so; for as the sage and historian tells us, a Nations prosperity is inseparably linked with the prosperity of its producing masses — the people. But they say more; that this foundation of prosperity rests with the farming classes; and we will not deny it, because our educational system has made them the best informed class of people on earth; and their constant communion with nature, instead of the perverted desires of the inhabitants of our great business centers, has given to them an integrity of purpose and honesty of intention, that has made the farmer on his farm, a king. Considering as settled, the proud position of the farm and the farmer, let us come to the consideration of the

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subject of crop-production.

This is pre-eminently the farmers business, and the business man must consider his work from all points of view, and then select such facts or methods as will prove beneficial to him in his particular line, whether it be wheat, corn alfalfa or milk. In regard to methods of preparation of soils, time of seeding, character of seed, cultivation, harvesting, and even feeding the product, there exists as many different ideas, as to how all these should be done, as there are producers, and this is in a manner, right, for every farmer even neighbors may have to work under conditions so different as to call for entirely different methods along some lines, and this is certainly true of different sections of our great nation or even of states, for different climatic conditions, or widely different soils calls for perhaps opposite methods of treatment, in order to secure the best returns.

In our subject, we refer to micro-organic life, and before we attempt to consider the relation they bear to crop production, we must first consider them as to what they are, their shape, size, habitat, and life history in a general way. We will find them referred to in a broad sense in this

subject of crop-production.

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discussion, as Bacteria, Germs, Microbes or Ferments.

All of these organisms are very small, in fact they can only be studied by the aid of a powerful microscope, but to give a numerical idea of their size, we find them varying from one twenty-five thousandth to one twenty-five-hundredth of an inch in size. We can hardly conceive how minute these are, but it may help our conception to say that an almost countless number can live and swim about in a single drop of impure or stagnant water. In shape, we find all variations: the Spherical or roundish; the rods, bent, straight, or curved and the long stringy or thread like forms; these three general classes and their subdivisions, comprise the most of the well-known classes of Bacteria with which we deal.

We will draw a simple analogy, which will, perhaps, be beneficial in explaining a complex process. Man in daily life consumes food. This food is composed of fats, starches or carbonaceous matter and proteids or compounds of the albuminoids. These food elements are unfit to be built into the body tissues, until they have been torn down by the digestive juices, or built into new material which can be assimilated, or built into muscle, bone or brain. Just so with the plant

only, as we shall see, the digestive juices of man are replaced in plant growth by the peculiar action of the microbe in the soil. We call the elements composing plant food, Nitrogen, Phosphoric acid, and Potash. These elements in varying quantities exist in commercial fertilizers, farm manures, decaying straw or leaves, or in fact, any decaying vegetation or partially decomposed organic matter. These elements cannot be used by the plant while in this form, but must be digested, torn down and built into a new and soluble substance. This is the process known to science as "Nitrification", and in the rest of this paper we will confine our study to the first named element, viz.: Nitrogen, and its metamorphosis. Perhaps before considering plant food, it would be well to consider how they feed.

Each plant is supplied with a more or less elaborate root system; these roots give the plant its crude nourishment in a soluble state, which is carried along by water in its upward passage. The entire absorbing process is provided for by an infinite number of root hairs, almost microscopic in size, yet each possessing the definite function of absorbing soluble liquids containing plant food.

Knowledge of plant food is of comparatively recent date, because it is only of late years that the knowledge has been made definite as to food and manner of feeding. We now have the assurance that the crude plant food is assimilated into plant tissue by the specific action of three classes of microbes. Plant growth requires the three distinct food elements, before mentioned, and as we stated it is in the first of these that we are particularly interested. This required Nitrogen can only be taken up by the root system of the plant when in the soluble form of nitrates. If, then, these Nitrates are of such importance, it is well that we should know something of the conditions which favor their formation. Soil containing animal or vegetable substances will, if exposed, produce these Nitrates, and as the physical conditions are more favorable, the Nitrates are formed much more rapidly in the hot summer weather, than when cold. These Nitrates are peculiar substances, in that they are not the product of an oxidation, nor are they the result of plain chemical reaction, but are produced by the action of microscopic, organized, ferments.

We do not know the exact action of these ferments, but we find, that when examined under the microscope, they look like the yeast fungus, and by careful study, we learn something of their habits. There are three essential conditions, moisture, darkness and warmth, and without these three, or lacking any one of them, the bacteria refuses to grow. The kind of soil in which they make their home, makes but little difference, so long as there is some decaying organic matter present, and they have the three above named conditions.

