OUTLINES OF SOIL SUBJECTS FOR TEACHERS

Thesis for the Degree of M. Agr.

Charles Henry Spurway

1914

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THESIS

PREFACE

Teaching outlines give logical sequence to subject matter. These outlines are not by any means complete, but they include the most practical and the best founded data of the present time. They are not intended to furnish subject matter for lectures, but rather to hold the line of thought directly upon one subject. They should be supplemented by other information gathered from the literature and teacher's own experience.

C. H. S.

SOIL FORMATION.

A. Soils are formed from rocks.

1. The amount of plant food in rocks varies with the different kinds, and the fertility of a soil depends somewhat upon the kind of rocks decomposed.

2. Discuss the effects of the following on rock decay and soil formation.

   (a) Air, wind, oxygen, and carbonic acid gas.

   (b) Heat and cold.

   (c) Water - freezing and thawing, solution, etc.

   (d) Ice - glaciers.

   (e) Plants and animals.

   (f) Loval examples may be:

      (1) Sand dunes, sand or gravel pits (wind and water), brown streaks of iron rust in soils and clay banks, lime in well water, etc.

      (2) Expansive power of freezing water.

      (3) Soil materials deposited in different places by running water.

      (4) Soil formations left by ice sheet.

      (5) Muck and swamp soils, work of earth worms, burrowing animals, beaver dams, etc.

3. Merrill's Classification of soils.

   (a) Sedentary soils.

      (1) Residual - decay of rocks in place.

      (2) Cumulose - accumulated materials.

   (b) Transported soils.

      (1) Gravity or colluvial - on slopes.

(2) Water

(a) Marine - on sea coasts.
(b) Lacustrine - lake bottoms.
(c) Alluvial - river deposits.

(3) Glacial soils - formed by glaciers.

(4) Aeolian soild - formed by wind.

4. How to tell the different soil formations:

(a) Residual - absence of evidences of ice and water action, usually highly colored - red or yellow, presence of refractory materials, texture not uniform.

(b) Cumulose - Accumulations of partially decayed plant remains.

(c) Gravity or colluvial soils - Accumulations on side hills and at bottoms of steep slopes.

(d) Water:

(1) Marine - stratified materials deposited in shallow water along shores.

(2) Lacustrine - unassorted glacial material on bottoms of old glacial lakes.

(3) Alluvial - Stratified materials in river valleys.

(e) Aeolian - assorted, rounded, material usually in layers or piles.

(f) Glacial - unassorted materials found in formations peculiar to glaciated regions.

5. In the process of soil formation different soils have been formed.

(a) Discuss soil provences of the United States and their formation. - Use map.

(b) Discuss the general soil formations of Michigan.- Use map.

(c) Discuss the formation and relative fertility of the following Michigan soils and show causes.

(1) Upland soils.

(2) Lowland soils.

(3) River bottoms.

(4) Swamp and mucks.

(5) Prairie soils.

(6) Ash and elm bottom lands.

(7) Beech and maple soils.

(8) Oak openings soil.

(9) Oak and hickory soils.

(10) Black walnut land.

(11) Northern hardwood lands.

(12) White pine soils.

(13) Jack pine soils.

PHYSICAL PROPERTIES OF SOILS.

A. A soil is made up of small particles called soil grains.

1. The soil grains are of many sizes, shapes and colors.

2. Pore space.

   (a) The space between soil particles is called pore space.

      (1) Pore space is due to the shape of the particles.

      (2) The amount of pore space depends upon size, shape, degree of packing of soil grains, and kind and quantity of soil matérials.

   (b) Show presence of pore space by pouring water on sand in graduate.

   (c) Determine per cent of pore space in a sandy soil.

   (d) Discuss pore space in sand, loam, clay, and muck soils; also in soils and subsoils.

   (e) Make list of things in the pore space of soils - air, water, plant roots, bacteria, etc.

   (f) Make list of processes that go on in soil pore space - solution, absorption, nitrification, etc.

3. Texture, structüre, and tilth.

   (a) Texture refers to the size of soil grains.

   (b) Structure refers to arrangement of soil grains.

   (c) Tilth refers to degree of structure under field conditions - good tilth proper structure for any soil; poor tilth improper structure.

   Note. - Show examples of above.

   (d) Show classes of soil as determined by texture - mechanical analysis.

4. Crumb structure.

   (a) Show difference between crumb structure and single grain structure.

   (b) Show crumb structure with per cent of pore space - by diagram.

(c) Show how small grains may fall between large ones and reduce pore space.

(d) Show what "puddling" the soil means.

5. Causes of crumb structure.

(a) Water content.

(1) Soils must contain the right amount of wat_er when they are worked by tillage implements.

(2) Surface tension.

(a) Explain surface tension - float needle on water.
(b) Show action of films, and location on frames by soap bubbles. - The film always occupies the smallest possible area.
(c) Show water films on soil grains - one grain, two grains, three or more grains.
(d) Show action of films on body of soil - pyarmid on watch glass.

(b) Organic matter.

(1) Binding power on sand and separating power on clay.

(c) Colloidal material.

(1) Composed of clay, silica, iron, and aluminum hydroxide, other hydrated compounds, and organic matter, and exerts a binding power.

(d) Soluble salts.

(1) Have binding power and flocculate or deflocculate colloidal material.

(e) Cohesion.

(f) Frost - ice crystals.

(g) Changing volume.

(1) By frost.

(2) By expansion and contraction.

(h) Biological factors.

(i) Drainage.

6. Benefits of crumb structure.

   (a) Free passage for roots.

   (b) Better movement of water and plant food.

   (c) More complete aeration.

   (d) Freer drainage.

   (e) Better germination of seeds.

7. How crumb structure may be destroyed.

   (a) By heavy rains.

   (b) By working soil when too wet.

   (c) By deflocculating chemical compounds - alkalies and phosphates.

8. Means of modifying crumb structure.

   (a) By controlling water content.

      (1) By tillage to form soil mulch.

      (2) By tillage to compact the soil.

      (3) Other kinds of mulches.

   (b) Development of ice crystals.

   (c) Tillage.

   (d) Growth of plant roots.

   (e) Organic matter.

   (f) Fertilizers.

   (g) Growth of animals, etc., within the soil.

   (h) Controlling effects of heavy rains.

ORGANIC MATTER IN SOILS.

A. <u>Organic matter in soils is the name given to decayed or decaying plant and animal life of the soil.</u>

1. Physical properties of organic matter:

   (a) Has great absorbtive power for:

   (1) Water.
   (2) Substances in solution.
   (3) Gases.

   (b) Gives dark color to soils - discuss heat relationship.

   (c) Swells greatly when wetted.

   (d) Organic matter may be waxy and repel water to a certain degree.

2. Chemical properties of organic matter.

   (a) Chemical composition.

   (b) Chiefly protein, fat and carbohydrates. May contain resins, hydro-carbons, alkaloids, acids, etc.

   (c) Contains the plant food - nitrogen.

3. Effects on soil.

   (a) Increases coherence, density, capacity for water, and absorbtive power.

   (b) Promotes tilth, aeration, water supply, and furnishes nitrogen, phosphoric acid and potash to a certain extent.

   (c) Effects nitrification.

   (d) Prevents leaching and erosion.

4. Decomposition of organic matter in soils.

   (a) Effected by bacteria (See soil bacteria.)

   (b) The richer the soil in humus the more rapidly is plant food made available.

   (c) In arid regions and on sandy soils in humid regions organic matter decomposes rapidly - oxydized.

   (d) A free circulation of air and sufficient supply of lime are necessary to the decomposition of organic matter.

(e) Only humified organic matter can be directly nitrified.

(f) In decay oxygen and hydrogen are last, which means that nitrogen containing both resist the action of decay longer than carbohydrates; or that the carbohydrates leave the soil first along with the easily decomposed nitrogen compounds - amino acids.

(g) Under natural conditions vegetation fails when humification ceases or becomes raw humus.

(h) More humus is found in pasture or forest than in a tilled field because of better aeration in a cultivated field, hence faster decomposition.

(i) The effect of green manure is increased by the addition of barnyard manure due to the inoculation of bacteria of decomposition.

(j) Decomposing organic matter in soils forms compounds with phosphorus which may become available again.

5. Organic matter and soil fertility.

(a) Decomposing organic matter in the soil necessaryto fertile soils - supplies nitrogen and causes beneficial structure.

(b) Lack of fertility very often due to lack of organic matter.

(c) Soils which have grown corn, potatoes, and small grains, without manure are usually deficient in organic matter.

(d) Crop rotation benefits soils by supplying organic matter when certain crops are used. Crop rotation increased the fertility of North Dakota soils about 50% due to the addition of organic matter alone.

6. Maintenance of organic matter in soils.

(a) Applying manures.

(b) Green manuring.

(c) Crop rotation, including legumes, etc.

SOIL WATER.

A. Functions of water in the plant.

1. Carries mineral food into the plant.
2. Transfers food from part to part in the plant.
3. Plants take most of their hydrogen from the water.
4. Forms part of plant tissues.
5. Helps to keep the plant rigid.
6. Regulates physical functions - temperature, transpiration, etc.
7. Amount of water used by crops.

B. Kinds of water in the soil.

1. Hygroscopic water.
2. Capillary water.
3. Gravitational water.

Note. - Show the different forms by pouring water through soil in the funnel.

C. Hygroscopic water.

1. Of small practical importance.
2. Plants can take very little from the soil - show table.

D. Capillary water used by plants.

1. Power of soils to hold capillary water - experiment.
   (a) Depends upon texture, structure, organic matter, material.
   (b) Show charts - the effect of organic matter on distribution of capillary water.
   (c) Best amount for plant growth is about one-half capacity of pore space.
2. Power of soils to move capillary water.

(a) Describe capillarity.

(b) Depends upon texture, structure, organic matter, material.

(c) Extent to which movement takes place - clay subsoils best, very little horizontal.

(d) Relation of surface tension to capillarity.

E. Gravitational water.

1. Harmful. Must be removed by drainage.

2. Drainage depends upon texture, structure, organic matter.

3. May be injurious:

(a) By keeping out the air.

(b) Making the soil cold.

(c) Preventing formation of nitrates.

(d) Promoting formation of poisonous compounds.

(e) Retarding decay.

F. Loss of soil water.

1. By percolation.

2. By evaporation.

3. By growing plants.

G. Control of soil moisture.

1. Tillage - mulching. Discuss fully.

(a) Describe mulch - give different kinds and used.
(b) Mulching effect of plow, harrow, roller.
(c) What the mulch does.
(d) Depth - clay and sand.
(e) Mulching after a rain.
(f) The effectiveness depends upon fineness and dryness.
(g) Effect of fall and spring plowing on saving water.
(h) Effect of early plowing on saving water.
(i) Effect of cultivation on drawing water to the surface.
(j) Time required for a heavy rain to soak into a soil.
(k) Effect of ordinary and frequent cultivation on saving of water yield of corn.
(l) The drying of a sandy soil by clover.

SOIL AIR.

A. Air is necessary to plant growth - CO_2, oxygen.

1. All parts of the plant take in oxygen and give off CO_2 - respiration.

2. The green parts of a plant take in CO_2 and give off oxygen - photosynthesis.

B. Soils need to be aerated.

1. Plant roots, bacteria, animals, insects, oxidation, nitrogen for nitrification, allow CO_2 to escape, germination of seeds.

C. Composition of soil air.

1. As affected by decaying organic matter, etc.

D. How air gets in and out of the soil.

1. Changes in temperature.

2. Changes in pressure.

3. Movement of water.

4. Diffusion of gases.

5. Upward movements of air.

E. Factors determining the amount of air in the soil.

1. Texture.

(a) Soils may be aerated too much - kind.

(b) Soils may be aerated too little - kind.

2. Structure.

3. Organic matter.

4. Moisture changes.

F. How volume and movements of soil air may be regulated.

1. By tillage.

2. Mulching.

3. Drainage.

4. Irrigation.

5. Cropping.

SOIL MULCHES.

A. A soil mulch is usually considered to be a soil covering. This soil covering may be composed of many different materials.

   1. Discuss materials.

B. <u>Objects of the soil mulch.</u>

   1. Conserves moisture.
   2. Regulates temperature.
   3. Prevents erosion.
   4. Maintains a good physical condition - good tilth.

C. <u>The dust or soil mulch.</u>

   1. Formed by tillage.
      (a) Discuss implements - plow, disk, harrow, roller, cultivator.
   2. Depth of soil mulch.
   3. Amount of water saved.
   4. Some soils form natural mulches - muck and sand.

D. <u>Mulches of other materials.</u>

   1. How they prevent erosion.
   2. How they affect the physical condition of the soil.

SOIL TEMPERATURE.

A. Affects

1. Chemical.
2. Biological.
3. Physical.

Note,- Develop above and show how.

B. Soils receive hear from -

1. Direct radiation of sun.
2. Precipitation and condensation.
3. Interior of earth.
4. Decomposition of O. M.
5. Other chemical reactions.
   (a) Oxidation.
   (b) Hydration.

C. Factors which influence -

1. Intrinsic factors:
   (a) Specific heat.
   (b) Specific graviey.
   (c) Heat conductivity.
   (d) Radiation.
   (e) Absorption.
   (f) Organic matter content.
   (g) Concentration of soil solution.
   (h) Evaporation.
   (i) Nature of surface.
   (j) Topographic position.
   (k) Chemical reactions.

2. External factors - Meteorological elements.

   (a) Air temperature.

   (b) Sunshine.

   (c) Barometric pressure.

   (d) Wind velocity.

   (e) Dew point.

   (f) Humidity.

   (g) Precipitation.

D. <u>All factors may be divided into two classes.</u>

1. Those that impart heat to the soil.

2. Those that take heat away from the soil.

E. <u>Specific heat of soils</u>.

1. Two methods of determining:

   (a) By equal weights.

   (b) By equal volumes.

   Method and results - Michigan Tech. Bul. No.17,pp. 10-12

2. Effect of water as sp. ht.

   (a) Freezing and thawing of soils.

   (b) In summer .5, in winter .25.

   Results Mich. Tech. Bul. No. 17, p. 13.

F. <u>Heat Conductivity of Soils.</u>

1. Order of conductivity of heat in soils.

   (a) Under lab. (wet & dry) and field conditions - sand clay, loam, peat.

   (b) Other conditions - uncultivated, cultivated, sod.

2. Rate of flow of heat decreases for a certain distance and then increases.

3. Effect of water on conductivity.

   (a) Expells air which is a non-conductor.

(b) Brings films closer together.

4. Effect of organic matter.

(a) Substance.

(b) Greater air space.

Results Mich. Tech. No. 17, pp. 14-23.

G. <u>Radiation of Heat</u>.

1. Not influenced by color or water content.

2. A dry surface reduces radiation - amount of reduction increases as water content of sub-surface increases

3. Radiating power in dry state - sand, clay, loam, peat.

4. Influenced by chemical constitution and soil covering.

(a) Organic matter, mulches, sod, cultivation.

H. <u>Absorption of Heat</u>.

1. Influenced by color, - black, blue, red, green, yellow, white in order. Difference in black and white in colored sands about 6° C.

2. Depends upon organic matter and iron principally.

I. <u>Effect of organic matter.</u>

1. The soil temperature increases with the organic matter content to a certain point (about 5% of O. M.) and then decreases.

Effect of Growing Crops on Soil Temperature.

A. Crops keep the summer soil temperature low, because:

1. The sun's rays are intercepted by the vegetation.

2. Air temperature is low around the plants.

(a) Transpiration.

(b) Evaporation.

B. Crops keep the soil covered as a blanket during the cold part of the year, and:

1. Prevent the cold air from coming in contact with the surface soil.

2. The layer may be porous and the layer filled with air - prevents radiation.

C. Snow has a similar effect as a crop.

D. General aspects.

1. The sod plot warmed faster in spring to about the beginning of May, then the temperature fell below that of the bare plot (cult. & uncult.) and remained so until about the middle of September. Then the bare plots became the coldest and remained so until the middle of the following spring.

Effect of Cultivation on Soil Temperature.

A. General Effects of Cultivation - Mulches.

1. Prevents evaporation of water.
2. Prevents radiation of heat.
3. Cultivated soils hotter on surface on surface.
4. Mulches increase sp. ht. by holding moisture.

B. General aspects.

1. After thawing in the spring the temperature of cultivated plot rose above the temperature of the uncultivated plot until about the middle of May after which the order was reversed until October.
   (a) The uncultivated soil absorbed more heat during the day but lost more during the night.
2. The temperature of the cultivated surface was greatest as long as the temperature of 20 in. deep remained the same in both soils. When the temperature under 20 in. under the uncultivated began to rise the temperature of upper layer of uncultivated rose above that of the cultivated.
3. The uncultivated soil was warmer in the day but colder in the night.

Effect of Soluble Salts on Soil Temperature.

A. Solutions of greater densities have the following properties which influence soil temperature.

1. A lower freezing point.

2. A lower vapor pressure.

3. A higher boiling point.

4. A higher surface tension.

5. A higher viscosity.

B. Rise of temperature.

1. Increases with the concentration of solution.

(a) Evaporation decreased.

2. Increase slightly different for different salts.

C. Fall of temperature.

1. Increases with the concentration of solution.

(a) Freezing point depressed.

(b) Time at freezing point decreases with increase in concentration.

(1) Freezing point still lowered by the increasing concentration of theunfrozen part of solution.

2. Supercooling usually takes place.

3. Decrease slightly different for different salts.

D. Thawing.

1. Rate of thawing exactly the reverse of freezing.

Effect of Decomposition of organic matter and Manure on Soil Temperature.

