Fertilizer Recommendations for 1941-42
Michigan State University Extension Service
Soils Department
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Fertilizer Recommendations for 1941-42

Soils Department

Fertilizer Analyses Recommended For Use in Michigan

0 - 20 - 0	2 - 16 - 8
0 - 12 - 12	2 - 8 - 16
0 - 20 - 20	3 - 9 - 18
0 - 8 - 24	3 - 12 - 12
0 - 8 - 32	4 - 10 - 6
0 - 20 - 10	4 - 16 - 4
0 - 14 - 6	4 - 16 - 8
0 - 10 - 20	5 - 10 - 5
2 - 12 - 6	10 - 6 - 4

Nitrogen Carriers
Potash Salts

MICHIGAN STATE COLLEGE
EXTENSION DIVISION

East Lansing

Cooperative Extension Work in Agriculture and Home Economics, Extension Service
Michigan State College and the U. S. Department of Agriculture Cooperating.

PERTINENT POINTS

1. The increase in use of commercial fertilizers is evidence that Michigan farmers are finding these fertilizers profitable. The quantity used may be expected to continue to increase, especially by the more progressive farmers.
2. Fertilizers are used to supplement and balance the plant food that becomes available in the soil and from manure in order that greater yields may be possible.
3. The greatest returns from fertilizer on mineral soils cannot be expected on strongly acid soils, soils low in organic matter, or poorly drained soils.
4. The method of application as well as the plant food content has much to do with the returns received from fertilizer applications.
5. Different soils have markedly different plant food deficiencies. Crops vary greatly in their nutrient requirements. Study Tables 1, 2, and 4 carefully to determine what fertilizer analysis is best suited to your soil for the crop you wish to grow.
6. Fertilizers are not a cure-all. On mineral soils use them in conjunction with good tillage, lime, green crops plowed under, rotation, manure, erosion control, and other good soil management practices.
7. The intensive production followed on muck soils requires special tillage and fertilizer practices. Refer to Table 4, and to Extension Bulletin 123 and Circular Bulletin 165.
8. Fertilizers containing less than 20 units of plant food are not recommended because of the high cost of the plant food. Low price per ton for fertilizer does not mean cheap plant food.
9. For good results and low plant food costs buy only fertilizers listed on the front of this bulletin.

FERTILIZER RECOMMENDATIONS FOR 1941-42

SOILS DEPARTMENT

Need for Fertilizer is Increasing—Increasing use is sufficient evidence that Michigan farmers are finding commercial fertilizers profitable. The same situation pertains in the states adjoining Michigan, as well as in all of the older agricultural states. In fact, Ohio and Indiana use very much larger quantities of fertilizer than does Michigan. It is reasonable to suppose, as soils are cropped for a long period of years, and are thus removed further and further from the virgin state, that the supply of available plant food will become less and less and hence the necessity of supplementing the soil's supply grows more urgent. Unfortunately, the quantity of animal manures on Michigan farms is inadequate to make up the plant food deficiency and hence it is necessary to resort to commercial sources.

Fertilizer does not Damage Soil—Experimental farms where commercial fertilizer has been used regularly for from 50 to 95 years have dispelled the old time fear that commercial plant foods will exhaust the humus supply or otherwise damage the soil.

Use "High-analysis" Fertilizers—In the last few years, fertilizers containing high percentages of plant food have been appearing on the market. These high-analysis mixtures supply plant food at a lower cost than the low-analysis goods and hence are more economical, even though they cost more per ton. The price per ton should not be given too much consideration in purchasing fertilizers, since the higher-priced (high-analysis) goods may be applied in smaller quantities and hence more acres may be fertilized for the same total expenditure. The use of high-analysis mixtures does require more information, however, as to proper rate and method of application in order to obtain best results and hence a more thorough knowledge of the soil conditions and crop requirements is being demanded of the farmer. In this publication a fertilizer containing **20 units (or per cent)** or more of plant food is considered a "high-analysis" fertilizer. No fertilizer containing **less** than **20** units should be purchased because the cost per unit of plant food is too high even though the price per ton makes the fertilizer appear cheap.