The microscopist has been able to determine three distinct species of these little plants, and that each species has its specific function. The First, causes the early stages of decay in organic matter, and sets free ammonia gas (NH_3). The Second, combines the liberated NH_3 , with the free oxygen of the air, forming nitrous acid, which by combining with the bases in the earth, forms an insoluble salt, called a Nitrite. This second is a mere transitory process, and the nitrite is hardly formed before it is attacked and torn down by a third set of micro-organisms, and oxidizes the nitrous acid, transforming it into Nitric acid, and again a salt is formed in combination with the earth; but this time it is soluble,

and the last step in the preparation of plant food has been completed. It is now ready to make the ascent as crude sap, to be finally worked over and elaborated by the mysterious power of photosyntax, then built into walls and tissue.

Perhaps it would at this point, be well to consider the individual bacterium, and gain some idea of its size and shape. It is nearly spherical, and so small that in a single grain of ordinary soil will be found from thirty thousand to one and a half million. We find these almost altogether in the upper three feet of soil, the first nine inches being especially highly charged, and below this the earth is almost sterile, leaving the ground water free from microbes. Of course the depth to which they penetrate depends upon the compactness of the sub-soil and the amount of humus present, yet too great an amount of humus, is as bad as none at all as far as bacteria are concerned; for under such circumstances, they refuse to form the nitrates. The last statement, tho a scientific fact, would be an exceptional case, and need not trouble the Kansas farmer.

We referred briefly to the three necessary physical conditions, but will now consider these a little more

fully. As this location suggests darkness, and as capilarity usually supplies the necessary moisture, we need not dwell upon these two points, but when we consider the matter of warmth, we find it of more importance, because it exercises a vital influence upon the value of the processes which forms the basis of our discussion. We find them very feeble below 40° Fahr., active at 54°, and reaching their maximum activity at 98° or 99°, but above 100°, decreasing very rapidly. With other things equal, they will form ten times as much Sodium Nitrate ($NaNO_3$), or as it is known in the market, Chilli Saltpeter, at 99°, as at 57°.

The process of Nitrication reaches its maximum in the months of July and August, that is if the three essential physical conditions be present, the process ceases, for contact with dry air kills the germ, or causes it to become dormant. This is one reason why manures or fertilizers should be applied in the spring, for then the food is present to be worked upon just when the organisms have the greatest power to digest their food. These ferments need food, in fact, certain foods are indispensable to their development; Phosphates come under this head, for a small amount is necessary for the ash ingredient of the plant.

Also oxygen and some compounds of carbon.

The Nitrous ferment can feed upon organic matter yet this is not necessary for the production of nitrates, since both nitrifying organisms can assimilate the carbon directly from carbonic acid gas (H_2CO_3).

Moisture is also one of the important elements, and for this reason we find the bottom or low lying lands much richer in nitrates than the uplands, and this has been assigned as one reason why alfalfa, which is an extensive consumer of nitrogen, does so much better upon the low land than upon the high.

In our methods of cultivation we can do much to promote nitrification, by a more complete system of stirring the soil, both in preparation for the crop, and in its cultivation during growth; for by thorough tillage we continually redistribute the germs, and bring them into contact with a fresh supply of food.

There are some conditions under which the germs will not thrive, and some where they they cannot live. If land has a tendency to be wet and soggy, it will soon become sour, and then acid in reaction, and an acid medium is sure death to germs of this sort. In cases of this kind it may be necessary to give the land a

a dressing of lime, which will neutralize the acidity, as soon as the lime is formed into a carbonate, and the water strained away to restore it to a normal condition. Also if the land is rich in deposits of a saline nature, or has had placed upon it such chemicals as cole-tar, or chloroform, it will be slow work until these poisons are neutralized, then we can start in with a clear field.

Because this phase of crop-production is new it is by no means unimportant. In fact, it is all important, for as Professor Chute says, "It is a fact not fully appreciated by laymen, that our crops, and hence, the very existence of agriculture, is dependent upon the activity of micro-organisms in the soil," for if present in sufficient numbers, they keep up a constant supply of food for growing crops. The Chemist tells us that an acre of soil three feet in depth may contain from seven to thirty thousand pounds of Nitrogen, and that a ton of a single crop such as clover, may use up but fifty pounds of this great store, yet the fact remains that this same store of nitrogen might as well be at the bottom of the sea, as far as its value as plant food is concerned, but for the action of the modest yet omnipresent germs.

But what is the practical application? It has been demonstrated that every thorough cultivation of the soil, is as valuable as a coat of commercial fertilizer. Also if we can aerate our land thoroly, either by tillage or by sub-drainage, and institute a system of deep and frequent plowing, then the common sense application of these principles will in fact make two ears of corn grow where one grew before, and give to the farm the old time prosperity of the days of the virgin soil.

Note. Special reference, as to data, has been made to the bulletins of the Experiment Station of Delaware.

Robert Bertice Mitchell, '99.