A. Rise in temperature depends upon:

1. Amount of O. M. in soil.
2. Rate of decomposition.
   (a) Aeration.
   (b) Reaction of soil.

B. Rise for different kinds of manure.

1. Order and extent of rise.

(a) Horse -	10	tons	per	A.	.30° C.
"	40	"	"	"	1.23° "
(b) Cow -	10	"	"	"	.49° "
"	40	"	"	"	.91° "
(c) Sheep -	10	"	"	"	.20° "
"	40	"	"	"	.80 "

General Aspects of SoilTemperature.

1. Make chart to show yearly magnitude.
2. Greatest amplitude in June for 6 and 12 in. in depth - sand, gravel, clay, loam, and peat in order.
3. Fluctuation greater in summer than in winter.
   (a) Soils heated only by conduction in winter.
   (b) Heated by conduction and absorption in summer.
   (c) Latent heat of ice prevents fluctuation.
   (d) Protected by layer of snow.
   (e) Sp. ht. less in winter than summer.
4. Temperature of air above soil temperature from April to December, and below the rest of the year.
5. Soil classes cool and freeze at about the same rate of time.
6. Soil classes thaw at different periods in the spring.
   (a) Order of thawing and rise of temperature - (sand gravel) clay, loam, peat.
7. In general we may say:
   (a) The air temperature tends to vary immensely with the pressure.
   (b) The sunshine varies directly with the pressure.
   (c) The air temperature tends to vary directly with the sunshine in summer.
   (d) The dew point varies directly with the temperature.
   (e) The wind velocity may vary directly with either extreme of pressure.

Discuss effect of each element.

SOIL BACTERIA.

A. What they are.

1. Bacteria are plants that form the simplest group of fungi and are lacking in chlorophyl.

B. What they do in the soil.

1. They effect changes in plant food - mineral or organic.

   (a) Decomposition: (a) In presence of air (b) in absence of air.

   (b) Ammonification.

   (c) Nitrification.

   (d) Denitrification.

   (e) And other changes.

2. Fixation of nitrogen in the soil.

   (a) Non-symbiotic - because they live in the soil itself.

   (b) Symbiotic - because they liveon the roots of plants.

C. Conditions which effect their growth.

1. Exist in fertile soils in large numbers - mostly at the surface - numbers diminish with depth.

2. Present in larger numbers in fertile soils than in unfertile soils.

3. Food:

   (a) Take in food like plant hairs and require soluble compounds containing NCHSO and some amounts of mineral substances.

   (b) Different kinds.require different foods.

   (c) Organic matter is the chief food supply.

4. Temperature:

   (a) Cold decreases action - warming increases action.

   (b) Most favorable ranges from 70° to 105° F. - 21° - 40° C

   (c) Most bacteria are killed at 212° F. - Spores.

   (d) Dry heat more effective than moist.

5. Oxygen.

   (a) Some bacteria require air (aërobic). They oxydize substances; produce nitrification and sometimes fix nitrogen.

   (b) Some bacteria cannot live in the presence of air (anaërobic). They take oxygen away from substances and may form gases.

6. Moisture.

   (a) Some bactefia become dormant when dry. Some are killed. They resume their activity when moistened.

   (b) Most soil bacteria require certain degrees of moisture for their best action.

7. Light.

   (a) Sun light kills most bacteria in a few hours - spores.

      (1) Bacteria in upper layers most affected.

      (2) Diffused sun light lessens activity.

8. Chemical and physical surroundings.

   (a) Presence of acids detrimental to bacteria that require alkaline conditions.

   (b) Killed by anticeptics, disinfectants, etc.

   (c) Bacteria do not thrive in pure clay, pure sand or soils filled with stagnant water.

9. Presence of other forms of life.

   (a) Soil may contain protozoa which feed upon living bacteria.

10. Other conditions - altitude, exposure, plant growth, cultivation, fertilizers, drainage, liming, crop rotation, organic matter and shading.

   (a) Gypsum is favorable to bacterial development. Sodium chloride checks nitrification.

D. Products of bacterial action.

1. When by-products reach a certain concentration they often act as poisons.

2. The products of some bacteria are poisonous to other kinds. These products may be removed and beneficial action continued.

3. Bacterial actions known under general name of fermentation.

   (a) By-products - sugar, acids, alcohols and soluble nitrogen compounds. (peptones, amino, acids, ammonia, nitrous acid, nitric acid, free nitrogen.)

   (b) Changes produced.

      (1) Effect changes in plant food, mineral and organic.

      (2) Fixing nitrogen in the soil.

E. Changes in the O. M. of the soil.

1. Decomposition:

   (a) In the presence of air - decay.

   (b) In the absence of air - putrefaction.

2. Compounds in the soil.

   (a) Non-nitrogenous organic compounds, con. carbon, H & O, carbohydrates, oils, and organic acids.

   (b) Proteins - cont. C, O, H, N, acid sometimes G & P.

   (c) Mineral - K, P, Ca, Mg, S, Na, & Cl.

3. Decay in the presence of air:

   (a) A burning or uniting with O.

      In detail: (A) Carbohydrates are decomposed rapidly and connected into simpler compounds - oxalic, acetic, etc., acids and finally CO_2 & H_2O.

4. Cellulose:

   (a) Less readily attracted but products are about the same as carbo.

5. Oils:

   (a) Are changed into acids and finally $CO_2 + H_2O$.

6. Organic acids - ultimately $CO_2 - H_2O$.

7. Proteins form simpler N. compounds.

   (a) Albuminoses or proteoses.

   (b) Peptons or peptids.

   (c) Amino acids - finally into NH_3 or N. The C, H, O, to CO_2 & H_2O, the S to SO_3, and P to P_2O_5.

8. Minerals - mainly the form of phosphates, sulphates, carbonates, chlorides.

F. <u>Decomposition in absence of air: - putrefaction, in soils, humification - different kinds of bacteria.</u>

1. Process much slower - as shown by difference in depth, looseness, outside of a particle, in well drained or water-logged soil.

2. Chemical changes are less complete - some CO_2 & H_2O & N are set free but the largest portion of the O. M. is very complex, is dark-colored and forms humus in the soil.

3. Humus not easily decomposed by bacteria even when exposed to air.

4. Offensive and poisonous compounds - many are bad smelling and poisonous - H_2S, PH_3, CH_4, Skatol and nidol.

5. Difference in gases formed - air, CO_2, H_2O, SO_2, NH_3, N - absence of air, small amount of above and H_2S, PH_3, CH_4.

G. Ammoniafication - conversion of Org. N. into NH_3 - by ammonifying bact., some aërobic some anaerobic - depends upon a variety of conditions as have been described. Such bact. found in air, rainwater, stables, manure, and surface soils. Important to agriculture.

$$COH_4N_2+2H_2O = CO_2+2NH_3+H_2O = (NH_4)_2CO_3$$

Nitrification - forming HNO_3

1. Chemical changes - two - two kinds of bacteria.

(a) NH_3 to HNO_2

(b) HNO_2 to HNO_3

(c) $NH_3 + 3O = HNO_2 + H_2O$

(d) $HNO_2 + O = HNO_3$

$$CaCO_3 = Ca(NO_3)_2 + CO_2 + H_2O$$

(e) $2HNO_3 + K_2CO_3 = 2KNO_3 + CO_2 + H_2O$

$$Na_2CO_3 = 2NaNO_3 + CO_2 + H_2O$$

$$MgCO_3 = Mg(NO_3)_2 + CO_2 + H_2O$$

Nitrification is an oxidation process and results in producing an acid. Bact. found in all cultivated soils, water, manure, and sewage.

H. <u>Conditions that influence their work.</u>

1. Location - upper layers 2/3 first foot, rest 2nd foot - depth depends upon looseness and warmth.

2. Moisture - does not take place in dry soil - not active in water-logged soil.

3. Food - NH_3 and the N of O. M. - air excess of sol. N. or carbohydrates prevents growth, this rarely occurs in a cultivated field, but may in gardens and green houses. Sewage-irrigation harmful. A certain supply of minerals necessary.

4. Oxygen - air necessary in the soil - may be too fast in sandy soils - slow on heavy land - cultivation promotes.

5. Temperature - most active 54° - 99° F., (12° - 37° C.) increases with rise and decreases with fall of temperature more in summer than winter - earlier in spring on warm soils.

6. Light - darkness is best for activity - not found close to surface where soil is bare - more active in shaded soil - on warm nights, under boards and stones.

7. Non-acid condition - acids are very injurious - soon die in excess of HNo_3 - not active in acid soils - soil must be made alkaline - carbonates are best.

I. <u>Denitrification - reverse of nitrification - reduction - 3 form</u>

1. Destructive Nit. - HNO_3 to HNO_2 to N - lost.

2. Partial decomposition - HNO_3 to HNO_2 to NH_3 - May go to HNO_3 again.

3. Conversion to O. N. Comp - HNO_3 to proteins - May go to HNO_3 again.

Takes place under two general conditions:

(a) Lack of air in the soil - some O is required and if there is no air it is taken from soil comp. cont. O - cult. diminishes - greatest in heavy soils - N. from fertilizer may be lost in this way.

(b) Too much O. M. in the soil - sol. condition - some N. from manure or green manures may be lost. Bacteria use N. and they may change it from sol. to insol. forms in the soil - may be beneficial or harmful. Nitrification does not increase the total amount of N. in the soil.

J. <u>Fixation of atmospheric N.</u>

1. Two kinds of bacteria:

    (a) Those that live in the soil itself - Non-symbiotic.

    (b) Those that live on the roots of plants - symbiotic.

2. Non-symbiotic:

    (a) Soils naturally increase in N. content - examples

    (b) Commercial ventures - "Alinit".

    (c) These bacteria require:

        (1) A generous supply of carbohydrate material.
        (2) The presence of $CaCO_3$ or $MgCO_3$ is important.
        (3) Some soluble phosphate is needed.
        (4) Organisms are injured by an acid condition.

3. Synbiotic:

    (a) Long noticed that legumes were beneficial tosoils.

    (b) Caused by certain kinds of bacteria - N.

        (1) Root nodules and bacteria.

            (a) Discovered 25 years ago.
            (b) Common in soils, waters, etc.
            (c) Make their way into the plant root. There they multiply rapidly and perform their work.
            (d) Found only on the younger parts of roots. When the parts grow old the nodules decay and the bacteria go back to the soil.

        (2) Relation of bacteria and legumes:

            (a) One of mutual helpfulness.
            (b) The bacteria use carbohydrates from the plant and give the plant N. in return.

        (3) Amount gathered by bacteria:

            (a) 100# to 200# an acre in a favorable season.
            (b) May be below 50# in unfavorable seasons or conditions.
            (c) In some cases the amount of N. remaining in the stubble and roots of a crop is equal to the amount removed from the soil by the crop. In this case no N. is taken from the soil.
            (d) Under favorable conditions one-third of the N. used by the crop may be taken from the soil and 2/3 from the air.
            (e) May not increase the N. in the soil but usually increase the feeding value of the crop.

(4) Kinds:

(a) Many different kinds.
(b) Those that grow on a certain kind of legume are best for that plant.
(c) Some combinations - alfalfa, bur clover, sweet clover, white and alsike clover and red clover; the common vetches.

(5) Conditions of action of legume bacteria:

(a) Same as those that favor nitrification.
(b) $CaCO_3$, O.M., air, and moisture, a supply of carbohydrates and mineral food.
(c) Use available N. compounds in the soil in preference to free N.
(d) Formation prevented where there is a supply of available N.

(6) Independent action of legume bacteria.

(a) May act independently of the plant but the amount of N. formed is small.

(7) May be found on other plants.

(a) Found on alder, New Jersey tea, buffalo berry, silver berry, mountain balm, sweet fern (corn ?). These are not money plants but may be beneficial on unused lands.

K. <u>Soil inoculation for legumes</u>.

1. In many cases the bacteria are present in soils, and always where the crop has been grown for a time - clover, alfalfa, and cow peas in their localities, alfalfa and cow peas and vetches in Michigan.

2. Bacteria may be supplied by inoculation. Two ways:

(a) By using soil. (b) By using pure cultures.

(1) By using soil:

(a) Probably best method - how to do.
(b) Remove the upper layer - 200# - 500# per A.used.
(c) Beware of weed seeds and plant diseases.
(d) Soil may be treated with water and the seed soaked in the extract.
(e) Glue and soil have been used on large seeds.
(f) Root nodules may be used.

(2) By pure cultures:

(a) One kind of bacteria.
(b) Difficult to keep them alive and vigorous.
(c) What inoculation does.
(d) Only one factor of crop growth. Good results may be obtained: (a) Where the soil is in good condition and legumes do not do well; (b) Where the roots do not have the nodules; (c) Where legumes are grown the first time.

(3) Soil inoculation usually fails to produce results:

(a) Where the specific bacteria are present.
(b) Where the soil is acid.
(c) Where the supply of K and P is deficient.
(d) Where there is too much sol. N. in the soil.
(e) Where the soil has a poor physical condition.
(f) Where seasonal conditions are unfavorable.

L. Changes in Mineral Constituents by Bacteria.

The products of bacteria comprise CO_2, Nitrous, Nitric, Sulphuric and organic acids. These acids bring about the following changes:

1. Calcium and other insol. carbonates are made soluble.

2. Insol. phosphorous compounds are made soluble.

3. Bacteria use minerals which are returned to the soil in a soluble condition.

4. Insoluble K. compounds are made soluble.

5. L. is changed to H_2S and finally H_2SO_4 or reverse (mucks).

6. $CaSO_4$ may be changed to H_2S by anaërobic bacteria.

TILLAGE.

A. Tillage refers to working the soil with implements.

B. Objects of Tillage:

1. To change the structure of the soil.

   (a) To control soil water, aeration, temperature.

2. To bury rubbish.

3. To cover seeds.

4. To kill weeds.

5. To make plant food available - nitrates.

C. Tillage implements.

1. Many kinds.

2. May be divided into two groups.

   (a) Those which loosen soil structure.

   (b) Those which compact soil structure.

D. The Plow

1. Object of plowing:

   (a) To change soil structure.

   (b) To bury weeds.

2. Two general types:

   (a) Moldboard plows.

   (b) Disk plows.

3. Moldboard plows.

   (a) Produce a shearing action on the soil. Explain.

   (b) Three general types.

      (1) Long, sloping moldboard -
         (a) Cuts a clean furrow and turns it over completely to bury weeds and manures - pulverizes little.

      (2) Short, steep moldboard.

(a) Thoroughly pulverizes soil.

(3) Intermediate moldboard.

(a) Better for soils that pulverize easily because of less draft and wider furrow slice.
(b) May be better on heavy soils when necessary to lighten draft.
(c) Better for soils which tend to clog on the moldboard.

(4) There is always a shape of moldboard, condition of moisture and depth of furrow for best condition of tilth.

(a) The more moisture, the steeper the moldboard, the deeper the furrow, the more the soil will be puddled.

(b) Therefore, for soil too wet, use less steep moldboard and plow as shallow as conditions will permit.

(c) If soil is somewhat dry use steeper moldboard and plow deep.

(d) When soil is too dry no shearing takes place.

(e) The steep moldboard works best with soil a little dry.

(5) It is not desirable to turn the furrow slice over flat.

(6) A general relationship between width and depth of furrow is 2 wide to 1 deep.

(c) The plow should be adapted to the soil.

(1) Coarse grained, porous soils should be plowed with a steep moldboard, a little over wet, and as deep as conditions will permit to break down granulation and secure closer texture.

(2) Mellow soils may sometimes be plowed with a less steep moldboard and with a wider furrow.

(3) Fine grained, heavy soils need the less steep moldboard and when the soil is a little dry, on these soils the moldboard should be as steep as possible consistent with the draft to get the most pulverizing action.

4. Disk plows.

   (a) Turns and pulverizes the soils.

   (b) Lighter draft for amount of work done.

   (c) Effective on hard, dry soil and in burying weeds and manures.

5. Draft of plows.

   (a) See King, pp. 243 - 246

6. Care of plows.

   (a) Surface of moldboard should be kept polished.

   (b) Plow should be kept in proper adjustment. King, 248.

7. Jointer attachment.

   (a) Helps to bury trash better.

   (b) Useful in plowing under crops and when sod groud is fitted for immediate use.

8. Subsoil plow.

   (a) Follows ordinary plow.

   (b) May puddle soil.

   (c) Best in fall in humid climates.

   (d) Of more benefit in arid climates.

9. Depth of plowing.

   (a) Must use judgment in determining.

   (b) In humid climates it is best not to go into the subsoil. If necessary the subsoil should be turned up gradually.

   (c) 6 to 7 inches - less for small grains.

   (d) Should be varied to prevent "plow sole".

10. Time of plowing and after treatment.

   (a) In spring.

      (1) Light soils.
      (2) Effects of mulches on heavy soils.
      (3) If plowed too wet, roller should not be used and the harrow only after a time.

(4) If plowed dry harrow should be used immediately.
(5) If for cultivated crops to be planted later and plowing in good condition it should be left rough.
(6) Mulching plow land.

(b) In fall.

(1) Lessens spring work.
(2) Heavy soils.
(3) Burying manure and cover crops.

(a) Deep fall plowing best or early spring.
(b) Roller should be used.
(c) Followed by disk.

(4) Action of frost, etc.
(5) Early fall plowing.
(6) Should be left with rough surface.

THE ROLLER.

A. Objects of rolling.

1. To compact soil after sod plow and where crops are plowed under.

2. To crush lumps.

3. To break crust on surface.

4. To cover seed when sown broadcast.

5. Weight should be 100# to running foot with a diameter of 2 feet.

B. Kinds of rollers.

1. Smooth.

2. Corrugated.

3. Subsurface packer.

C. Smooth roller.

1. Rolling fields after seeding.

2. Stops excessive ventilation in soils - this may be beneficial or injurious.

3. Harrow should follow roller.

4. Should not be used on heavy soils when they are wet especially after seeding; may also stop nitrification.

D. Corrugated roller.

1. To break crusts on small grain fields especially if the soil surface is rough and somewhat dry.

E. Sub-surface packer.

1. Useful in the conservation of moisture.

THE HARROW.