Buy "Recommended" Fertilizers Only—Although methods of manufacturing fertilizers are up-to-date and efficient, considerable expense is incurred in changing from the mixing of one analysis or grade to another. As a result the more frequently a change must be made or in other words, the more grades that have to be mixed the higher is the manufacturing cost. To reduce the manufacturing cost caused by

the mixing of small quantities of a large number of unnecessary grades the fertilizer manufacturers and dealers are cooperating with the Soils Department and Extension Service of Michigan State College in ad-

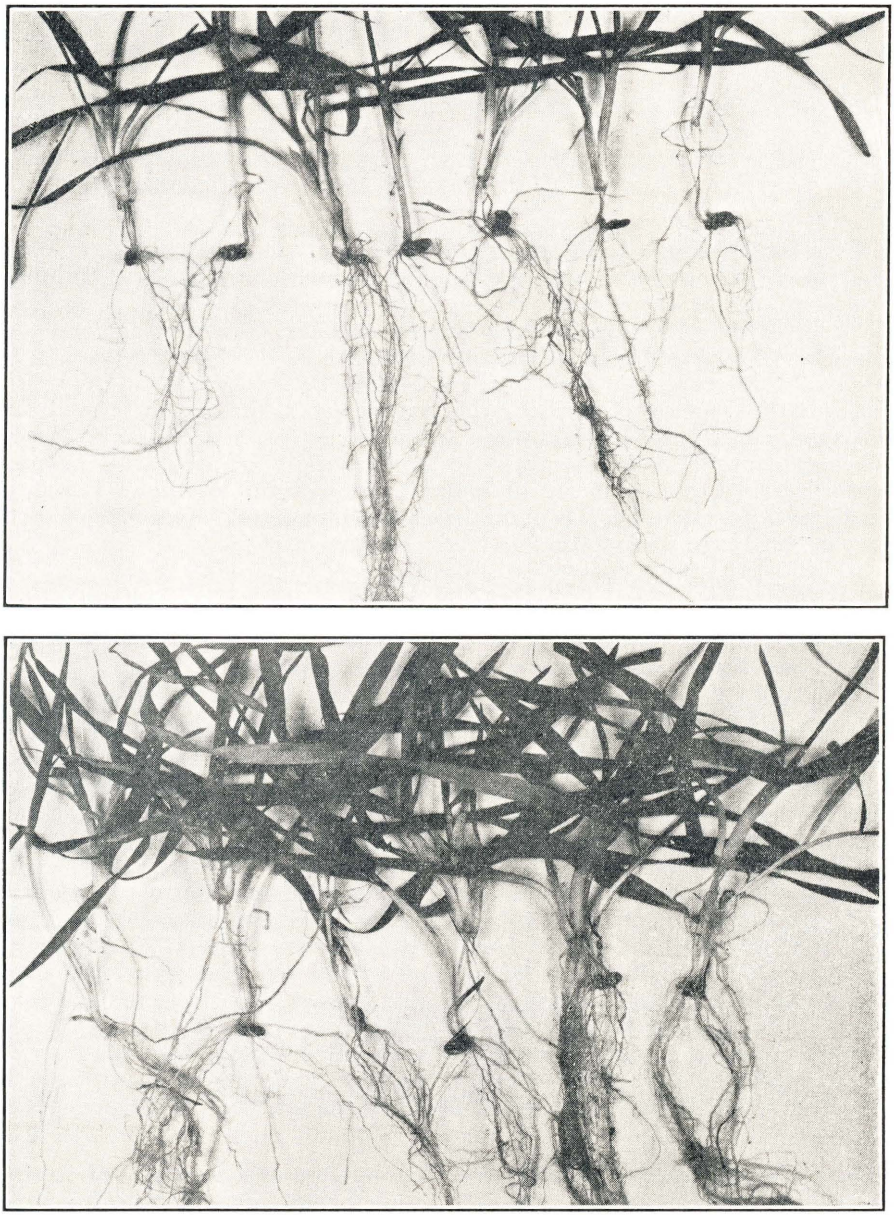

Fig. 1. Fertilizer high in phosphate increases root growth of crops and gives hardiness to fall seeded grains. (Above)—Wheat on limed but unfertilized Fox sandy loam. (Below)—Wheat on Fox sandy loam treated with lime and complete fertilizer.

vocating the use of a limited list of fertilizer analyses which will meet the requirements of Michigan crops grown on Michigan soils. This list of "Recommended" fertilizer analyses is printed on the cover of this bulletin and specific recommendations for their use for different crops under different soil conditions are given in the tables on pages 10 to 12, 14, 15, 22, 23. Persons who have been in the habit of ordering fertilizer analyses or grades not on this list are urged to change their order to a similar analysis on the "Recommended" list. Likewise, offerings by salesmen of an analysis differing only slightly from a "Recommended" grade at an apparent saving of a dollar or so a ton should be rejected. In purchasing such offerings, the farmer pays full price for plant food obtained and ultimately increases the cost of fertilizer in general. A total of 88.6 per cent of the fertilizers used in Michigan in 1939 were of grades or ratios from the "Recommended" list.

How is the "Recommended" List Prepared?—For many years the Soils Section has been conducting tests with different fertilizers, applied at different rates and by different methods in all sections of Michigan. These experiments have been very largely on the farms of successful farmers and under the actual conditions existing on Michigan farms. They have been carried on for a long period of years so as to get averages covering different seasonal conditions of rainfall and temperature. As many as 70 such fields are in operation some years in order to cover the soil conditions and farming systems in different sections of the state. Needless to say, all fertilizers are applied and all yields are taken with the greatest care by members of the Soils Department. It is from the results of these experiments that the "Recommended" list of fertilizers is compiled.

Selecting the Proper Fertilizer Analysis

The success obtained from fertilizers depends on their proper utilization. Some of the principal points to be considered are:

(1) Select a mixture containing the plant food elements which your soil will not supply in adequate quantities to the crop to be grown.
(2) Be sure that the plant food elements are in the right proportion to fit the needs of your soil and crop.
(3) Use an adequate quantity of fertilizer.
(4) Apply the fertilizer at the right time and in the right way to give best results.
(5) Do not expect fertilizers to take the place of organic matter or of lime in soils deficient in these materials.

Many years of experimentation have demonstrated that at least three fertilizer constituents may be needed by crops growing on Michigan soils. It is a well-recognized fact that soils vary greatly in their ability to supply the different plant food elements to crops. Many mineral soils are quite deficient in nitrogen and phosphate but contain sufficient potash. Other soils have a satisfactory nitrogen content but require additional phosphate and potash. Very few Michigan soils supply sufficient phosphate for maximum crop yields.

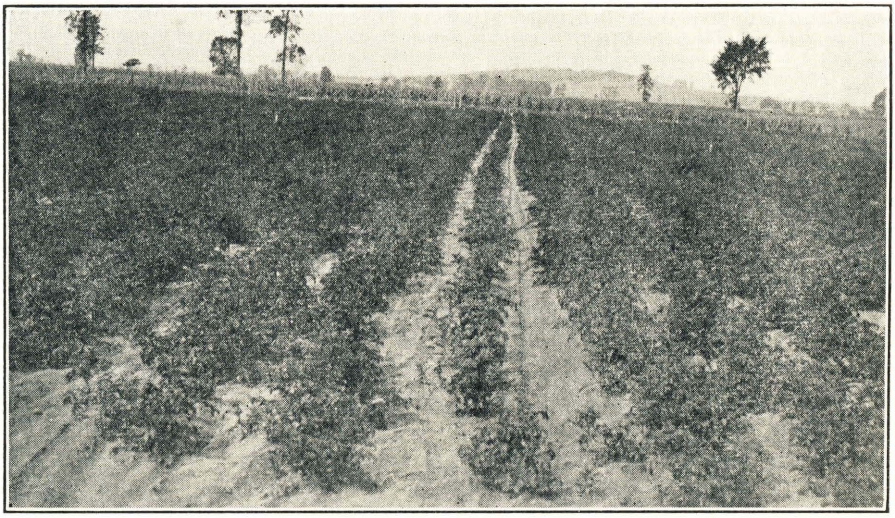

Fig. 2. Potatoes growing in Mancelona gravelly sandy loam. The center row was unfertilized while those on either side received a complete fertilizer.

Crops use many plant food elements in addition to the three mentioned. Most normal soils supply adequate quantities of these when the soil contains sufficient humus and is sufficiently but not over-supplied with lime. Soils have been found in the State which need boron, copper, or manganese for the growth of certain crops. Muck soils are more likely to need these elements (with the exception of boron) than are mineral soils, and their use is discussed later. No general need for these or other so-called "minor elements" has been found in Michigan soils.