A. <u>Objects of Harrowing.</u>

1. Killing weeds.
2. Saving moisture by soil mulch.
3. Smoothing the soil surface.
4. Preparing the seed-bed.

B. <u>Kinds of Harrows.</u>

1. Disk.
    - (a) Smooth disk.
    - (b) Spike disk.
    - (c) Spading disk.
    - (d) Cutaway disk.
2. Springtooth.
3. Spike tooth.
4. Weeder.
5. Planker.
6. Acme.
7. Meeker.

C. <u>Disk Harrow</u>.

1. Very useful where soil is drying out and there is not time to plow.
2. May be used on alfalfa.
3. Preparing plowed land for a cultivated crop, especially when land is plowed in fall.
4. This harrow thoroughly pulverizes the soil.
5. May be used in place of the plow where small grains follow a cultivated crop.

D. Springtooth harrow.

1. Useful in preparing plowed land for a cultivated crop, especially when the ground is rough and stony, or on new land.

E. Spiketooth harrow.

1. To break crusts on small grain fields, where the soil surface is smooth and not too heavy or by driving across the ridges.

2. May be used on alfalfa alone and after the disk.

3. May be used to advantage on plowed land when used after the springtooth or disk.

4. Useful in killing weeds before the crop is up, and where the weeder is too light.

5. Where soil is mellow this type of harrow may be used after plowing - covers ground fast.

F. The planker.

1. Crushes lumps and leaves soil surface smooth without firming it.

G. Weeder.

1. Very useful to destroy weeds when they are small, and on light soils before the crops come up.

H. Acme.

1. Efficient pulverizer where ground is free from stones.

I. Meeker.

1. Pulverizes hard ground.

CULTIVATORS.

A. Objects of cultivator.

1. Same as tillage in general

B. Kinds of cultivators.

1. Spring tooth shovel cultivators.
2. Rigid tooth shovel "
3. Disk.
4. Rigid tooth with long, flat shovels.
5. Garden cultivators.

C. General considerations.

1. Cultivator shovels should be small and many rather than few and large.
2. Rigid tooth cultivators usually do better and more uniform work than spring tooth.
3. Spring tooth cultivators are better adapted to stony soils.
4. Disk cultivators good for covering weeds in the row.
5. Flat bladed shovels are good for shallow surface cultivation.

DRAINAGE.

A. Drainage refers to the removal of excess water from the surface soil.

B. What drainage does to soils.

1. Increases room for plant roots.
2. Makes more water available for the plant.
3. Soils are made warmer.
4. Aeration of soils is increased.
5. The physical stnucture of heavy soil is greatly improved.
6. Action of micro-organisms enhanced.
7. Allows soils to be worked earlier in the spring.
8. Lessens surface washing.
9. Drainage prevents "heaving".

C. Kinds of drains.

1. Open ditches of many kinds.
2. Tile drains.
3. Miscellaneous - plank, stone, pole, brush, etc.

D. Tile drainage.

1. A good drain tile should:
   (a) Be hard burned.
   (b) Contain no limestone.
   (c) Have straight ends.
2. Depth of tile drains.
   (a) Depth of drain is determined largely by:
      (1) Kind of soil. - The finer the soil the deeper the drains.
      (2) Fall or gradient of drain.
      (3) Amount of earth to be removed.

(b) For most cereal crops the water table should be kept from 2½ to 3 ft. below the surface. Fruit trees and deep-rooted plants require greater depth of soil.

(c) 3 ft. is the usual depth for the tile drains, 4 ft. is considered deep drainage, and 2 to 2½ ft. shallow drainage.

3. Distance apart of drains.

   (a) Depends upon:

      (1) Porosity of soil - The finer the soil the closer the drains.

      (2) Depth of drain - The deeper the drains the farther apart they may be placed.

      (3) Rainfall. - Drainage should be complete enough to remove the excess of water from a cultivated crop in from 24 to 48 hours. The more rainfall the more tile drains.

      (4) Tile drains are usually placed 50 - 100 ft. apart, more or less, depending upon the actual soil conditions, - 100-150 for sandy soils, 60-70 for muck, 40-50 for clay.

4. How water enters the tile.

   (a) If the tile walls are porous, like cement tile, some water will seep through them, but most of the water enters the tile drain at the joints between the tiles.

5. Fall or gradient.

   (a) A tile drain should have a certain fall to allow the water to run through it freely, - 2 in. fall in 100 ft. is the least allowable for good drainage.

   (b) Fall shouls be as uniform as possible.

   (c) Changing from a greater to lesser fall is undesirable.

   (d) A change from lesser to greater fall may be desirable.

6. Size of tile to use.

   (a) There are many factors involved and the proper size is hard to determine.

(b) Should be large enough to give good drainage in 24-48 hours after a heavy rain.

(c) Larger tile should be used when single drains are laid in irregular order.

(d) The greater the fall the smaller the tile may be. Doubling the grade increases the carrying capacity about 1/3, but small tiles have greater friction than larger ones.

(e) Tiles smaller than 3 in. readily fill with sediment and are not recommended.

(f) Size of tile depends somewhat upon the length of line - 2 in. tile should not be laid in lines of over 500 ft. in length and 3 in. tiles in lines more than 1000 ft. long, 4 in. 1500 ft., etc.

(g) The flow of water through tiles varies directly as the square of the diameter, not considering friction.

(h) C. G. Elliott's figures on size of tile to give complete drainage:

3	in.	tile	will	drain	5	acres.
4	"	"	"	"	12	"
5	"	"	"	"	20	"
6	"	"	"	"	40	"
7	"	"	"	"	60	"

7. Outlets of drains.

(a) Should be above the water line in a larger ditch or stream.

(b) Should be protected with masonry and screen.

(c) Best to have outlet point down stream.

(d) Glazed tile is best where there is danger of breakage by frost.

8. Silt basins.

    (a) Main purpose is to catch silt and prevent the drain from clogging.

    (b) A silt basin should be placed in any long line of tile.

    (c) Or where two mains come together.

    (d) Or at a bend in a long line of tile.

    (e) Or where the grade changes from greater to less fall.

    (f) Or where surface water enters the drain.

9. Junctions.

    (a) It is well to have the laterals dump their water into the main at the top if the grade permits.

    (b) A good junction is made by knocking a hole in the side of the main and inserting the first tile of the lateral. A lateral should always enter the side of the main at an angle so as to throw the water down stream in the main.

    (c) Junctions may be purchased.

10. Passing trees or quicksand.

    (a) The joints should be cemented where tile drains pass trees to keep out the tree roots.

    (b) It is also good policy to close tile joint where the line passes through quicksand. (A quicksand shield is servicable in laying tile under this condition.)

11. Laying out drains.

    (a) Drainage systems should be laid out to get:

        (1) The greatest possible fall consistent with

        (2) Least amount of digging

        (3) The most perfect drainage.

        (4) With least expense for tile.

(b) Systems.

(1) For diagrams of drainage systems see

King - Physics of Agriculture, p. 254 - 255.

(c) The laying out should be done with some kind of drainage level and the tiles laid exactly to grade.

12. Intercepting surface and under-flow water.

(a) Where a low situation that receives surface or seepage water from higher land is to be drained, it should be protected from this water by

(1) Surface ditches,
(2) or tile drains.

13. Basins without outlets.

(a) May sometimes be drained by making holes down to a porous stratum.

ESSENTIAL ELEMENTS OF FERTILITY AND THEIR EFFECT ON THE PLANT.

A. There are ten essential elements of plant growth;-

1. From air and water - C, O, H, N.

2. From body of soil - Ca, K, P, Fe, Mg, S.

B. The chemical analysis of a soil depends upon the analysis of the kind of rock which has undergone decay, method of soil formation, and content of organic matter.

C. Compare Michigan soils in regard to chemical analyses.

D. Role of p lant food elements.

1. Nitrogen:

(a) Found in the soil in organic matter, NH_3, and nitrates.

(b) Used Heavily by crops - principally as a nitrate - other forms.

(c) Amount available for immediate use is small.

(d) Most expensive of plant foods.

(e) Easily lost to the soil - leaching, etc.

(f) Usually the first element exhausted.

(g) Burning over soils frees the N.

(h) Influences and produces the following effects:

(1) Growth of foliage:

(a) Promotes the growth of stems and leaves which are the laboratories of the plant - some plants grown for these parts.

(b) Lack of N. causes stunted growth. In case of grain stems will be short and the leaves small. The weight of straw will be less in comparison with the weight of the grain.

(2) The flowering process:

(a) Retarded by an abundance of N - the N is used for stem and leaf growth and the flowering is retarded.

(b) The seeds produced under these conditions are apt to be improductive or even sterile.

(3) Maturing of plants:

(a) Retards maturity by continuing growth - growth in stems and leaves instead of seed and fruit.

(b) In case of grain crops the excess of N. tends to cause lodging, due to the long-jointed, soft, weak stems.

(4) Effect on color.

(a) Usually causes a deep green color in the foliage when present in quantities.

(b) When plants cannot get N. they cannot make chlorophyl.

(c) Large quantities of N. in soil cause green apples.

(5) Regulation of Plant Growth:

(a) The use of KP_2O_5 regulated by N. supply.

(6) Effect on quality:

(a) Large applications of N. cause softness of tissue, but the keeping qualities are generally impaired, - garden crops.

(b) Too much N. makes wheat lighter, the barley berry is lighter and thick skinned and not satisfactory for malting purposes.

(7) Power to resist disease:

(a) An excess of N. makes plants less resistant to diseases - nursery stock, greenhouse crops, rust on wheat and oats, etc.

(b) Shrubbery and young trees that have been forced too much are less resistant to cold weather.

(8) Effect on composition:

(a) An increase of N. in the soil causes more to go into the grain.

2. Phosphorus.

(a) Effect on germination.

(1) P favors rapid development of the young seedling by stimulating the growth of the roots and thus giving the young plant a good start.

(b) Effect on early ripening.

(1) P favors the early ripening of crops. The formation of the grain begins sooner.

(c) P. Increases the proportion of grain to straw.

(d) Abundance of P causes a decrease in percent of N in the straw.

(e) Protoplasm cannot be formed without P.

(f) P is absorbed by soil and very little is lost by drainage.

3. Potassium.

(a) More abundant in older parts of plants.

(b) K is necessary in order that the plant build up carbohydrates.

(1) The starch is first produced in the leaves in an insoluble form, but is changed to the soluble form and transferred to the different parts of the plant. K and Ca are supposed to be directly concerned in this.

(c) When K is deficient the stems are weak and brittle - K is mostly in stems and leaves.

(d) K compounds are supposed to be requisite to the normal development of the fleshy portions of fruits.

(e) K compounds supposed to keep plant cells turgid.

(f) K is present in sour plant juices, combined as an acid salt with tartaric, oxalic, citric, etc., acids.

(g) An excess of K prolongs growth of stems and leaves - same as N.

(h) K enables plants to withstand fungous diseases:

(1) In absence of K wheat and oats are more liable to rust. Grasses are affected by fungous diseases. The effect is greater with excess of N.

(i) Effect on leguminous crops.

(1) Produces a favorable effect.
(2) Promotes growth of bacteria.
(3) Effective on sandy soils.

(j) Absorbed by soil.

(k) Gramineous plants require less potash than legumes.

4. Calcium.

(a) Aids in the growth and strengthening of cell walls.

(b) Similar to K in transferring starch.

(c) Aids in development of root hairs.

(d) Found in plants where the greatest vegetative activity is taking place as oxalate chiefly - sometimes carbonate, phosphate, and sulphate.

(e) Large quantities lost in drainage waters.

(f) An excess tends to cause Mal-nutrition.

5. Sulphur.

(a) Constituent of protein - action important.

(b) Constituent of odorous oils - mustard oil, as in mustard, horse radish, turnip, cabbage, etc., and garlic oil in onions, garlic, and leeks.

(c) Occurs in leaves and stems.

6. Magnesium.

(a) Abundant in seeds and fruits.

(b) Poisonous when in excess.

(c) Mg is concerned in the transfer of P_2O_5 and starch in plants.

7. Iron.

(a) Found mostly in leaves.

(b) Absolutely necessary to the formation of the green coloring matter in plants.

8. Oxygen.

(a) About 42% of dry matter.

(b) Comes almost entirely from water.

(c) Free O of air used in germination, flowering, etc.

9. Carbon.

(a) Most prevalent of all elements - 45%

(b) Comes from CO_2 of air.

(c) Constituent of all plant compounds except water.

10. Hydrogen.

(a) Comes from water.

(b) Distributed throughout plant.

E. How plants take and use their food.

1. Plant cells as manufactories.

(a) A plant may be considered as a factory made up of small fooms - cells. Cells contain protoplasm, the living part.

2. How plants obtain and use carbon.

(a) Nearly one-half of the dry matter is carbon.

(b) Comes from the CO_2 of the air and is absorbed by the leaves.

(c) Depends upon chlorophyl and sunlight.

(d) Assimilation or fixation of C. photosynthesis.

(e) Depends upon intensity of sunlight, temperature, water supply, CO_2 in the air, number of pores on the leaves, the supply of mineral plant food.

3. Relation of roots to food supply.

(a) The plant food from the soil enters the plant by the roots.

(b) In solution through the root-hairs.

(c) Root-hairs come in close contact with the soil particles.

(d) Roots excrete acids which may have some solvent power.

4. Absorption of soil solution.

(a) Osmosis.

(b) When the soil solution becomes concentrated enough the water may pass out of the plant.

(c) 1 pt. in 500 is the limit of concentration (?)

(d) Indications - Leaves turn yellow on edges, become spotted, drop off, growth is checked, dwarfed, shortened, leaves become puckered and twisted.

5. Turgor of plant cells.

   (a) Intimately connected with osmosis.

   (b) Evaporation may concentrate the soil solution.

   (c) Plants wilt after a heavy rain - why ?

   (d) Too heavy an application of fertilizer may cause plants to wilt.

6. Selective power of plants.

   (a) Plants use some foods in greater quantities than others.

   (b) The food is removed from solution when it enters the cell.

7. Forms of constituents used.

   (a) $NaNO_3$ does not necessarily pass into the plant.

   (b) The NO_3 may be taken in and Na rejected. The Na might combine with CO_2 and form Na_2CO_3 and make the soil alkaline ? $NaHCO_3$.

   (c) In case of KCl or K_2SO_4 the K may be taken in and the acid radicle rejected and the soil become acid.

   (d) Each substance is used more or less independently of the others.

8. Feeding power of crops.

   (a) Ability to absorb plant food from the soil.

      (1) Depends upon area of root hairs and the activity of the chemical processes of the plant - chiefly. (excretions)

   (b) Corn, oats, cabbages, often grow well on soils where wheat and onions fail.

9. Effects of plant food distribution on root growth.

   (a) Roots grow in the direction of food supply.

   (b) Shown by experiments.

   (c) Plant food should be mixed thoroughly with the soil.

AMOUNTS, LOSSES, AND GAINS of PLANT FOOD in SOILS.

A. Amount of Plant foods used by Principal Crops. (Chart)

References - King's PHYSICS OF AGRICULTURE, p. 97.

SOILS - Lyon & Fippin, p. 282.

SOIL FERTILITY AND PERMANENT AGRICULTURE, Hopkins, p. 154.

B. Amount of Plant Food in Michigan Soils.

1. See table of analyses of Michigan soil types. (Chart 1.)

2. Consider what plant foods are lacking in Michigan soils.

   (Amounts necessary for fertile soils - k 24,000# per A. ft. P 2,000#, Ca. 12,000#, N 5,000#.)

C. Losses of plant foods from Soils.

1. Removed by growth of crops.

   (a) Different crops use the same foods in different amounts.

   (b) Food removed by crops - amounts.

   (c) Where the leaves and stems go back to the soil not so much plant food is removed. (Chart systems of farming.)

   (d) A Crop may be fed and the manure put back - loss small.

2. Loss by leaching.

   (a) Carried away by leaching and surface washing.

   (b) Some elements absorbed - some are not.

      (1) Amount and time of rainfall.
      (2) Lack of O.M. in the soil.
      (3) Form of plant food influences amount of loss.

   Remedies -
      (a) O. M.
      (b) Crop.
      (c) Terracing hillsides.

3. Loss by mechanical agencies.

   (a) Soil particles carried away by the water, and wind.

   (b) Affects the physical condition of the soil.

Remedies:

Same as (7-5-2) including wind breaks and mulchings.

4. Loss by conversion into gases.

(a) N. is lost in this way as free N. and NH_3.

(b) Burning the soil.

5. Plant foods are held by the soils by:

(a) Chemical fixation. Explain.

(b) Physical fixation. "

6. Kinds and amounts of plant food removed from the soil.

(a) The blowing and washing of the surface soil removes all kinds of plant foods.

(b) Calcium compounds - loss 500# - 1000# per A. per year, as calcium carbonate (acid). Ca is converted into sol. forms by acid (mineral and organic) substances, bases, formation of nitric acid in the process of nitrification.

(c) N. compounds - lost in the form of nitrate - 25# - 50# per A. per year.

(d) P. compounds - only small amounts lost. - 400,000 tons for U. S. annually.

(e) K. compounds - may exceed 10# per A. per year, usually less - 3,500,000 tons for U. S.

Loss is probably greater in the particles carried away, except lime, than leaching.

D. <u>Gains of plant foods by soils.</u>

1. Application of fertilizers:

(a) Depends upon the composition of the material added.