It is not the total quantities of plant food elements in the soil, but rather the rate at which these nutrients become available for plant use that determines the need for fertilization. In this connection, the system of soil management practiced is of vital importance, since decaying organic matter is one of the most potent agents in making plant nutrients soluble. In determining what analysis of fertilizer fits his requirements, the farmer must not only consider the natural deficiencies of his soil, but also the crop rotation he plans to follow, how much manure has been applied in the last few years, and whether a green manuring crop or a heavy leguminous sod has been plowed under recently.

Different crops have quite different plant food needs. Some crops are grown primarily for their tops; in others, it is the grain or seed which is desired. In some cases, the plant is required to manufacture and store large quantities of starch or sugar and sometimes of oil. Frequently, early maturity of crops is of prime importance either for early market or to avoid frost and almost universally a product of high quality is desired. Those factors also must be considered in choosing a fertilizer.

Some of the most noticeable effects on crop growth of the three plant food elements, nitrogen, phosphate and potash, are as follows:

Nitrogen:

1. Causes rapid early growth.
2. Gives a dark green color to plants.
3. Hastens maturity when applied in small amounts, but large applications may delay maturity.
4. Gives markedly increased top growth of crops.

Phosphate:

1. Gives hardiness to fall-seeded grains.
2. Causes rapid growth in the early season.
3. Stimulates root development.
4. Hastens maturity of crop.

Potash:

1. More frequently needed by crops growing in mucks and sandy soils than on heavy soils.
2. It is important in obtaining stands and satisfactory growth of legumes on sandy soils and frequently benefits alfalfa and clover on heavy soils.
3. Improves vigor of the crop.
4. Gives resistance to disease.
5. On muck soil, potash stimulates root development of crops and increases sugar content of root crops.
6. Is essential for production of starch, sugar, and other carbohydrates.

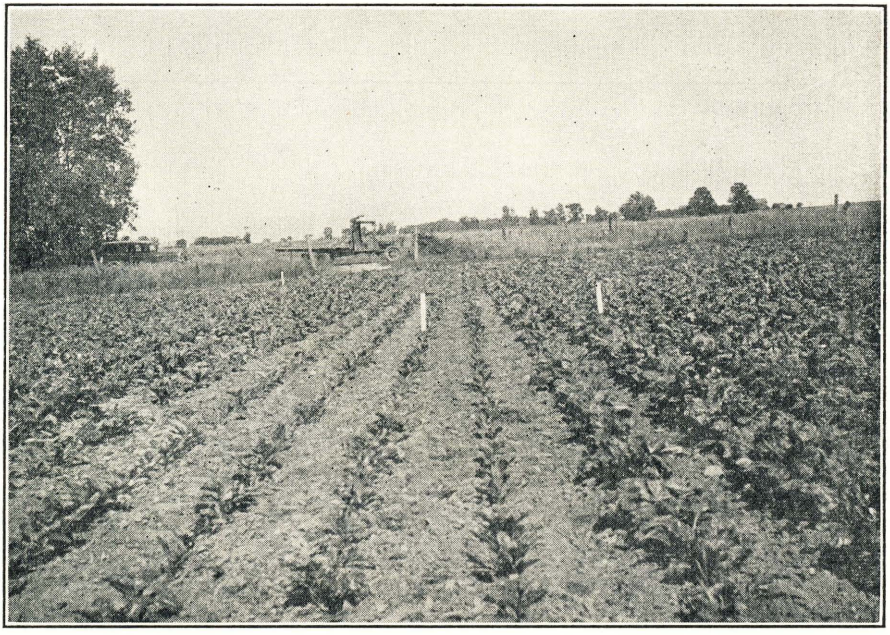

Fig. 3. Sugar beets growing in Miami silt loam. The rows in the left center received no fertilizer. The rows on the right were fertilized with 300 pounds of 2-12-6 placed in bands on both sides of the seed and about 1½ inches from it. The placement of fertilizer for row crops is important.

Fig. 4. Effect of fertilizer on quality of wheat. (Left)—Wheat from unfertilized soil. (Right)—Wheat from fertilized soil.

Fig. 5. Alfalfa on Gilford loam soil. The haycock on the left shows the yield from unfertilized land. On the right is the hay from an equal area of soil top-dressed with 250 pounds of superphosphate.

In making up a fertilizer mixture, it has been found convenient to express the content of these three constituents in the mixture by an analysis in which the percentage of each constituent is given, the constituents being arranged in alphabetical order in the analysis. Thus a **2-16-8 fertilizer** contains 2 per cent of **nitrogen,** 16 per cent of **phosphate** (calculated as **available** P_2O_5), and 8 per cent of **potash** (calculated as **soluble** K_2O).

Home Mixing of Fertilizer

The manufacturer should be able to mix fertilizer more cheaply and more efficiently than the farmer; however, conditions are sometimes such that one can economically mix them at home. The use of ready-mixed fertilizer is advisable if one can purchase a mixture which meets his needs, at a cost not appreciably above that of the home mixture when ready to apply to the soil. Directions for home mixing may be obtained by writing to the Soils Department, Michigan State College, East Lansing.

FERTILIZER NEEDS OF MINERAL SOILS

Relation of Soil Type and Method of Farming to Fertilizer Needs

The mineral soils (soils other than muck) include two main divisions: (a) the sands and sandy loams; and (b) the loams, silt loams, and clay loams. If the soils in the sands and sandy loams division have been poorly managed, receiving only little to no manure or green manures, they respond best to a complete fertilizer—that is, one containing nitrogen, phosphate, and potash, as is shown in Group 1 of Table 1.

Fig. 6. Wheat grown on light soils responds to spring top dressings of nitrogen. Right—No treatment. Left—100 pounds per acre of nitrate of soda.

TABLE 1.* FERTILIZERS RECOMMENDED FOR VARIOUS CROPS GROWN ON SANDY AND SANDY LOAM SOILS

Fertilizers are usually more effective on soils containing sufficient amounts of lime than on soils deficient in lime

Crop	Group 1 Soils low in humus. No alfalfa or clover grown and little manure applied recently.		Group 2 Soils medium to high in humus. Clover or alfalfa grown recently and manure applied in the rotation.	
Without seeding of alfalfa or clover	2-16-8 or 3-12-12	*200-300 lbs.	2-12-6 or 2-16-8	200-300 lbs.
Wheat or Rye	An early spring topdressing with 75 to 150 pounds of nitrogen fertilizer is recommended. Do not topdress with nitrogen fertilizer where alfalfa or clover seedings are made.			
Seeded to alfalfa or clover	Seeding not recommended		0-12-12 or 0-20-20	250-350 lbs.
Without seeding of alfalfa or clover	2-16-8 or 3-12-12	150-250 lbs.	2-12-6 or 2-16-8	150-250 lbs.
Oats or Barley	When late plantings are made, a spring topdressing of 60 to 120 pounds per acre of nitrogen fertilizer is recommended. Do not topdress with nitrogen fertilizer where alfalfa and clover seedings are made.			
Seeded to alfalfa or clover	Seeding not recommended		0-12-12 or 0-20-20	250-350 lbs.
Alfalfa or Clover, seeded alone or with a light nurse crop	0-8-24	250-350 lbs.	0-12-12 or 0-20-20	250-350 lbs.
	Drill the fertilizer deeply into the soil at the time of seeding or before. On stands two or more years old, topdress every two years after the first cutting has been removed.			
Corn	2-16-8	125-175 lbs.	0-20-10 or 0-14-6	125-200 lbs.
	Apply the fertilizer in the row beside the seed. If other crops in the rotation have been judiciously fertilized, no fertilizer may be needed for corn.			
Sweet Corn	4-16-8	150-175 lbs.	4-16-4	150-175 lbs.
	Apply fertilizer in the row beside the seed.			