2. Plant food in rain water:

(a) Dew and rain bring 3 - 10# N annually. 4 - 5# in the form of NH_3 and N as nitrate.

(b) Depends updn, rainfall, cities, climate, etc.

3. Plant food added by means of bacteria.

   (a) N.

4. Plant food from subsoil.

   (a) By growing deep-rooted crops.

   (b) By increasing the depth of plowing.

   (c) By movements of the soil water.

   (d) By burrowing animals.

5. Plant food from feed-stuffs.

   (a) In the increase of manure.

FERTILIZERS - KINDS AND PRACTICAL APPLICATION.

A. Principal carriers of nitrogen.

1. Mineral Products.

(a) Nitrate of soda - 15-16% N. supply comes chiefly from Chili. Minor sources Egypt, Peru, Bolivia. Soluble form, directly utilized by plants. Application 100 to 400 lbs. per A. Should be applied as top dressing when plants are dry. May burn leaves when wet. Should not come in contact with seed. Tends to promote tellering when used early in spring. This may reduce yield of grains but good for grass. Tends to gradually correct acidity. May injure structure of heavy clay soils when used frequently. The residual soda may liberate and replace potash. May injure highly basic soils. May cause a more economical use of phosphorus and potassium by the plant. Lessens loss of carbonate of lime from soil. (200 - 300# per A. per an.) Yields quick returns on the investment.

(b) Sulphate of Ammonia - 20.2% N. Supply mainly from the destructive distillation of coal in coke ovens, blast furnaces, gas works, etc. Must not be mixed with alkaline substances. The ammonia is readily absorbed by the soil and less loss from leaching results. Takes lime from soils $(NH_4)_2SO_4$ - $CaCO_3$ → $(NH_4)_2CO_3$ + $CaSO_4$ + H_2O. Nitrogen of $(NH_4)_2SO_4$ is fixed by micro-organisms. About .9 as efficient as

$NaNO_3$. Increases the toxic effects of acid soils. Not always detrimental to plants adapted to acid soils. May suspend bacterial action when used in large amounts. Liberates bases from their combinations in the soil. Fertilizing effects not permanent. May cause imjury on light limestone soils.

(c) Calcium Cyanamid - Comm. 10 - 16% N. Made by passing N. gas over calcium carbide at a high temperature. $CaC_2 + N_2 = CaCN_2 + C$. Action in soil, $CaCN_2 - H_2O = Ca(OH)_2 - CO(NH_2)_2$. Slowly decomposes when exposed to air. Compares with sulphate of ammonia on heavy soils. Toxic to young plants by formation of dicyanamid. Should be applied some time before seeding or planting. Good for acid soils on account of the CaO.

(d) Calcium Nitrate - 13% N, 25% CaO. Made by passing an electric spark through air. Very hygroscopic. Good for soils deficient in lime. Less valuable on limestone soils and for plants that do not require lime. Under favorable conditions produces results comparable with nitrate of soda.

(e) Potassium Nitrate - About 11% N. From India and Cape Colony. Often made artificially in nitre beds. Expensive but may be economically used on garden crops or when other forms of N are high-priced, or transportation charges high. Chlorine is avoided when this compound is used.

(f) Ammonium Nitrate - 35% N. Expensive but freight charges low. Excellent fertilizer.

2. Animal products.

(a) Dried Blood. - Red, 13 - 14% N. Dried in vacuo. Black, 5.5 - 12% N. Dried at high temperatures. Blood contains .5 - 1.5% P_2O_5 and .6 - .8% K_2O. Contains considerable moisture when finely ground. One of the best organic fertilizers. Does not work well on an acid soil.

(b) Dried meat or meal - 10 - 14% N, 13% P_2O_5. Next to dried blood in efficiency.

(c) Horn & Hoof Meal - About 12% N, 5.5% P_2O_5. Not as good as blood and meat meal but better than leather, etc.

(d) Leather meal, wool and hair waste, feathers, etc. Contains varying percentages of N (5 - 17%) and P_2O_5 (.5 - 3%). All low grade fertilizers. Some may be improved by steaming and other treatments. Wool waste should be spread broadcast and plowed under. Shoddy and felt wastes highly esteemed for grapes, other small fruits and hops. N becomes gradually available. 1 - 2.5 tons equal to 20 tons manure. Good effect on physical condition of soil.

(e) Fish Scrap - About 3 - 10% N, 6 - 14% P_2O_5. Principally from fishing industries. Sometimes treated with H_2SO_4. May be applied directly to the soil when easily obtained. Best adapted to warm, moist climates and on sandy or open soils.

(f) Bone tankage - 4 - 12% N, 7 - 20% P_2O_5. Rendered

and steamed bone, meat, etc., from packing houses. Value depends upon degree of fineness. Best method is to mix well with the soil.

(g) Natural Guanos - Contain varying percentages of N & P_2O_5. (3 - 15% N), (12 - 25% P_2O_5). Excrements and remains of birds and marine animals. Chiefly from main land and islands of Peru. Does nothave a long-continued or marked influence on the physical character of the soil. Often treated with H_2SO_4. Raw guano readily loses ammonia and should be mixed with the soil. The treated guano is ideal for top-dressing. Should be balanced by introducing lacking elements. Bat guano - 1 - 12% N, 2.5 - 16% P_2O_5. Found principally in caves and grottos in different parts of the world. Needs supplementing. Fish guano - 7 - 8% N, 9 - 10% P_2O_5. Use depends upon soil conditions favoring decomposition. Should be supplemented with forms of P_2O_5 and K_2O.

3. Plant Products.

(a) Garbage Tankage - 2.5 - 3% N, 1.5 - 3%, P_2O_5, .7 - 1.5% K_2O. Kitchen wastes chiefly. Fertilizing value low. Usually steamed.

(b) Cotton-Seed Meal - 4 - 7% N, 2.5% P_2O_5, 1.7% K_2O. Refuse from cotton seed oil manufacture. Used extensively in South and East on sugar cane, cotton and tobacco. In North usually fed to dairy animals and manure applied to the soil.

(c) Linseed Meal - 4.9 - 5.8% N, 1.8% P_2O_5, 12% K_2O.
Refuse from linseed oil factories.

(d) Castor Pomace - 5.5 - 5.75% N, 1.5 - 2.25% P_2O_5, 2% K_2O. Refuse from castor oil presses.

(e) Sea Weeds - .17 - 1.35% N, .05 - .25% P_2O_5, .16 - 1.45% K_2O. Applied economically only where found. Some decompose readily and may be used in small amounts as autumn and winter top dressing on grass. Best plowed under. Give smooth potatoes, sometimes of inferior quality. On account of the adhering salt they may be injurious to hops, the burning quality of tobacco, and may depress the sugar content of beets. Often leached by rains before applied to the soil. Not a balanced fertilizer. May introduce lime in shells attached. Are free from weed seeds. Sometimes composted with lime or manure and soil.

(f) Peat and muck - 1 - 4% N. Valuable on light soils that require organic matter.

4. Miscellaneous products.

(a) Soot - .5 - 6% N. in form of ammonia. From combustion of coal. Improves physical condition of clayey soils. Color supposed to have a beneficial effect in warming the soil.

B. Carriers of Phosphorus.

1. Mineral Products.

(a) Floats - (Name applied to finely ground raw rock phosphate). South Carolina rock - 26 - 28% P_2O_5.

Found on land and in the beds of rivers. Florida phosphates - 18 - 30% P_2O_5. Varies greatly. A whiteish product found on land and in river beds. Canadian Apatite - Best grades 40% P_2O_5. A crystalline rock, expensive to mine. Tennessee Rock - 30 - 32% P_2O_5 and exists in veins and pockets. Floats especially beneficial on peat or muck soils, and upland soils rich in organic matter. Not advisable on light, sandy soils low in organic matter. Often used in stable gutters with good results. Should be mixed thoroughly with soil. Best on those plants which have a long season of growth. Not good for plants having a low feeding power for P - turnip, cabbage and similar plants. Might be used with limestone for plants desiring alkaline soils.

(b) Treated Rocks - Acid Phosphate - made by treating phosphate rock with H_2SO_4. 14% P_2O_5. $Ca_3(PO_4)_2 + 2H_2SO_4 = 2CaSO_4 - CaH_4(PO_4)_2$. In the manufacture of superphosphate. More H_2SO_4 is used and free phosphoric acid is liberated. $Ca_3(PO_4)_2 + 3H_2SO_4 = 3CaSO_4 - 2H_3PO_4$. Double superphosphate is made by treating low grade rocks with H_2SO_4 as for superphosphate, purifying the H_3PO_4 and using it to treat a high grade phosphate rock. $Ca_3(PO_4)_2 + 4H_3PO_4 = 3CaH_4(PO_4)_2$. The object of these treatments is to make the P more soluble. Monocalcium Phosphate easily reverts in the soil. May form compounds with iron and aluminum. Lime should be added as the calcium phosphates are the most soluble. P. fixation in the soil rapid, and very little leaches away. The upper nine inches of soil holds nearly all of applied P_2O_5. Superphosphates should be applied to the soil some time before seeding. Do not have good effect on acid peat or upland soils. Have a flocculating effect upon the soil. Very good on Calcareous soils for turnips. Acid soils should first be limed on fertilized with wood ashes Residual effects of acid phosphates long-continued. Turnips, cabbage, Brussels sprouts, kale, kohl-rabi, cauliflower, lettuce, beets, spinach, radish, sugar beets and potatoes. Soluble phosphates good when rainfall is light. They greatly hasten maturity.

(c) Basic Slag - 12 - 28% P_2O_5. A waste product from the manufacture of steel. Matarial important, 80% should pass 100 mesh sieve. Contains 40 - 60% CaO. Needs moisture to become available and is good on clay, peat, or muck soils. Improves physical condition of clay. Good for sandy soils except in case of drouth. Ideal use is on acid soils. Should not be mixed with organic nitrogenous materials or ammonia compounds.

2. Animal Products.

(a) Bone phosphates - 1 - 3% N. 20 - 30% P_2O_5. Chiefly from packing houses. Sometimes steamed and sometimes treated with H_2SO_4. Ideal soils for raw or steamed bone are sandy or gravelly, although they should not be too dry. Acts slowly on heavy soils. Lasts in the soil. Much used before seeding land to clover or grass, fruit, hops, and crops which require a long season of growth. Dissolved bone black - waste boneblack from sugar refineries treated with H_2SO_4.

Bone tankage - See A-2-(f).

(b) Fish scrap - See A-2-(e).

(c) Guanos - See A-2-(g)

C. Carriers of Potassium.

1. Ashes - wood-- 3 - 8% K_2O, 30 - 25% CaO, 3 - 4% MgO, 1 - 2.5% P_2O_5. Cotton-seed hull - 10-42% K_2O, 3-13% P_2O_5, 9% CaO, 10% MgO. Corn cobbs - 50% K_2O.
2. Tobacco stems. 3.76%-8.82% K_2O, also rich in N.
3. Sea weeds. See 9 - 3 - (e).
4. Potassium Nitrate - 44.5-45.5% K_2O, 12-14.5% N. Valuable when necessary to avoid sulfuric acid and chlorin.
5. Potassium Carbonate - 90% K_2O. Supply chiefly from Russia. Good when sulfates and chlorides are objectionable. More applicable to acid soils. May dissolve humus and cause deflocculation.
6. Kainit - about 12.4% K_2O. Contains chlorides and sulphates. Much used in making complete fertilizers. Not good for sugar beets, tobacco, or potatoes because of the harmful effect of chlorine when kainit is applied the same spring. Not harmful if applied the preceding year.

7. Muriate of Potash - 48-50% K_2O.

8. Sulphate of Potash - 47-48.5% K_2O.

9. Double sulfate of potash and magnesia or double manure salt - 25-27% K_2O, 34% $MgSO_4$. May be used where sulfur is needed and chlorin is to be avoided. Should not be used on soils rich in magnesia.

10. General considerations on use of potash fertilizers - The use of chlorin increases need for liming. Ca & Mg chlorides are formed, are toxic and leach away. Held tenatiously by soils except perhaps in case of very light ones. K_2O remains close to the surface. Very beneficial to legumes. Act best in wet seasons.

BARNYARD MANURES.

A. Factors which influence the composition of manures.

1. Influence of feed and age of animals.

(a) Where feed is the same manure is richer in case of

(1) Mature animals.

(2) Those not producing milk or bearing young.

2. Charactef of feed.

(a) The richer the feed in plant food elements, the more value the manure will have as a fertilizer.

3. Influence of absorbents.

(a) The amount and composition of bedding and other absorbents will affect the value of manure.

4. Influence of care.

(a) Four-fifth of the value of manure may be lost if allowed to leach.

(b) Horse manure may "fire-fang" and lose nitrogen

(c) Manure should be kept compact and moist for best results. Stall manure lost 15% of nitrogen, yard manure 30 - 40% in same time.

(d) Should be left in large rather than small piles, if necessary to pile.

B. Horse Manure.

1. On account of less complete digestion in the animal this manure is loose in physical character and easily ferments and loses nitrogen. This heating characteristic is of value in making hotbeds and cold frames.

2. Composition.

(a) Solid portion	.55% N,	.30% P_2O_5,	.40% K_2O
(b) Liquid portion	1.35% "		1.25% "
(c) Mixed (liquid & solid)	.7 % "	.25% "	.55% "
(d) Pounds in a ton	14 "	5 "	11 "

3. Amount produced per animal.

   (a) 100# dry matter in feed will produce 210# manure with 77.5% water.

   (b) Allowing 6.5# of bedding per animal per day each horse would produce 6¼ - 7 1/3 tons of manure per year.

C. <u>Cow Manure.</u>

1. The food of the cow is better digested than that of the horse.

2. Composition.

(a) Liquid	1.32% N,	___ P_2O_5,	1.00% K_2O.
(b) Mixture	.51% "	.35% "	.51% "
(c) Pounds per ton	10.2 "	7 "	10.2 "

3. Amount of manure produced.

   (a) 100# dry feed produces 384# manure.

   (b) About 65# of mixture per day, or 12 tons per year.

   (c) About one-fourth of the nitrogen in feed is used by the cow, one-fourth goes in the solid excrement and one-half in the liquid excrement.

D. <u>Sheep Manure.</u>

1. Contains less water than horse or cow manure but ferments easily.

2. Composition.

(a) Mixture	.95% N,	.35% P_2O_5,	1.00 K_2O
(b) Pounds per ton	19 "	7 "	20 "

3. Amount produced.

   (a) 100# feed produces 183# manure.

   (b) 1 animal under average conditions produces about 1500# per year.

E. Hog Manure.

1. Much of this manure is left in field.

2. Varies widely in composition.

3. Composition:

(a) Mixture .83% N, .04% P O , .61% K_2O

(b) Pounds per ton 16.6 " .8 " 12.2 "

4. Amount produced.

(a) 100# dry feed will produce 237# manure.

(b) 1 pig makes about 1½ tons per year.

F. Hen Manure.

1. Materially different from other manures because voided in one portion.

2. Composition.

(a) Average - 1.97% N, 1.53% P_2O_5, .73% K_2O

(b) Pounds per ton 39.4 " 30.6 " 14.6 "

3. Amount produced.

(a) About 40# per fowl per year.

4. General characteristics.

(a) Nitrogen of this manure is easily lost by leaching.

(b) Should be supplemented with 12 - 15# of acid phosphate, 4 - 5# muriate of potash, 5 - 10# of gypsum per 100# manure.

(c) A black, sandy loam soil makes a good absorbent.

(d) May burn small plants when applied as a top dressing.

G. Absorbents.

1. Principal kinds used.

(a) Peat or muck. - This substance is undoubtedly a good absorbent for manure because of its great power to take up water. It also contains about 2.5% N, .88% P_2O_5, .34% K_2O. Sprinkled dry in stalls and gutters best.

(b) Loamy soil good but quite heavy to handle.

(c) Gypsum is frequently used. It changes ammonium carbonate to ammonium sulphate which stays in the pile. 100 - 120# per ton a good treatment.

(d) Acid phosphate and raw rock phosphate make good absorbents and also reinforce the manure with phosphoric acid.

H. Application of manures.

1. Well rotted manure gives best results.

2. Fresh manure should be applied long before seeding - effects worse on sandy soils.

3. Direct application better than storage; however, economy of hauling must be considered.

4. Danger of loss on slopes depends upon:

   (a) Absorbing power of soil - tight soils, steep slopes, frozen soil, ice sheet, and heavy rains all tend toward producing loss in applied manures.

5. The general opinion is that manure should be plowed under on light soils but on heavy soils it should be spread on the plowed surface and disked or harrowed in.

6. Great losses result when manure is spread on soil in warm windy weather.

7. Just before a rain or a light fall of snow is a good time to apply manure as the ammonium carbonate may be carried into the soil better.

8. Manure should be spread evenly.
9. The practical benefits of manure come from its physical effect upon soil texture as well as its plant food value.
10. Manure may be profitably supplemented by chemical fertilizers - phosphoric acid and potash.
11. Best place formanure in the general rotation is on clover sod for long-season crops like corn, beans or potatoes. It may also be useful as a top dressing.

SYSTEMS and PRINCIPLES of FERTILIZATION FROM SOIL and CROP STANDPOINT.

A. Factors to be considered in applying fertilizers.

1. The character of the soil. - Whether sand, loam, or clay.
2. Moisture conditions. - Whether wet or dry. This refers to both soil and season.
3. Kind of subsoil. - Whether loose, medium, or tight - deep or close to surface. Conditions with respect to hardpan.
4. Previous soil treatment. - Manuring, legumes, cultivation, fertilization, produce sold or fed on land.
5. Object of growing the crop. - Whether for early or late produce, immature produce, or matured seed.
6. Kind and habits of crop. - Whether cereals, legumes, trees, etc., root systems, early or late developing.