Early Potatoes	4-10-6	400-500 lbs.	4-10-6	400-500 lbs.
	Applications made in bands 2 inches to the side of and on the same level or slightly below the seed piece are advisable.			
Late Potatoes	4-16-8 or 3-12-12	400-500 lbs.	4-16-8 or 3-12-12	400-500 lbs.
String Beans**	2-12-6 or 4-16-4	150-250 lbs.		
	Fertilizer placed in bands 2 inches to the side and slightly below the seed is recommended. Do not place fertilizer with or below the seed. If equipment is not available for this method of placement, drill fertilizer with a grain drill before seeding.			
Tomatoes**	4-10-6 or 5-10-5	400-500 lbs.		
	Fertilizer placed in bands 2 inches to the side and slightly below the root cluster at setting time is recommended.			
Cabbage**	5-10-5 or 4-16-8	400-500 lbs.		
	Fertilizer placed in bands 2 inches to the side and slightly below the root cluster at setting time is recommended.			
Cantaloupes and Cucumbers**	4-16-8	300-500 lbs.		
	For early market 200 to 300 pounds mixed with the soil in the hills and the remainder broadcast and worked into the soil before planting. Cucumbers for pickling, 300 to 500 pounds broadcast before planting. In cool springs side dress with 100 pounds of nitrate of soda.			
Beets, Carrots, Turnips, or Rutabagas**	4-10-6 or 5-10-5	300-500 lbs.		
	Apply 300 to 500 pounds per acre broadcast and work into the soil before planting.			
Asparagus** (In Nursery Beds)	4-10-6	500 lbs.		
	Broadcast and work into soil before planting. Topdress once or twice with 150-200 pounds of nitrogen fertilizer during growing season.			
Newly Planted Beds (First and second year)	2-8-16	800-1000 lbs. early in spring.		
	Topdress with 300-500 pounds nitrogen fertilizer during July.			

TABLE 1—Concluded

Asparagus** Established beds (3 Years old and older)	2-8-16, 800 to 1000 pounds and nitrate of soda 125 pounds, disk into soil before cutting season. After cutting season apply 150-200 pounds muriate of potash and 200-300 pounds of nitrogen fertilizer. Lime when soil test shows acid.
Extremely weedy plantings	Apply 600-800 pounds 0-20-0 and 400 pounds muriate of potash before cutting season. When first crop of weeds are 2 inches high, apply 350 pounds cyanamid in band 18 inches wide over the row. If second crop of weeds appear, repeat cyanamid application. This treatment controls annual weeds but not quack-grass.
Tomatoes and Cucumbers under glass**	30 to 40 tons of manure each summer—1000-1500 pounds, 0-20-20 or 1700-2500 pounds, 0-12-12 worked into soil. After third cluster of tomatoes or early setting of cucumbers apply 150-200 pounds sulphate of ammonia at intervals of 10 days to 2 weeks. If manganese deficiency occurs, apply 50 pounds manganese sulphate with one topdressing.
Leaf Lettuce under glass**	30 to 40 tons of manure each summer, 800-1000 pounds 5-10-5, 100-200 pounds sulphate of ammonia, 50 pounds manganese sulphate worked into soil before planting.
Strawberries (new beds)***	4-16-8 500-1000 lbs.
	Worked into soil before setting plants. Topdress in August or early September with sulphate of ammonia, 100-200 pounds.
(old beds)	4-16-8 500 lbs.
	When renewing the bed after harvest.
Cane Fruits***	Nitrogen fertilizer 200-250 lbs.
	Applied about the time growth starts in the spring. If manure is applied no commercial fertilizer recommended.
Tree Fruits**** Apples	Nitrogen fertilizer, if yield and twig growth indicate need. ¼ pound for each year of age of orchard per tree, maximum application not to exceed 10 pounds. Apply at time leaves show in spring or in September. Broadcast under full spread of tree and in mature orchard over entire area. No fertilizer usually advised for first two years after planting. Cover crops are benefited by phosphate fertilizer also.
Peaches****	Same as for apples with three-pound maximum tree application.
Pears****	Same as for apples with five-pound maximum tree application.

*All rates of application are on the acre basis.
**Recommendations by H. L. Seaton of Horticultural Department.
***Recommendations by R. E. Loree of Horticultural Department.
****Recommendations by R. E. Marshall of Horticultural Department.

Clover and alfalfa on this group of soils should receive a fertilizer containing only phosphate and potash. Somewhat different plant food mixtures are suggested (Group 2, Table 1) for soils which have received good management including the frequent growing of legumes and application of manure; and also for soils having from medium to high contents of organic matter and of higher productivity.

The loams, silt loams, and clay loams, as a rule, require smaller proportions of nitrogen and potash in the fertilizer mixture for general crops than do the soils of the lighter-textured groups. On those soils where clover or alfalfa has not been grown and where manure has not been applied in the rotation, as in Group 1 of Table 2, a complete fertilizer is usually the most economical. The nitrogen may be omitted from the mixture for the growing of alfalfa. Where a better system of management is practiced, including either the growing of clover or alfalfa or the application of manure in the rotation, as in Group 2 of Table 2, the proportions of nitrogen and potash in the fertilizer mixture may be reduced somewhat from those recommended in Group 1. Under a good system of soil management, where clover or alfalfa has been grown and where manure also has been applied in the rotation, phosphate should be given first consideration. For some crops on such soils, however, some nitrogen and potash should be included with the phosphate as is indicated in Group 3.

An efficient use of fertilizers can be obtained by fertilizing heavily the more responsive crops as wheat, alfalfa, sugar beets, and potatoes, and supplementing the fertilizer remaining in the soil with smaller applications for the other crops in the rotation. Fertilizer applied for alfalfa, sweet clover, and clover seems particularly effective in building up fertility for use by following crops.

Fertilizer Application

In the early days of fertilizer applications it was customary to broadcast the fertilizer and work it into the soil before seeding the crop. As machinery became available for making row applications it was found that fertilizers frequently were more effective when applied in the row than when broadcast and worked into the soil. This is probably due: first, to the fact that row applications put the fertilizer where the roots of young plants can easily come in contact with it; and second, to the smaller contact between the fertilizer and the soil particles. Chemical reactions between the soil minerals and the phosphate in the fertilizers tend to render the phosphate unavailable to plants.

Fertilizers for small grains may be applied directly in contact with the seed. The grain drill with the fertilizer attachment is recommended for this purpose.

It is important to remember that when a grain crop is to serve as a nurse crop for alfalfa or clover the fertilizer application should be sufficient for two or three years. In the case of alfalfa production, top-dressing applications are recommended when the crop is left for hay more than two years.

The cultivated crops present some special problems in fertilizer application. Fertilizer should never be applied in direct contact with corn or bean seeds because of the danger of injury to germination. Fertilizer applications for corn should be made with a planter which places the

TABLE 2. FERTILIZER RECOMMENDATIONS FOR VARIOUS CROPS GROWN ON LOAM, SILT LOAM, AND CLAY LOAM SOILS

Fertilizers are usually more effective on soils containing sufficient amounts of lime than on soils deficient in lime

Crop	Group 1 No alfalfa or clover recently. Not recently manured.	Group 2 In alfalfa or clover recently or Manured recently.	Group 3 In alfalfa or clover recently and Recently manured.
Without seedings of clover or alfalfa	4-16-4	4-16-4 or 0-20-0	0-20-0
Wheat or Rye	Grain alone, apply 200-250* pounds with the seed. If clover or alfalfa is to be seeded, increase the rate of application to 300 pounds.		
Seeded to clover or alfalfa	2-12-6 or 4-16-4	2-16-8 or 0-20-0	0-20-0
Without seedings of clover or alfalfa	4-16-4	4-16-4 or 0-20-0	0-20-0
Oats or Barley	Grain alone, apply 150 to 250 pounds with the seed. With seedings of clover or alfalfa, increase the rate of application to 300 pounds.		
Seeded to clover or alfalfa	2-12-6 or 4-16-4	2-16-8 or 0-20-0	0-20-0
Alfalfa	0-14-6 or 0-20-10	0-14-6 or 0-20-0	0-20-0
	Seeded alone, 150 to 200 pounds drilled with the seed or 250 pounds broadcast and worked into the soil before seeding. On stands two or more years old, topdress with 150 to 200 pounds every two years.		
Corn	2-16-8 or 0-20-0	0-20-0	0-20-0
	Apply 100 to 150 pounds in the row beside the seed. Large applications in contact with the seed may prove injurious. Fertilizer may not be needed on soils of high fertility and where the other crops in the rotation are rather heavily fertilized.		
Sweet Corn	2-12-6 or 2-16-8	2-16-8 or 0-20-0	0-20-0
	Apply 100 to 150 pounds in the row beside the seed.		