B. Systems of fertilization.

1. System of Ville. - This system is based on the specific influence of a certain element upon the crop. Nitrogen seems best for wheat, rye, oats, barley, grass, and sugar beets. Phosphorus for turnips, rutabegas, corn, sorghum, and sugar cane. Potassium for peas, beans, clover, vetches, flax, and potatoes.
2. The German system. - An abundant application of the minerals because they are not lost much by leaching. The nitrogen is then added in small amounts, in soluble forms, when needed by the plants. This system is highly desired for market garden crops.
3. The Chemical analysis System. - Heavy applications made to soils for money crop and no other applications during

the rotation.

Note. - All these systems presuppose that the soil is in good mechanical condition, has the proper reaction, and well supplied with organic matter.

C. Fertilization of cereals.

1. General characteristics of the cereals. - The roots brahch just below the surface, and each shoot produces feeding roots which grow in every direction and absorb food from the lower layers of the soil as the plant grows older. Their root system is wide and they are able to acquire food from the insoluble phosphates and potassium compounds of the soil, but they do not seem to be able to feed to any extent upon the insoluble N compounds. (Corn is an exception.) They develop early in the summer before nitrates are fonmed in the soil and are especially benefitted by applications of soluble N fertilizers.

2. Fertilization of cereals.

   (a) Corn. - A crop of 50 bu. shelled corn with stalks will remove from the soil 80 lbs. N, 29# P_2O_5, 55# K_2O. It is an exhaustive crop. A part of the P_2O_5 should be soluble and the rest ground bone or tankage. The K_2O may be applied as KCl or Kainit, but KCl is preferable if applied in the drill which is perfectly safe for the plant. If soil is light and sandy N should be added even though manure is used. The amount of N needed would be supplied in 100# high grade blood or 200# cotton-seed meal.

   (b) Forage corn. - When grown after clover or on good soil 500# of a 2-6-8 fertilizer makes a good dressing. If soil is poor more N should be used when there is no clover or manure, and organic N is preferable. P_2O_5 in superphosphates, and K_2O as Kainit or KCl. Kainit should be well worked into the soil.

(c) Silage corn. - The object of growth is to obtain a large yield of dry matter rich in nitrogenous substances and poor in starch and woody fibre. More N should be used than for field corn. 30# N, 40# P_2O_5, 60# K_2O - (250# dried blood or 450# cotton-seed meal, 300# acid phosphate, 120# muriate of potash.)

(d) Wheat. - For wheat following oats farm manure after plowing well disked or harrowed in and a fertilizer rich in available P_2O_5 with a sufficient amount of available N to give a good fall growth. When the soil has been well fertilized for previous crops a dissolved animal bone superphosphate is a good fertilizer for wheat (200 - 300#). If more N is needed, as is frequently the case, when the winter has been severe or the soil is light, use $NaNO_3$ in the spring as a top dressing (75 - 150#).

(e) Wheat and rye for forage. - Larger amounts of N. should be used to give succulence and a larger growth of leaf and stem. When sown after fertilized corn, N and P_2O_5 may be used, but if sown on poor soils the three elements are necessary and some top-dressings should be made in the spring. The N should be in quickly available forms.

(f) Oats. - This crop develops early in the season so quickly available forms of N are desirable, as is also P_2O_5 which is used in large quantities by the oat crop. Nitrate of soda and superphosphates have proven of value to this crop. 50# $NaNO_3$, 150# acid phosphate. An application of K_2O is not necessary if applied to corn preceding oats, except on light sandy soils.

(g) Oats for forage. - Oats are adapted for forage because they make a good, early growth in moist, cool weather. 12# N, 20# P_2O_5, 10# K_2O makes a good dressing ($NaNO_3$, superphosphates, KCl). Shortly after germination there is a period when growth is extremely slow (pouting period) supposed to be due to lack of plant food early in the season. Nitrates and superphosphates shorten and sometimes stop this period which is important in case of forage crops. Winter oats should be fertilized in the same manner as wheat.

(h) Millets. - These are surface feeders and are particularly benefited by liberal applications of all the elements. Maximum crops can not be maintained without a good supply of plant food. N and P_2O_5 should be largely in soluble forms. 150# $NaNO_3$, 200# acid phosphate 100# KCl has given good results.

(i) Buckwheat. - This crop is well adapted to mountain lands and is extensively used in breaking new lands. P_2O_5

most required. Heavy N fertilization is not required because the growth is mostly in July and August. Light soils deficient in organic matter require N for this crop. On medium soils 10# N, 25# K_2O, good fertilization.

(j) Barley. - Characteristics and fertilization similar to wheat. This crop has a short period of growth and a limited root system and requires plant food in available forms. When used for feeding N should be liberally used but for malting less N and more K_2O is desirable to give more starch. Salt is successfully used and is supposed to make the insoluble K_2O compounds of the soil more soluble. N should be used with care in order to prevent lodging.

(k) Rye. - Characteristics almost the same as wheat, and fertilization should be the same on similar soils. Excessive N should be avoided.

D. Fertilization of grasses.

1. General characteristics. - Nearly all species of grasses are perennial. They send their fibrous roots into the surface soil in the same manner as the cereals, but they form a set of buds which become active in the late summer and develop new roots and shoots. They resemble the cereals in their power to gather food and are even more benefited by applications of soluble N fertilizers. Leaf and stem growth are desired and not matured grain, hence a good N supply should be maintained.

2. Fertilization.

(a) Timothy. - Especially benefited by N fertilizers when the minerals are well supplied. It is best to apply minerals in the spring as a top-dressing. An application of 150# $NaNO_3$, 100# acid phosphate and 50# KCl per acre is now used by many successful hay growers. The application should be made as soon as the crop has well started in the spring.

(b) Lawn grasses. - Well rotted manure spread in winter or early spring and raked over as soon as growing weather begins is one of the best treatments for lawns, but manure is troublesome because it introduces weed seeds. 5 parts ground bone and 1 pt. KCl make an excellent dressing before seeding, 5# to the sq. rd.

as a top-dressing twice or thrice during the season; the first just after the plants have come up and the others just before a rain. Ground bone and KCl may also be used as a top-dressing. Too much KCl encourages the growth of the clovers.

E. Legumes.

1. General Characteristics. - The clovers are not perennial (except white or Dutch clover) and with this exception they possess a tap root which grows downward and sends out fibrous roots at different levels. They are capable of readily acquiring their mineral food and get N from the air. The tendency of their growth is to inrich the soil with N.

2. Fertilization.

(a) Clover. - When clover follows wheat that has been fertilized with N or manure only P_2O_5 and K_2O need to be applied. 12# P_2O_5, 25# K_2O (100# acid phosphate, 50# KCl) is a minimum dressing and may be applied as soon as the wheat has been harvested.

(b) Clovers for forage. - They get plant food which is in accessible to the cereals, and are less exhaustive. They furnish early food. On soils of medium fertility the need of N is not marked. On light soils N is serviceable, before the plant can get N from the air. A good supply of minerals is desirable, and less available forms of P_2O_5 maybe used.

(c) Alfalfa. - Requires an abundance of mineral food. Insoluble forms may be used for preparatory dressings but soluble forms are best for top-dressings which may be made annually. 125# $NaNO_3$, 600# acid phosphate, 400# KCl a good preparatory fertilizer. Top-dressings should provide 30# P_2O_5, and 100# K_2O . The fertilizer may be used on the preceding grain or cultivated crop.

(d) Cow pea and soy bean. - Obtain their food during a short period and hence require more plant food than the clovers. 200# acid phosphate and 100# KCl a good dressing on medium soils for clovers, but should be increased by about one-half for summer crops.

(e) Peanut. - A legume, not especially benefited by N fertilizers. 300# acid phosphate and 100# Kainit good. Lime is useful, 20 bu. per A. once in four years.

(f) Beans. - K_2O best on clay soils. 200-400# of a 2-8-10 fertilizer good. N. should be preferably in organic forms, and minerals well supplied. Superphosphates and KCl good forms.

(g) Peas. - Similar to beans. (See market garden crops.)

F. Meadows.

1. Characteristics. - See characteristics of grasses and legumes.

2. Fertilization. - A liberal application of mineral elements is recommended because they encourage growth of clovers and make a richer herbage than grasses. Heavy N fertilization is expensive and encourages grasses rather than clovers. Mixtures of acid phosphate, ground bone and KCl make good dressings, when used in equal proportions at the rate of 300-500# annually. The ground bone is recommended because it furnishes a continuous supply of N and P_2O_5. Applications should be made in spring and late summer to encourage clovers. When organic matter is added to the soil in large quantities it is advisable to make an application of lime.

G. Forage crops. - Cereals and Legumes.

1. Characteristics - See characteristics of cereals and legumes.

2. Fertilization.

(a) Oats and peas. - More of the minerals should be applied to encourage growth of the pea crop. It is also desirable to encourage the growth of the oats by the use of N. 75# $NaNO_3$, 175# acid phosphate, 25# KCl good.

(b) Barley and peas. - A good combination when late fall forage is meeded and is adapted to fall conditions. Fertilization should be liberal. Same as for oats and peas above.

H. <u>Root crops.</u>

1. Characteristics. - The crops can not make ready use of the insoluble mineral compounds of the soil. They must be liberally supplied with soluble mineral foods. Phosphates are useful to turnips while the slow growing (beets and carrots require N in quickly available forms. Root crops are exhaustive of plant food elements, more so in proportion to dry matter contained in them than legumes. It requires twice as much root crop to supply the same amount of food as in legumes. 20 tons of roots contain 60# N, 35# P_2O_5, and 150# K_2O.

2. Fertilization.

(a) Fodder beets and carrots. - Require liberal amounts of N and P_2O_5in available forms to meet the large and early demand of the plant for them. K_2O is essential on soils of a light character; these plants are better able to obtain this compound on loam and clay soils. A liberal use of barnyard manure is good. 40# N, 50# P_2O_5, and 100# K_2O makes a good application. N should be applied in fractional dressings, and the crop cultivated soon after.

(b) Turnips, Sweeds, and rape for Fodder. - These plants are able to get $P_2O_5$from combinations not readily reached by other plants. 20# N, 40# P_2O_5, 40# K_2O a good dressing. Success with these crops depends largely upon having a good supply of plant food on hand so as to give a rapid continuous growth.

(c) Sugar beets. - This crop draws heavily on the soil for N and K_2O. On rich, loamy soils K_2O is not necessary but is on light, sandy ones. Growth must be forced early in the season. Too long or too rapid growth has a tendency to decrease the sugar content. A large leaf should be made early and P_2O_5required to make this leaf. $NaNO_3$ or $(NH_3)_2SO_4$ and acid phosphate should be used early. On good soils 40-50# N, 50-60# P_2O_5, 40-50#

K_2O would be a good application. Best to apply in fractional proportions. $NaNO_3$, KCl, and K_2SO_4 depress germination. On light soils above amounts should be increased by one-third, on soils rich in organic matter the N might be reduced. This mixture will give best results when soil has been cultivated deeply before the crop., and might be harmful on shallow cultivated soils by producing too great a growth above the ground.

(d) Potatoes. - Potatoes and sweet potatoes do not possess strong foraging powers and require their food in available forms.

(1) Early Crop. - Requires an abundance of plant food and heavy fertilization is usually more profitable than light or medium. Average plant food removed from the soil by 200 bu. 27# N, 12# P_2O_5, 60# K_2O. It is always advisable to add plant food in excess because crops must be grown quickly, and a large part of the growth must take place before the soil becomes active. A 4-8-10 is a good formula. The fertilizers should be applied to the soil just before planting and mixed thoroughly with the soil. When the soil is heavy and the circulation of water not free, the fertilizer may be put part in the row and part between the rows. When the soil is light and open all may be put in the row. K_2SO_4 is best for quality, but KCl gives about the same yield. K_2SO_4 gives potatoes clean and uniform in size. A portion of the N should be in $NaNO_3$ or $(NH_3)_2SO_4$ and the remainder in quickly available organic forms. A top-dressing of N after the potatoes have come up is desirable on light, sandy soils which have been supplied with minerals. 800# of the above formula is a minimum application on a good potato soil.

(2) Late Potatoes. - The late crop takes more plant food from the soil. The N may be reduced and come from organic sources.

(e) Sweet potatoes. - Quality, size, shape, and results in cooking important. The potato that brings the best price is round rather than oblong, about the size of a white potato, and dry and mealy when cooked. These characters are influenced by soils, climates, and fertilizers. The best soils are the dry sandy loams. The best fertilizers are those that contain an abundance of the minerals and not too much available N. Yields are not as large when quality is maintained. 200 bu. contains about 30# N, 10# P_2O_5, 45# K_2O. Applications of 20# N, 50# P_2O_5, and 80# K_2O give good results in N. J. In northern sections and in cold seasons the soluble forms of N are useful, but in the South the organic forms are best. Should be applied when making up the hills 2 to 3 weeks before planting. On clay soil K_2O is best applied broadcast the previous year. Kainit should be well mixed with the soil.

I. Fruit Crops - Tree Fruits and Grapes

1. Characteristics of tree fruits. - A longer period of growth required than for other plants. A knowledge of the habits, periods, and object of growth is a useful guide to fertilization. The growth of each succeeding year of tree and fruit is dependent upon the food acquired during the year and also the previous year's supply which has been stored up in buds and branches. These crops must be provided with food that will insure a slow continuous growth rather than a quick growth and development. There should be a constant transfer of N from the tree to the fruit during the entire growing season. A fruit tree will not make a normal growth in a soil poor in N. N encourages leaf growth. K_2O constitutes a large proportion of the ash of wood, and about 50% of the ash of fruits and acts as the base of fruit acids. P_2O_5 helps to nourish the tree and to insure proper ripening of fruit. Lime is important in the production of stone fruits. Itsfunctions seem to be to strangthen the stems and woody portions, shorten the period of growth, and hasten the time of ripening. Fruit trees growing on a soil rich in lime show a sticky, steady, vigorous growth and the fruit ripens well, while those on soils with little lime, particularly the clays, appear to have an extended period of growth, the result being that the wood does not mature and the fruit does not ripen proper-

ly. The fertilizers need not be all immediately available. For convenience two basic formulas are given. No. 1, 100# ground bone, 100# acid phosphate, 100# KCl; No. 2, 150# ground bone, 100# KCl. These formulas will be referred to later as No. 1 and No. 2. An excess of N should be avoided. Fertilizers should be well mixed with the soil. They may be applied before plowing or soluble forms added just before a rain. The main part in the fertilization of fruits tends to be a liberal application of the minerals, with particular attention paid to the N fertilization. Fruit is wanted, not wood, and all energies should be directed towards producing a tree or vine that will produce fruit.

2. Fertilization.

(a) Apples and pears. - On light soils fertilization should begin when trees are set, but not on fertile soils until trees bear. 400# an A. of No. 1 applied in the early spring and worked well into the soil. On light soils N may be needed and is best supplied in organic forms which decay slowly. N may also be supplied in leguminous crops. On very poor soils 500# No. 2 before setting trees and continued annually with green manuring. If the leaves lack vigor and are yellow in the spring, $NaNO_3$ should be applied (about 150#.)

(b) Peaches. - Peaches, more than apples and pears, should have forms of N that are more available because the development of the tree before bearing is more rapid. Fertilization of peaches will increase and maintain the yield and help overcome unfavorable weather conditions. On good soils fertilization should not begin until the second or third year. On medium to poor soils 400-600# per A. if No. 1 before setting the trees, followed by an application of more soluble forms after the trees begin to bear. On the better soils No. 2 may be used instead of No. 1. The need of N is often apparent, and is shown by lack of vigor in leaves and trees. Soluble nitrates are good in this case, but the tree should not be kept growing too late in the fall

Green manuring should be practiced and carefully carried on so as not to supply too much N to the tree.

(c) Plumbs, cherries and apricots. - The fertilization of these fruits should be carried on about the same as for peaches, but cherries require a relatively larger supply of lime in the soil. Too much N should be avoided. Unless these trees show a need for N a moderate application of No. 2 will be sufficient.

(d) Citrus fruits. - On the lighter soils of Florida growers have found that potash is the fertilizer most required. They require a greater proportion of K_2O than stone fruits and an excess of N should be avoided.

(e) Grapes. - Grapes are a more exhaustive crop than most of the other fruits largely because of the greater total yield. Their special need is for P_2O_5 and K_2O. Very liberal dressings of the basis formula are recommended after the bearing period begins. On light soils $NaNO_3$ may be used as a top-dressing to encourage early and rapid growth of leaf and vine. N. is not necessary when cover cropping is practiced. The cover crop should be plowed down early in the season.

J. Small Fruits.

1. Characteristics. - The crops have a shorter preparatory season and have a shorter period of bearing life. The strawberry does not advantageously bear more than two crops without resetting. The blackberry and raspberry may range in life from four to eight years. The gooseberry and currant are relatively long-lived when supplied with an abundance of plant food. These crops possess a high market value and a low fertility value per A., hence natural sources of plant food may be ignored in their growth, and the more quickly available N and P_2O_5 fertilizers used.

2. Fertilization.

(a) Strawberries. - 500-800# of No. 1 is recommended to be applied to the soil before the plants are set. An additional application of dried blood, $NaNO_3$, or

$(NH_3)_2SO_4$ (100#) is advisable on soils not rich in organic matter. A quick acting fertilizer is desirable in the spring to give a strong growth of plant and a better setting of fruit, if other conditions are favorable. Top-dressings of $NaNO_3$ may be desirable later, after the plant has blossomed. Later applications may soften the fruit and injure shipping qualities.

(b) Raspberries and blackberries. - The main object is to secure strong, well-ripened canes, and for this purpose organic forms of N with plenty of the minerals is recommended. 500# of No. 2 annually on good soils in spring. On poor soils more N should be used but in slowly available forms. Quick acting N after plants have blossomed has given success on light soils. It encourages a more complete development of fruit but should be used with caution since the fruit canes of both the present and the next year grow in the same bed and the young canes may not mature properly if too much N is used.

(c) Currants and gooseberries. - These fruits are seldom fertilized but may be at a profit. They are less likely to need N and heavy fertilization with this element should be discouraged because it aids in the development of mildew, a common disease. They should be well supplied with the minerals. The basic formula with slow acting N materials as a top dressing.

K. Market-Garden Crops.

1. Characteristics. - The particular object is to secure rapid growth and high quality which is measured by the element of succulence and sweetness. Palatibility is determined by succulence, and sweetness of the vegetable, or its freedom from bitterness and stringiness and other undesirable characteristics. Any delay in the growth of any of these products mitigates against quality; radish and lettuce get a sharp taste and pungent flavor, a bitterness and tough fibre in the latter; beets become stringy and wiry and are less palatible; turnips have an unpleasant odor, etc. Unfavorable conditions of growth seem to cause a reversion of characters to

some stage before cultivation and improvement. They must be well supplied with large amounts of quickly available plant foods and should never lack for a good supply of N. A 4-8-10 fertilizer may be considered a basic formula for these crops, leaving the specific needs of each to be supplied as applications or top-dressings. The first application should consist of soluble and insoluble forms, and later dressings of soluble forms. When yard manure is used the amount of chemical fertilizers may be reduced.

2. Fertilization.

(a) Early Tomatoes. - Tomatoes respond quickly to fertilization. $NaNO_3$ is one of the best N fertilizers for this crop. At time of setting 50# acid phosphate, 100# KCl to A., thoroughly cultivated into the soil, and 100-150# $NaNO_3$ around the hill but not touching the plants (may be mixed with soil or sawdust or other bulky material to insure an even distribution.) Three or four weeks later another application of similar amount. It is not desirable to have a late plant growth. When manure is used it should be applied first and worked into the soil, and $NaNO_3$ used as above. Large quantities of manure should not be used.for early tomatoes because it tends to produce a late plant growth.

(b) Late tomatoes. - This crop should have less N and more P_2O_5 and K_2O. N may be used in organic forms. Crimson clover or some other legume grown after the tomatoes are harvested would reduce the amount of N necessary to add in fertilizers. (if weather conditions are favorable.)

(c) Beans and Peas. - Acquire N from the air. Best to apply N, when grown on soil not containing the specific bacteria, to insure a balance of food. Organic N is better because it encourages a longer period of growth. 500-600# of the basic formula will be sufficient.

(d) Beets and Turnips. - Earlyness is the primary consider ation and this is determined largely by the amount of available N and P_2O_5 present. Proper fertilization very important. Early growth takes place before nitrification begins in the soil. Fractional dressings of N recommended. 1000-1500# of the basic formula at time of seeding followed by 50-100# $NaNO_3$ every week or ten days until three or four weeks growth , insures a rapid, continuous growth, and lessens the dangers which arise from too much rain or drouth. Fractional applications prevent losses by leaching if heavy rains follow.

(e) Cabbage, cauliflower, and Brussels sprouts. - These large-leaved plants are voracious feeders, and are benefited by large applications of N and P_2O_5. The basic fertilizer with additions as top-dressings of N and P_2O_5 and on poor soils K_2O also. Too rapid an early growth usually results in an abnormal growth of leaf, and not a proper formation of the head, hence part of the N should be in organic forms. 1000-1500# of the basic formula with 100-200# $NaNO_3$ and 200# acid phosphate after the plants begin to make growth, with more N when the heads begin to form. Climatic conditions greatly affect these crops.

(f) Cucumber, water melons, musk melons, pumpkins, and squashes. - The crops require an abundance of organic matter in soil to make best growth. Composts in the hill of great advantage. A continuous growth is desirable. Organic forms of N or small amounts of $NaNO_3$ applied often are good. Apply basic fertilizer at planting with compost, then later 200-300# cottonseed meal, or 100-200# dried blood or 300-400# fine ground tankage. $NaNO_3$ good for cucumbers for pickling where a large setting of immature fruit is desired.

(g) Onions, onion sets and scallions. - The growing of onions from seed or from sets requires a soil of suitable physical characteristics well supplied with the elements of fertility. N, P_2O_5, and K_2O should be added in soluble forms and even in larger amounts than for the other crops. The sets and seeds should be planted thicker than usually supposed necessary to give a large yield per A. Rapid growth after setting is not desirable except for early crops. Where food is plentiful care should be taken not to allow the bulb to grow too large. To avoid this the seed should be spread thickly in the rows and rows about eight inches wide. When so much of the surface area is covered by the crop the danger of too large development from heavy fertilization is greatly reduced.

In growing scallions the soil should be provided with minerals and organic forms of N as well as $NaNO_3$ before nitrification begins. For crops which require a large amount of hand labor as onions, fertilizers are better than yard manure, because there is less danger from weed seeds and plant diseases. A 5-6-10 formula, 1000# to the A. well worked into the soil previous to planting, with top-dressings of 75-100# $NaNO_3$ two or three times at intervals of three weeks would be an abundance of food of the right sort. The scallions should receive an application of $NaNO_3$ as soon as growth begins in the spring.

(h) Asparagus. - A perennial, and its length of life depends upon treatment. Only one crop in a season. Yield and quality depend upon the number and size of the shoots. Some markets demand a bleached shoot with green top, some a green shoot. The size determines the salability. Small shoots usually indicate that the plant has not been properly fed. The root is enlarged and invigorated by the character and growth of the tops after cutting is finished, so a rapid growth of shoots should be encouraged as well as a good growth of tops later in the season. The plant should be fed with soluble food for the shoots and gradually soluble food for its future growth. At the end of the cutting season the root is weak and should have food. 1000-1500# of basic formula applied previously to setting the crowns and well worked into the soil, and less soluble forms for late summer growth.

(i) Celery. - Celery requires a soil rich in organic matter and an abundance of water, and plant food in soluble forms. In the absence of sufficient water fertilization will not give satisfactory results. 2000# per A. of the basic mixture at time of setting plants followed by dressings of $NaNO_3$ well worked into the soil. An abundance of N will give a rapid growth, crispness, and sweetness of flavor. NaCl is sometimes used.

(j) Sweet corn. - Early crop the most profitable. Fertilization should be the same as truck crops in general. Large amounts of available plant foods with top-dressings of $NaNO_3$. The basic formula with quickly available forms of N as dried blood, $NaNO_3$, cottonseed meal, or tankage.

(k) Egg Plant. - This plant belongs to the same family as the potato. Use fertilizer recommended for potatoes but with more top-dressings of N in available forms to stimulate leaf growth.

(l) Spinach and Lettuce. - Need abundance of N to stimulate leaf growth. 1000# of the basic formula at time of planting and a top-dressing of 100# $NaNO_3$ after the plants are well started. The late fall and winter growth of spinach is especially benefited by nitrates.

(m) Rhubarb. - A plant similar to asparagus. Food should be applied for the crop and also for growth in the fall. 1500# of basic formula each year and a top-dressing of 150# $NaNO_3$ after harvesting has begun and a like application after harvesting has ceased. N should be added just before a rain or cultivated into the soil. Plant from which only one crop is secured should be stimulated extensively.

L. <u>Special crops.</u>

1. Characteristics and fertilization.

(a) Cotton. - Not an exhaustive crop although the methods used in its production have been exhaustive. 300# of lint per A uses 46# N, 12# P_2O_5, 30# K_2O. In regard to fertilization cotton may be classed with the cereals. Best growth obtained in rotation. P_2O_5 seems to exercise the most influence. Complete fertilizer best. Leguminous crops may be used to supply part or all of the N. Responds to fertilization and its period of growth may be shortened to fit a special climate. Organic forms of N are best suited to the plant. Acid phosphates and cheapest forms of K_2O best. A 3-9-3 fertilizer, 700# to the acre, gives good results when applied in the drill at time of planting not more than three inches deep and well mixed with the soil. This formula is also well suited to corn.

(b) Tobacco. - Fertilization influences both yield and quality and should be properly done. 1000# an acre contains 67# N, 9# P_2O_5, 87# K_2O. The best quality of wrapper can be grown best on sandy soils, and if large crops are to be secured plant food must be added. Large amounts of chlorine or sulfuric acid in the soil may damage the leaf. Care should be taken not to produce a coarse, rank growth. Any form of N superphosphates, or K_2O free from chlorine, good; best applied at the rate of 100, 75 and 150# an acre, respectively, on medium soils.

(c) Sugar Cane. - 30 tons per A. will remove 102# N, 45# P_2O_5, 65# K_2O. K_2CO_3 and ash of cotton-seed hulls have injured the soil for sugar cane. Not less than

24# or more than 48# N per acre. $(NH_3)_2SO_4$, cottonseed meal, dried blood, and $NaNO_3$ good; preference in order named. The amounts will vary as the cane is grown in succession or rotation. Soils used for this plant are usually rich in P_2O_5 and K_2O but may be deficient. Fertilizers may be applied under the hill when the plant is young or as a top-dressing later.

(d) Sorghum. - For forage the fertilizer recommended for maize is good. When grown for sugar an excess of N should be avoided as it hinders ripening, and tends to increase the amount of non-crystallizable sugar in the cane. 20# N, 35# P_2O_5, 60# K_2O, makes a good amount to apply per A.

(e) Forcing House Crops. - A loam soil mixed with one-half to one-third its bulk with stable manure is usually used for truck under glass. The addition of fertilizer to this is seldom necessary. In the absence of manure, a rich loam soil is good fertilized witn ½# $NaNO_3$, 1# acid phosphate, 1# ground bone, and ½# KCl to each 100 sq. ft. After growth starts well, ¼# $NaNO_3$, 1# acid phosphate, 1# KCl is added to each 100 sq. ft. every two weeks. Fertilizers may be applied just before watering or in solution. Not much danger of applying too much.

(f) Roses and flowering plants. - Require a rich unnatural soil and applications of fertilizers. P_2O_5 is especially required. Ground bone is useful. Too much N tends to increase leaf and stalk growth at the expense of the flower. 4 pts. ground bone, and 1 pt. KCl at the rate of 4# per sq. yd. well worked into the soil before setting the plant is a good application. Applications of soluble P_2O_5 may be made later. The need for N is indicated by a yellowish foliage. In such cases $NaNO_3$ may be used in light dressings, ½ to 1# to the sq. yd., in solution or just before a rain.

SOILS AND THEIR FERTILIZERS.

A. <u>Fertilizers for well-drained, open soils that are not acid</u>. On these soils animal and plant by-products seem to give the best results. Dried blood, meat meal, fish scrapp, tankage, guano, raw or steamed bone, cotton-seed meal, etc. These fertilizers should be reinforced with minerals. Raw rock (in presence of organic matter), acid phosphate, superphosphates, for P_2O_5; and wood ashes, muriate or sulphate of potash, and kainit for K_2O.

B. <u>Fertilizers for poorly-drained, tight soils.</u> - Ammoniafication and nitrification is slow in these soils, hence soluble forms of plant food are desired. $NaNO_3$ good because it tends to liberate K_2O, but may injure structure if used in too large amounts. $(NH_4)_2SO_4$ good because it has a flocculating action; continued use tends towards acidity. Calcium cyanamide is about equal to $(NH_4)_2SO_4$ and also contains lime. Soot contains NH_3, improves physical condition, and helps to warm heavy, wet soils. Superphosphates good because they have a flocculating action and free K_2O in soil, but their continued use tends toward acidity. Basic slag good and improves physical condition. Wood ashes, KCl, K_2SO_4, and kainit are useful forms of K_2O. KCl and kainit should be thoroughly mixed with clay soils.

C. <u>Peats and mucks that are not acid.</u> - $NaNO_3$, $(NH_4)_2SO_4$, blood and manure good carriers of N. Raw rock, basic slag, and superphosphates for P_2O_5. K_2O is best supplied in KCl or wood ashes.

D. Fertilizers for acid soils. - Acidity in soils interfers with ammoniafication and nitrification. Fertilizers which do not require bacterial changes and which do not tend to increase the acid condition should be used. $NaNO_3$ is the best form of N, and this compound tends to gradually correct soil acidity. Kalcium cyanamid, calcium nitrate are also good forms. Basic slag is a good form for P_2O_5 and contains lime. Wood ashes and K_2CO_3 are the best forms of K_2O. When these soils are welll drained and not too low in fertility the acid condition should be corrected by liming, after which fertilizers as given under A. will be good. Soils low in fertility had best be cropped with crops that will tolerate the acid condition. Muck soils may be too acid to economically correct by liming.

E. Limestone soils. - Raw rock with sufficient organic matter and superphosphates especially good. See A & B for N and K_2O fertilization.

SOIL ACIDITY AND LIMING.

A. Causes of Soil Acidity.

1. Organic acids resulting from decay of organic matter.

   (a) Fermentation of green manures.

   (b) Breaking down of carbohydrates to acetic, formic, butyric, and lactic acids.

2. Breaking up of mineral fertilizers - $(NH_4)SO_4$, KCl, etc.

3. Lack of alkaline earth bases.

4. An acid clay (Argillic acid) - Loew, Porto Rico.

B. Effects.

1. Unfavorable to the growth of many plants particularly legumes.

2. Prevents the growth of beneficial bacteria.

3. Causes formation of toxic soil compounds.

C. Treatments.

1. Liming.

   (a) Soils usually lacking in lime:

      (1) Those formed from granites, mica shist, sandstone, certain conglomerates, slates & shales.

      (2) Limestone soils may have lost all their $CaCO_3$ and become in need of lime.

      (3) Acid soils are usually deficient in available P_2O_5 - Wisconsin.

      (4) Mucks that do not receive water from uplands charged with lime.

   (b) Chemical action of lime on soils.

      (1) Makes the soil alkaline in reaction.

      (2) Overcomes the harmful effects of fermenting and decaying organic matter on some plants.

      (3) Makes K_2O compounds more soluble.

(4) Lack of lime allows the formation of insoluble aluminum and iron phosphates in the soil.

(5) Supposed to free P_2O_5 from these insoluble compounds.

(6) Sulfate of lime renovates alkali soils by changing the sodium carbonate to sodium sulfate.

(7) Changes protosulfate of iron and other poisonous compounds to harmless forms.

(c) Physical action of lime on soils.

(1) Flocculates clay particles and colloidal materials making a better physical condition in heavy soils.

(a) Many beneficial results come from making a heavy soil porous.

(2) Lime binds coarse soil grains together and makes them more compact. Limestone or clayey marls best for this.

(d) Biological action.

(1) Promotes nitrification in soils.

(2) Hastens decomposition of organic matter in muck and other soils.

(3) Helps nitrogen fixing and symbiotic bacteria.

(4) Furnishes the element Ca to plants and microorganisms.

(e) Injurious effects of lime.

(1) Excessive amounts may be injurious on light soils low in organic matter. Burned lime most harmful.

(2) High magnesium lime may prove injurious if used continuously or in excessive amounts. Effects may be overcome by applying pure limestone.

(f) Influence on plant diseases.

(1) Favors production of potato scab.

(2) Lessens effect of "finger and toe" and "club root" in vegetables.

(3) Reduces soil rot of sweet potatoes.

(4) Prevents root disease of alfalfa.

(g) Application.

(1) Depends upon character of soil, kind of plants grown, and rotation of crops.

(2) From ½ to 1½ tons every five or six years an average application. Very acid soils may require more.

(3) Small amounts applied frequently seems to be preferable.

(4) Carbonate forms may be applied at any time of the year but fall is best time for caustic lime.

(5) Should be applied before the crop benefited is sown.

(6) Top-dressing quite satisfactory on sandy soils when the materials are fine and non-caustic.

(7) Apply immediately after plowing and harrow into the soil.

(8) Should be well incorporated with the soil.

(9) Lime spreader best - manure spreader or fertilizer drill sometimes used - may be placed in small piles and respread or spread directly from a wagon.

(10) Caustic forms should not be left in the field too long in piles.

(11) Non-caustic forms may be spread with manure.

(h) Forms - sources, composition, and characteristics.

(1) Caustic ("quick" or "burnt") lime.

(a) Obtained from burning limestone, marl, and shells.
(b) Contains about 95% CaO.
(c) Cheapest form when transportation charges are great.
(d) Readily changes to other forms.

(2) Gypsum, or land plaster.

(a) Mined from deposits.

(b) May flocculate soils and liberate potash.
(c) Does not correct acidity.

(3) Marl.

(a) Found in deposits mostly under mucks and swamps.
(b) Varies greatly in limestone content.

(4) Phosphate of lime.

(a) Contained in bone, guano, and phosphate rocks.
(b) The animal products are effective on upland acid soils and the ground rock on mucks.

(5) Basic slag.

(a) A waste product from the manufacture of steel.
(b) Contains 40-60% of CaO.
(c) Effective on all kinds of soils.

(6) Wood ashes.

(a) Unleached contain about 35% of CaO.
(b) Leached contain jore lime but less potash.

(7) Ground limestone.

(a) Usually by-products from stone crushing establishments, but finer and purer grades may be crushed from high grade rock.
(b) Contain varying amounts of calcium and magnesium carbonates.
(c) Heavy to haul and is nott carried great distances.
(d) The finer the particles the greater the value.

(8) Waste lime from beet-sugar factories.

(a) That from the process is fine and contains a small amount of other plant foods. Lime kiln refuse is similar to burnt lime.
(b) Usually contains a large amount of water.
(c) Nearly all carbonate of lime.

(9) Miscellaneous products.

(a) Shells, waste products from tanneries, wood alcohol distilleries, soda manufactories, salt evaporators, and many other factories where lime is used in processes.

(i) Plants benefitted by liming.

(1) Field crops.- Swedish turnip, flat turnip, peanut, tobacco, sorghum, saltbush, hemp, alfalfa, clover (red, white, crimson, and alsike), barley, immer, wheat, oats, timothy, Kentucky blue grass, and Canada peas. Pota-toes are usually of better size but may be scabby.

(2) Garden crops. - Beets (all kinds), spinach, lettuce (all kinds), okra, salsify, celery, onion, parsnip, cauliflower, cucumber, egg plant, canteloupe, asparagus, kohl-rabi, cab-bage, dandelion, pepper, upland cress, marty-nia, rhubarb, pea, pumpkin, summer squash, golden wax bean, red valentine bean, pole bean, bush lima bean, lentil, Hubbard squash.

(3) Trees and shrubs. - American linden, American elm, Burbank Japan plumb, cherry, quince, orange, raspberry, gooseberry, currant.

(4) Flowers - Sweet alyssum, Mignonette, balsam, nasturtium, pansy, poppy, and sweet pea.

(j) Plants little benefited by liming.

(1) Indian corn, spurry, rye, carrot, chicory, Rhode Island bent grass, red top, and millet.

(k) Plants usually injured by liming.

(1) Injured under certain conditions. - Cotton, tomato, zinnia, cowpea, phlox, (Drummondi) Concord grape, peach, apple, and pear.

(2) Decisively injured. - Lupine, common sorrel, radish, velvet bean, castor bean, flax, blackberry, black-cap,raspberry, cranberry, Norway spruce, American white birch, chestnut, azalia, rhododendron, and watermelon.

l. Fertilizing.

(a) The injurious effectsof soil acidity may be some-what overcome by applications of manure, cover crops plowed down, etc.

(b) Many commercial fertilizers contain lime and will gradually correct acidity.

(c) Some fertilizers give rise to alkaline compounds in the soil.

D. <u>Crops adapted to acid soils</u>. (see 1.-(k) above).

1. Non-legumes - Blueberry, cranberry, strawberry, blackberry, raspberry, black-cap raspberry, potato, sweet potato, rye, oats, millet, buckwheat, red top, corn, carrot, turnip, and radish.

2. Legumes - Cow pea, soy bean, hairy vetch, and crimson clover.

CHARACTERISTICS, CROP ADAPTATION, andMANAGEMENT OF MICHIGAN SOIL TYPES.

A. Miami Series. - Light-colored, upland, timbered soils of glacial origin, found on morains, till plains, outwash aprons, eskers and other ice formations. They are nearly all low in organic matter and those not containing carbonates are usually acid. The sand and fine sand soil are not adapted to general farming but are good for early truck and fruit. The stony and gravelly sandy loams are fairly good for light farming truck and fruit. The sandy loam and fine sandy loam are used for general farming but best adaptation is for medium to late truck and fruit. The heavier members are well adapted to wheat but not as good for corn as the corresponding soils of the Marshall Series. The clay loam is most important for general farming and well adapted to small grains and grass. The silt loam is good for general farming and hardy fruits.

1. Miami Gravel. - A water-worn gravel mixed with sand. Occurs as outcrops of glacial gravels in deposits and narrow bands or strips, or small areas in fields where it is easier to cultivate or not. Supports only a scanty growth of grass. Might produce grapes and peaches. The present agricultural value is almost nothing.

2. Miami Gravelly Sand. - A brown gravelly sand, of medium to coarse texture, 9 - 12 in. deep, grading through a lighter brown gravelly sand into a mixture of coarse

sand and fine gravel at about 3 ft. below the surface. In some places the gravel comes close to the surface, closely associated with Miami sand. Material deposited by wave or stream action. Occupies ridges and old beach lines with usually rolling or ridgy topography and good drainage. Apt to suffer from drouth. Soil usually contains only a small amount of organic matter. Subsoil sometimes cemented with iron to form hardpan but not usually hard. Stones vary in size from coarse sand to cobbles. This soil is usually low in productiveness and is best adapted to barley, oats, corn, rye, beans, potatoes, and fruits; corn yields 10 - 25 bu., beans, 8 - 15 bu., rye 10 - 20 bu. The type is often used only for pasture. However, in the Owosso Area this type is a much better soil. Clover does well but not adapted to timothy; corn 60 bu., wheat 12 - 15 bu., oats 35 - 40 bu., beans 15 - 18 bu., 1½ tons of hay, 150 - 200 bu. potatoes, and fair yields of sugar beets.

3. Miami Sand. - An extensive type with wide variations. The soil is of varying depths resting on a subsoil of varying thickness. Soil and subsoil consist of a yellowish sand usually much alike in texture. Sometimes a small amount of clay occurs in soil or subsoil which makes it a much better soil for agriculture. Derived mostly from beach sand laid down by water and wind at the close of the Glacial Epoch. Topography is rolling and undulating. It is easily tilled and workable with-

in a wide range of moisture conditions. Susceptible to drouth. Occasionally the subsoil is white, water washed sand or quicksand; these two conditions are unfavorable to trees and other deep-rooted plants. Presence of iron andiron pan in subsoil is a common feature. Great variation in drainage conditions. Virgin timber. - Jack pine on the lighter phases, white pine where water supply is good and hardwood in well watered depressions, with cedar and tamarack in swamps. Scrub oak in South and West portions of state. This type is light and general farming is hazardous. Best adaptation is fruit and truck. Variations of the type make its adaptation wide, however. Cass County. - Wheat 8 - 20 bu., corn 20-40 bu., oats 20-45 bu., hay ¾ ton, potatoes 100 bu., in good season. Oxford Area. - Yields lighter than on heavier types. Owosso Area. - Admixture of clay makes it a better soil. Oats 30 bu., beans 8-10 bu., corn 20 bu., potatoes 150-200 bu., moderate yields of hay, low yields of wheat. Munising Area. - Growing season short and presence of iron common. Lacks drainage. Timothy hay, potatoes, legumes, roots, vegetables and fruits do well. Soil of low agricultural value.

Management. - Growth of legumes and applications of muck highly recommended. Responds to manure but effects not lasting. Cowpeas plowed under good in South gave best results with lime, manure second. Responds to fertilizers of the proper kinds.

4. Miami Stony Sand. - A light-brown, fine to medium sand 7-8 in. deep. Subsoil a yellowish-brown fine to medium sand. Soil and subsoil contain varying amounts of small stones and gravel. It usually occurs in long, narrow areas very rolling and uneven. Well-drained and inclined to be droughty. Gravel in the subsoil may make it leachy. Hills are apt to wash when cultivated. Best adaptation fruit and truck. Not of great agricultural importance. Wire basket tests showed best results from manure, nitrate of soda, and sulphate of potash on wheat plants.

5. Miami Stony Loam. - A light-brown sandy loam 7-10 in. deep, containing streaks of gravel (5-40% of mass). Subsoil yellowish to brown sandy loam containing 5-50% of gravel and stones. Gravel hardpan usually deep. Topography broken and diversified. Natural drainage good. Steep slopes are subject to drouth in dry seasons. A fairly good general farming, grass and grain soil. 1-2½ tons, hay, corn 25 bu., wheat 12 bu., oats 25, potatoes 75, sugar beets 8-11 tons, peas for canning ¾ to 1½ tons, cabbages 4-12 tons, good fruit soil on elevations. Alfalfa good where limestone exists, 3 tons, and a much better general farming soil.

6. Miami Gravelly Sandy Loam. - Great variation in the type. Soil is generally a light or dark-brown sandy loam 8 in. deep. Subsoil a gravelly or sandy clay. A high percent of gravel and small stones in soil and

subsoil. Of morainic origin. Found bordering lakes or old lake basins as a chain of rounded knolls or hills. Soil easily washed. Affected by drouth. Crops best when rainfall is evenly distributed. Gravel and stones may interfere with cultivation. Naturally well-drained. Good fruit and general farming soil. Corn 50 bu., potatoes 125-200 bu., hay 1½ tons, rutabagas 400-700 bu. A complete fertilizer gave best results in wire basket test.

7\. Miami Fine Sand. - A brown to yellowish sand. Not much difference between soil and subsoil. Origin same as Miami sand. Drifts badly by wind. Surface rolling. Naturally well-drained. Has about the same adaptation as Miami sand but yields are somewhat better. Corn 20-25 bu., wheat 10 bu., oats 25 bu., beans 10-12 bu., beans 10-12 bu., sugar beets 7-10 tons, potatoes and vegetables do well, clover and timothy fair.

8\. Miami Gravelly Loam. - A heavy, sticky, reddish-brown loam to 12 in. Subsoil reddish-brown, clay-loam containing a large amount of gravel. Drainage good. Very good general farming soil. Corn 50-60 bu., wheat 20-30 bu., oats 40 bu., potatoes as high as 150 bu.

9\. Miami Sandy Loam. - A sandy loam soil 8-20 in. deep. Subsoil a yellow, mottled, clay sometimes quite sandy. Surface rolling. Fair natural drainage but artificial drainage necessary for good tilth in the depressions.

Formed from weathering of the glacial clays and beach sands. Tillable with a wide range of moisture conditions. Grass and grains suffer from long drouth. Wheat is often injured in a dry open winter. Clods sometimes form when worked too wet. A good general farming and fruit soil. Pontiac Area. - Corn 20-35 bu., wheat 10-25 bu., oats 30-65 bu., rye 12-30 bu., buckwheat 15-20 bu., beans 10-18 bu., hay 1-2 tons, good potato soil. Green manuring should be practiced on this type.

10. Miami Fine Sandy Loam. - A light-brown, medium to fine sandy loam 6-18 in. deep. Gravel and stones are usually present. Aubsoil is a brown to chocolate-colored loam to clay loam, increasing in clay content with depth. Subsoil may be sand or gravel in spots. Surface is rolling with knolls and ridges. Drainage is good, but some wet hollows. "Kame" and "kettle" topography marks the type. Knolls of stiff clay found scattered over the areas. Usually withstands periods of drouth. Good general farming type. Alma area. - Sugar beets 7-12 tons, hay 1-2 tons, potatoes 60-150 bu., corn 25-40 bu., beans 12-15 bu., barley 20-30 bu. Manure benefits most by basket test, cowpeas and lime second. The proper management is a systematic rotation with crops plowed under.

11. Miami Loam. - A brown or light-brown loam of medium to fine texture 8-10 in. deep. Small gravel and stones sometimes present. Subsoil a heavy, yellowish-brown

loam or clay loam sometimes with coarse sand and gravel. Beds of sand and gravel underlay the type. There is usually a thin layer of sandy, silty material, light in color between soil and subsoil. Easy to cultivate if plowed at the right time, but when plowed wet the soil clods and the lumps are hard to pulverize. Surface level to rolling, sometimes hilly. Natural drainage is fair. Artificial drainage is necessary for best yields where clay approaches the surface. Clover sometimes killed by severe winters. Good general farming soil. Wheat 12-35 bu., oats 20-50 bu., corn 45 bu., hay 1¼ tons, rye 18 bu. By wire basket test cowpeas and green manuring gave best results, complete fertilizer second.

12. Miami Silt Loam. - A yellowish to gray silt loam 6-12 in. deep. Mellow and open, never bakes into hard clods. Subsoil rather stiff, tenatious, red-brown loam. Soil well drained and has good water-holding power. Soil washes on slopes. Loess formation. Rich in plant foods. Good general farming soil. Subject to "cloversickness". Yields are good. (No. Mich. yields.)

13. Miami Clay Loam. - Light-brown to yellow loam 6-7 in. deep. Subsoil is a reddish-brown or yellow clay or clay loam with occasional gravel. A thin layer of lighter colored silty material separates soil and subsoil. Contains enough clay to cause soil to lump and clod to a considerable degree. A moderate quantity of

organic matter present. Topography slightly undulating to rolling. Slopes never steep enough to interfere with cultivation. Derived from weathering of the glacial drift. Holds moisture well and sometimes impervious. In most cases tile drainage would be beneficial. Crop values have been greatly increased by tile drainage. Soil is wet and cold in spring as a rule. Requires great care in plowing and pulverizing. Can only be worked within narrow moisture content. Many stiff clay knolls present. Boulders usually strewn on surface. Baking of soil after rains greatly hinders germination of seeds. Good general farming, stock, and grain soil. Corn 35 bu., wheat 15-18 bu., oats 40 bu., beans 18-20 bu., hay 1½ to 2 tons, sugar beets, 8-10 tons, rye 25 bu. This soil requires drainage and careful cultivation for best results.

B. Clyde Series. - Composed of reworked glacial material. Occupies old lake beds. Contains a large amount of organic matter. The surface soil is dark-brown to black in color, and is underlain by grey, drab or mottled-yellow subsoils. The dark color of the surface soil is due to accumulation of organic matter under swampy conditions. They almost always require drainage but are very productive when this is provided. The loam is the most important, giving uniform and satisfactory results. When drained this type produces good yields of corn, wheat, oats, hay,

crops. Much of the series is undeveloped for lack of drainage. The clay occupies low areas and is not much used for agriculture. When drained it is good for general farming and sugar beets. The fine sandy loam is very desirable for truck and potatoes. When drained apples and pears do fairly well. The sandy loam is next to the loam for farming, and with the stony sandy loam is used for this purpose. The gravelly sand and fine sand give good yields of grain but are best adapted to trucking and small fruits.

1. Clyde Stony Sandy Loam. - A medium-textured, gravelly sandy loam 18-24 in. deep, underlain by a sandy loam or mottled brown clay loam containing a small amount of gravel. A large number of boulders strewn over the surface which must be removed. Glacial or lake origin, level to rolling topography, and naturally well-drained in the larger areas. Some small areas receive seepage

from the higher land and have only a sluggish outlet. Used mainly for general farming. Corn 25-40 bu., oats 20-50 bu., wheat 15-20 bu., beans 10-20 bu., hay 1-1½ tons, sugar beets 7-15 tons.

2. Clyde Gravelly Sand. - A medium-textured, dark-brown, loamy sand carrying 5-20% of gravel. The subsoil is a coarse, incoherent, gravelly sand grading into a mixture of coarse sand and gravel at 24-30 in. Clay is found at 4-8 ft. Contains a normal amount of organic matter. Naturally well drained. Does not bake and clod under cultivation. Topagraphy varies from gentle slopes to broad, gently rolling, ridges representing old beach lines. The type occurs as the result of shallow water deposition, but in some places is influenced by wash from higher land. The Miami gravelly sand is of the same origin but is not as good a soil. Type is formed in strips. Fairly good yields of corn, oats, wheat, rye and timothy are obtained. Sugar beets do fairly well but difficult to get a good stand. Well adapted to fruit and truck and should be devoted to these.

3. Clyde Gravelly Sandy Loam. - A coarse to medium black sandy loam 8-15 in, deep and containing varying amounts of fine gravel. A small amount of stones sometimes found on the surface. The subsoil consists of medium to coarse sand with a high percent of gravel sometimes stratified. It is usually well drained and sometimes subject to drouth. Deposited in shallow water in sloughs and bays

higher than the loams. Potatoes main crop with smaller yields than on clyde loam, but the crop matures earlier; 150-300 bu. Not so well adapted to wheat, oats or grass as the loam because of the leachy subsoil. Soft grained wheat or oats 25-40 bu., onions, carrots and sugar beets, 5-10 tons. Early potatoes best. Truck crops good.

4. Clyde Sand. - Saginaw Area, Michigan; May be called a "mucky sand." The soil is dark-grey to black medium-textured sand 8-14 in. deep. The subsoil an incoherent white sand of medium to coarse texture to a depth of 2½ feet where a heavy silty clay is usually found. Subsoil may consist of a light-yellow sand where drainage has been good. A small amount of gravel present. The large amount of O. M. present makes the soil friable and retentive of moisture. The type is of lake or stream origin and is still in process of formation along the lake front. Not modified by wind action. Poorly drained. When drained, a most desirable soil for truck farming, and nearly all of the general crops may be grown with success. The soil must be supplied with O. M. or it soon reverts to a harmful condition. Where the surface is level and clay lies near the surface, the best soils are found, and they are more succeptible to lasting improvement. Corn, oats, wheat, timothy, and clover, and buckwheat. Beets and chickory are extensively grown. Corn 20-30 bu., wheat 15-30 bu., beets 10-15 tons, chickory 10 tons, cabbage, cauliflower, tomatoes, pota-

toes, onions, cucumbers, and beans are the principal truck crops.

Alma Area, Michigan. - Closely associated with muck areas. The subsoil is a light-colored sand, sometimes containing clay enough to make it sticky, it is commonly wet at 30 in. Sometimes coarse and fine gravel is found at 3 ft. and sometimes clay at 4-5 ft. Surface is uniformly level. Natural drainage poor, but loose open character of the soil permits percolation. Formed from glacial wash modified by stream action. Corn 20-35 bu., oats 25-40 bu., hay 1-2 tons, sugar beets good on the better drained areas 10-15 tons. Some parts not well suited to sugar beets. Timothy, potatoes, and beans do well. Soil is easily tilled and moisture conditions are favorable during most of the year. Best suited to corn, oats, potatoes, cabbages, melons, and cucumbers, celery can also be grown.

5. Clyde sandy Loam. - A dark-grey or brown medium-textured sandy loam 8-12 in. deep. Subsoil of similar texture but lighter in color, underlain by a drab or brownish mottled light sandy clay. A small quantity of gravel present. Does not bake or clod and is easily tilled. Topography level to gently rolling and slightly higher than the loam. Natural drainage good but artificial drainage often necessary. Origin principally water-laid moraines and sandy beach deposits. Adopted to general farming and dairying. Soil mixture varies. Sugar beets

10 tons. Beans mature quickly. Corn 25-40 bu., oats 25-45 bu., sugar beets 7-14 tons, hay 1-2 tons, potatoes 80-150 bu., beans 15-25 bu.

6. Clyde Stony Sandy Loam. - A medium-textured, gravelly sandy loam. Subsoil a sandy loam or mottled brown clay loam containing a small amount of gravel. A large number of boulders is strewn over and sometimes below the surface. When the stones are removed the soil is easily cultivated. Topography level to rolling. Small areas receive seepage and outlets are usually sluggish. Used mainly for general farming. Corn 25-40 bu., oats 20-50 bu., wheat 15-20 bu., beans 10-20 bu., hay 1-1½ tons, sugar beets 7-15 tons.

7. Clyde Fine Sandy Loam. - A fine sand to fine sandy loam 9-12 in. deep, homogenous in texture, friable and easily tilled. Subsoil similar to soil except lighter in color and overlies clay. No gravel present; slightly undulating to rolling in topography. Formed by wind-blown beach deposits or old lake deltas. Modified by wind and wave action. Natural drainage depends upon elevation. Adaptation general farming and dairying. Corn 20-40 bu., oats 30-60 bu., beans 10-25 bu., hay 1-1½ tons, beets 10-15 tons, chickory 7-12 tons.

8. Clyde Loam. - A moderately friable to heavy compact loam, dark-grey, brown or black in color 8-12 in. deep. Subsoil sandy or silty, drab-colored, iron mottled clay.

Because of inadequate drainage the soil is largely in a puddled, compact state, sticky and impervious when wet and very hard when dry. A hard soil to cultivate. Where well drained the structure is much better. Topography almost level with low, broad swells and shallow depressions. Derived from glacial lake deposits unmodified to any extent.by stream action. Adaptation dairying and grain farming. Corn 40-60 bu., oats 40-60 bu., wheat 15-30 bu., hay 1 - 2 tons, sugar beets 10-20 tons. Best sugar beet soil. Beneficial results secured from liming. Soil apt to be cold and sour.

9. Clyde Silt Loam. - Light to chocolate -brown silt loam 10 in. deep. Subsoil a lemon-yellow silt loam containing little organic matter. Texture is homogenous to 3 ft. with little gravel present. Usually a number of boulders on surface. Soil is very friable and easily tilled. Perhaps derived from stream deposits in glacial lakes. Topography somewhat rolling and drainage fairly good. Devoted to general farm crops.

10. Clyde Clay Loam. - A black clay loam to the depth of 6 or 8 in. Subsoil a bluish or drab-colored heavy, plastic clay loam. Soil is quite variable. Nearly all swamp land. Drainage poor. Clods badly. Used for production of hay mostly. Not extensively found. Hay 1-2 tons.

11. Clyde Clay. - A silty clay loam sometimes of marley nature 6-9 in. deep. Light-grey to dark depending upon

amount of organic matter present. When organic matter content is low soil bakes and clods badly. Better when considerable organic matter is present. Subsoil is a bluish or drab-colored, tenacious, and practically impervious clay. Poor texture due to undrained condition. Found on low lake levels and sometimes covered by muck. Adaptation dairy farming, grains and grasses. Good for sugar beet. Possibilities not realized until artificially drained.

C. Marshall Series. - The typical prairie soils. Of glacial and Loessal formation. This series includes the soils of the great corn belt and are the best corn soils of the country. Are dark-colored and well supplied with organic matter. Very productive soils. Only three types have been located in Michigan.

1. Marshall Gravel. - A coarse to medium sand containing 5-20% of fine water-worn gravel and small pebbles. Subsoil a coarse, yellow sand with more gravel than the soil and occasionally underlain by a gravel bed at 3 or 4 ft. Topography level to low swells. Probably formed on lake shores. Soil is loose and susceptible to draught. Yields well in wet seasons. The porous nature of the soil soon alowed the organic matter to disappear and now contains some abandoned forms. The heavier phases when well managed yield fair crops. Rye 10-20 bu., potatoes 60-125 bu., hay 1-1½ tons, beans 8-12 bu., corn 10-30 bu. The soil is adapted

to light farming, early truck and small fruits. Should receive plowed-down legumes.

2. Marshall Loam. - A black or dark-brown loam 12-16 in. deep. Sometimes high in silt content, subsoil a dark brown heavy loam or clay loam. A quantity of coarse sand and fine gravel present. Beds of sand and gravel underlie the whole type at about 36 in. Subsoil becomes hard in dry seasons and is called "hard pan". Where the gravel comes near to the surface (22-24 in.) the soil produces poorer crops. Easy soil to cultivate when not plowed too wet. Topography level to undulating and rolling. Drainage is good. Derived from glacial till. Devoted to general farming and stock raising. Received its organic matter through the growth of a wild grass. Corn 45-75 bu., oats 40-60 bu., hay 2 tons, wheat 10-45 bu. Yields are decreasing of late. The growing of cowpeas for green manure should be practiced more. By a basket test manure gave best results. Nitrate of soda and sulfate of potash gave good results as did also a complete fertilizer.

3. Marshall Black Clay.Loam. - A black clay loam 8-12 in. deep. Very sticky when wet and cracks open when dry. Subsoil a sticky drab-colored clay loam slightly heavier and more tenatios than the soil. Found in low lying areas. Requires drainage. May have a band of sandy loam or quicksand in the subsoil. Clover sometimes fails and small grains lodge. A better working soil than analysis

warrants. Soil heaves in winter. Corn 50 bu., wheat 22 bu., oats 45 bu., hay 2 tons, sugar beets 11 tons. Well adapted to general farming and stock.

D. Superior Series. - These are red soils with red (usually clay) subsoils and lie around Lake Superior. The sandy loam is a warm, easily tilled soil, adapted to clover timothy and small fruits. The topography of the silt loam is uneven, and the type is of low agricultural value. The clay is a heavy soil difficult to cultivate, but yields good crops of clover, timothy, potatoes, peas, and beets. The series has not been extensively developed.

1. Superior Sandy Loam. - Superior Area, Wis., Minn.
A grey to reddish sand of medium texture 12-24 in. deep. Subsoil stiff, tenacious, red clay. The surface sometimes strewn with stones and bowlders. Sometimes strata of fine sand in the subsoil. Well adapted to all crops grown in the region. It has the advantages of the Superior without its disadvantages. Warm soil, easily tilled. Fertilizers are more lasting than on Miami Sandy loam. Clover and timothy nearly as well as on Superior Clay. Potatoes 100-200 bu., quality better than Superior Clay. All root crops do well. Well adapted to strawberries, raspberries, gooseberries, and currants. Wheat, oats, rye, and barley have not been grown extensively. Original timber heavy pine and soil expensive toclear, but when cleared it is the most desirable soil of the area.

2. Superior Silt Loam. - Carlton Area, Wis., Minn. Light colored, very fine sandy or silty loam 6-10 in. deep, having the properties of clay in some places, and grading into a stiff, tenacious, red clay. Clay is of the same origin as Superior Clay and lies from 2 to many feet below the surface. Surface is rough and broken and eroded by stream action. Slopes too steep to be cultivated. Level areas, when drained, should produce good crops. None of the type is under cultivation and of low agricultural value.

3. Superior Clay - Carlton Area, Wis., Minn. - A heavy, tenacious red clay, to 6 in. deep. O. M. gives the surface 2-3 in. a brownish color. The subsoil is a heavy, stiff, tenacious red clay. Lime concretions occur on the surface, in the soil and subsoil. When wet the soil adheres to wheels of vehicles and impedes travel. Type is uniform. Good quality of brick made from it. Surface level to slightly rolling. Streams have cut valleys. Drainage necessary. Glacial drift.

E. <u>Miscellaneous Soils.</u>

1. Muck. - Soil consisting chiefly of organic matter, resulting from the growth of plants in place. Often mixed with clay and sand wash from higher land. Occurs at varying depths. Subsoil may be gravel, sand, clay, or marl. Owes origin to lack of drainage. When material is coarse it is called peat. Topography uniformly flat

however, muck may be found running up side hills. Must be drained. Clay and marl subsoils make muck more adapted to crops. A shallow muck (2 ft.) over gravel or sand is not considered a good feature; however, much depends upon drainage. The value of the soil is determined largely by the extent of decomposition. The finer and blacker the better. Often strongly acid. Crops easily injured by frost. Mucks that grow ash and elm timber are usually good soils. Onions 500-800 bu., corn 40-50 bu., hay 1-2 tons. Celery, peppermint, potatoes, root crops, oats, rye, cabbage, are well adapted to muck soils.

2. Fort Payne Sandy Loam. - Derived from weathering of calcareous rocks and is located in about the central part of the Upper Peninsula. A brown sandy loam to 6 in., usually mixed with gravel and fragments of stone. Subsoil is a sandy loam of lighter color and mixed with rock fragments finally pressing into partly decomposed rock. The depth of soil is variable; from 5 or 6 ft. to places where the rock outcrops. Soil is productive and maintains its productiveness under cultivation. Organic matter is well retained. Topography more or less hilly. Derived from weathering of sandy dolomite. Potatoes 200 bu. of superior quality. Type good for general farming. Wheat, oats, rye, barley, peas and other legumes adapted to the climate. Vegetables and root crops grow well.

COMMON CROPS and THEIR BEST SOILS.

ALFALFA - Well-drained clay loams, loams, and sandy loams. This crop likes a deep, limestone soil. It does not like an abundance of iron in soils and will not stand swampy or wet land; the water must drain off quickly. Alluvial soils especially good.

APPLES - A variety of soils. Clay loams to sandy loams. Best on land that is well-drained and contains considerable clay. Rolling or elevated land is desirable.

Apricot - Deep, dry, loams or gravelly loams with porous subsoils.

Asparagus - Deep, well-drained, loose, rich, loams.

BARLEY - More sensitive to character of soil than other cereals. Well-drained and well-subdued clay loams and loams are best and shouldnot have too much nitrogen for malting barley.

BEANS - Clay loams to loams. Light soils must be well supplied with organic matter. Limestone soils are best. Heavy clay, mucks, and light sandy soils unsuitable.

BEETS - Deep, mellow soil required. Rich, clay loams good for yield. Light soils mature crop early. Quality poor on muck.

BLACKBERRIES & RASPBERRIES - Variety of soils but must be well supplied with organic matter. Soils which lose moisture easily when plant is fruiting are undesirable.

BUCKWHEAT - Best on sandy, well-drained land, but often grown on very poor, wet soils. Not desirable on rich soils because of lodging.

CABBAGE - Rich, mellow soils required. Loams, sandy loams and mucks good.

CARROTS - Variety of soils. Best on deep, rich, mellow soils. Do well on muck.

CELERY - Fine, black, non-acid muck best. Will do well on slightly acid muck and on deep, mellow upland soils.

CHERRIES - Similar to peaches. Limestone soils are best. Will grow on heavy soils.

CLOVERS - Do not thrive well on acid soils.

1. Red clover - Well drained clays to sandy loams.
2. Mammoth, alsike, and white clover - Moist clays and loams.
3. Crimson clover - Best on light, sandy loams.
4. Sweet clover - Well-drained clays to sandy loams.

CORN - Variety of soils. Best on deep, rich, mellow, well-drained, clay loams and loams. Well adapted to new land and often used to subdue the soil.

COTTON - Variety of soils. Clay and silty loams with mellow subsoil are superior.

COWPEA - Variety of soils. Will withstand a moderate amount of soil acidity. Not suited to wet soils. Light soils best in nortnern climates.

CUCUMBER - Warm clays to sandy loams.

CURRANTS & GOOSEBERRIES - Best on moderately heavy, rich, moist, soils in a cool situation.

FLAX - Deep, moist, rich, well-drained clay loams or loams best for fibre. Soils should be rich in organic matter. Often used on new lands to subdue them. Improves the physical condition of the soil.

GRAPES - Well-drained, mellow soils on hill-sides, or in warm situations; not too rich in nitrogen.

GRASSES - 1. Timothy - Best on heavier soils with plenty of water.

2. Red-top - Will grow on heavy wet and acid soils where timothy does not do well.

3. Blue grass - Requires good land.

4. Tall meadow fescue - Requires good soil.

5. Orchard grass - Does best on good soils, but makes fair growth on poor soils. Withstands

drouth well.

6. Perennial rye grass - Does best on stiff, wet, soils or marshy land.
7. Red fescue - Grows on dry, light soils.
8. Rhode Island bent grass - Similar to red-top.

HOPS - Variety of soils. Best on well-drained, moist, rich, sandy loams not too rich in nitrogen. A slight elevation protected from cold winds is best.

LETTUCE - Loams and clay loams with plenty of organic matter.

Oats - Do well on a wide range of soils.

ONIONS - Rich, well-drained, mellow loams or subdued, non-acid mucks.

PARSNIPS - Heavy loams, clays and mucks.

PEANUTS - Well-drained, sandy loams well supplied with organic matter. Forage may be grown on heavier soils. Shells are stained by dark-colored soils.

PEACHES - Well-drained sandy loams to sands on elevations. Too much nitrogen in the soil is undesirable.

PEARS - Well-drained clays or loams with porous subsoils. Will do well on lighter soils but may winter-kill.

PEAS - Similar to beans.

PINE APPLE - Florida soils are fine sands low in plant foods. On fertile soils in Hawaii.

PLUMBS - Resemble pears. Limestone soils desired.

POTATOES - Variety of soils. Deep, rich, loams or sandy loams best when well supplied with organic matter. Quality not so good on heavy soils or mucks.

PUMPKINS - Warm loams to sandy loams.

QUINCES - Similar to apples..

RADISHES - Mellow soils well supplied with organic matter.

RHUBARB - Same as asparagus.

Rye - Grows well on soils too poor for other cereals. Best on light, rich, loams and sandy soils. Not adapted to wet soils or heavy clays.

SORGHUM - Similar to corn but does better on poorer soils than corn. Leaves soil in bad physical condition.

SOY BEANS - Variety of soils. Withstands drouth and grows well on rather wet soils.

SPINACH - Same as for lettuce.

SQUASHES - Warm sandy loams not too rich in nitrogen.

STRAWBERRIES - Clay to sandy loams. Light soils ripen crop earlier. Seem to prefer an acid soil.

SUGAR BEETS - Soils should be well-drained, deep, and mellow. Rich clay loams best.

SUGAR CANE - A well-drained, well-watered, fertile soil containing limestone.

SWEET POTATOES - Well-drained, porous, warm, sandy loams. Heavier soils may be used if they have an open structure and are well-drained.

TOBACCO - Easily affected by character of the soil. Different varieties require specific types of soil, but all must be rich, friable, and well supplied with organic matter, and contain limestone.

TOMATOES -Variety of soils. Good clay loams furnish large yields, but early crops require lighter soils.

TURNIPS - Similar to sugar beets.

VELVET BEAN - Variety of soils. Best on well-drained, friable land.

VETCH - Variety of soils. Does best on light, sandy, limestone soils.

WATER MELONS - A warm, light, sandy soil with clay subsoil. Too much organic matter is not desirable.

WHEAT - Fertile clays and clay loams. Does well onlighter soils. Not well suited to soils rich in organic matter.

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2. Soils - Hilgard.
3. Soils - Hall.
4. Soils and Soil Fertility - Whitson and Walster.
5. Soils and Fertilizers - Snyder.
6. Soil Conditions and Plant Growth - Russell.
7. Physics of Agriculture - King.
8. Manures and Fertilizers - Wheeler.
9. Fertilizers and Crops - Van Slyke.
10. The Feeding of Crops and Stock - Hall.
11. Principles of Agricultural Chemistry - Fraps.
12. First Principles of Soil Fertility - Vivian.
13. Soil Fertility and Permanent Agriculture - Hopkins.
14. Agriculture - Stoner.
15. Physical Properties of Soils - Warington.
16. Rocks, Rock Weathering and Soils - Merrill.
17. Fertilizers - Voorhees.
18. Michigan State Board of Agriculture Reports.
19. Field Operations of the Bureau of Soils.
20. American Encyclopedia of Agriculture - Bailey.

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1. The Liming of Soils, No. 77.

2. Tile Drainage on the Farm, No. 254.

3. Drainage of Farm Lands, No. 187.

4. Management of Soils to Conserve Moisture, No. 266.

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5. Soil Acidity and Liming - Wisconsin, No. 230.

6. The Right Brain for the Right Place - Wisconsin, No. 229.

7. The Principles and Practice of Land Drainage - Wisconsin, No. 199.

8. Some Factors Concefned in the Fixation of Nitrogen by Azotobacter - Wisconsin Research Bulletin, No. 12.

9. Acid Soil, (Soil Studies II) - Florida, No. 93.

10. Lime and Liming - Rhode Island, No. 46.

11. Lime for Virginia Farms - Virginia, No. 187.

12. Drainage in New York. - Cornell University, No. 254.

13. Tile Drainage - New Hampshire, No. 118.

14. Tile Drainage - Michigan Special, No. 56.

15. Soil Temperature, Etc., - Michigan Technical, No. 17.

16. Soil Moisture; Its Importance and Management - Michigan, No. 219.

17. Some Essential Soil Changes Produced by Micro-organisms - Michigan, No. 218.

Miscellaneous.

18. The Mechanics of Soil Moisture - Bureau of Soils Bulletin, No. 10.

19. Studies on the Movements of Soil Moisture - Bureau of Soils Bulletin, No. 38.

20. Acid Soils - Office of Experiment Stations, Farmers' Institute Lecture, No. 3.

21. Studies on Acid Soils of Porto Rico - Porto Rico Bulletin, No. 13.

22. The Utilization of Acid Lands by Acid Tolerant Crops - U. S. D. A. Bulletin, No. 6.