Sugar Beets	4-16-4 or 2-16-8 or 2-12-6	4-16-4 or 0-14-6 or 0-20-10	0-14-6 or 0-20-10
	Apply 100 to 200 pounds in the row at planting time. Where larger applications are to be made plow under 200 to 400 pounds and apply 100 to 200 pounds in the row. Where fall plowing is practiced, plow under 0-14-6 or 0-20-0 and if needed apply a complete fertilizer in the spring. Larger applications in contact with the seed may prove injurious.		
Early	4-10-6	4-10-6	2-12-6
Potatoes	Apply 300 to 500 pounds in bands 2 inches to the side and slightly below the seed.		
Late	4-16-4 or 2-16-8	4-16-4 or 2-16-8	2-16-8 or 0-20-0
Beans	4-16-4 or 2-16-8	0-14-6 or 0-20-10	0-14-6 or 0-20-10
	Apply 200 pounds in a band 1 inch to the side of the seed and 1½ inches below the level of the seed. Applications of fertilizer in contact with the seed should be avoided. On soils in high state of fertility and where other crops in the rotation have been well fertilized, apply no fertilizer.		
Tomatoes**	4-16-8 or 5-10-5	4-16-8 or 2-12-6	2-16-8 or 0-14-6 or 0-20-0
	Apply 400 to 800 pounds in bands to the side and slightly below the root cluster at setting time.		
Cabbage**	4-16-4 or 2-16-8	4-16-4 or 2-16-8	4-16-4 or 2-16-8 or 0-20-0
	Apply 400 to 800 pounds in bands to the side and slightly below the root cluster at setting time.		
Cucumbers**	4-16-4 or 5-10-5	4-16-4 or 5-10-5	4-16-4 or 5-10-5
	Apply 250 to 500 pounds in bands beside the hills at planting time.		
Beets, Carrots, Turnips, or Rutabagas**	4-10-6 or 2-16-8	2-16-8 or 4-10-6	2-16-8 or 4-10-6
	Broadcast 250 to 500 pounds and work into the soil before planting.		

*All rates of application are on the acre basis.
**Recommendations by H. L. Seaton of Horticultural Department.

fertilizer in bands apart from the seed. The results of seven years' cooperative experiments by the Michigan Experiment Station and the Bureau of Agricultural Engineering of the United States Department of Agriculture show that the only profitable way to fertilize beans is to place the fertilizer in bands close to, but not in contact, with the seed. It is recommended that the fertilizer be placed in a single band 1 inch to the side of the seed and 1½ inches below the level of the seed. With this method of application, yield increases have not been large but have been consistent. Perhaps the best way to fertilize both corn and beans is to apply larger quantities of fertilizer for the legumes which precede these crops in the rotation, then plant the corn and beans without fertilizer.

As much as 200 pounds of fertilizer per acre may be applied in contact with the sugar beet seed when the beets are planted in 24-inch rows on the silt and clay loam soils. On the loam soils where 28-inch row spacings are used the rate of application with the seed should not exceed 150 pounds. Heavier applications should be made in a band one inch to the side and one to two inches below the seed. Good results have also been obtained by plowing under 200 to 400 pounds of fertilizer and then applying 100 to 200 pounds in the row. Soluble nitrogen fertilizer should not be plowed under in the fall as the nitrogen may be lost by leaching before the crop is planted.

Fertilizer experiments with potatoes, conducted on the representative soils, have shown that fertilizers should not be placed directly in contact with the seed piece but rather in bands 2 inches out from the seed piece and on the same level or slightly below it.

Use of Borax on Mineral Soils

Much experimental work has been done, during the last few years, to determine the need of Michigan soils for boron. The results indicate that several crops frequently obtain insufficient boron when growing on soils well supplied with lime and containing a high percentage of organic matter. The shortage of boron seems to be most severe during periods of drought. Symptoms of boron starvation have been found most frequently in sugar beets, mangels and canning beets. It is recommended that borax be used for these crops at the rate of 8 to 10 pounds per acre when applied in the row. When applications are to be made broadcast, from 20 to 40 pounds should be used for sugar beets and mangels, and 40 pounds for canning beets.

Use of Lime on Mineral Soils

Fertilizers are usually more effective on soils containing sufficient amounts of lime than on soils which are very strongly acid. Lime is continually being removed from soils through leaching and crop removal, and as a result it is advisable to test the soil for acidity unless an adequate application of lime has been recently made. On acid soils lime application should be one of the first steps in soil management.

Use of Manure and Green Manures

On the mineral soils, organic matter added in the form of manures or green manures greatly increases the efficiency of fertilizers. Where barnyard manure is applied, it not only increases the soil's organic

content, but also adds to the essential elements in the soil. If manure is not obtainable, green manures furnish an excellent source of organic matter. On those soils which have a low content of organic matter and are strongly acid, it is advisable to apply lime in order that the growing of sweet clover as a green manure crop may be included in the rotation. Such a procedure will also make it possible to grow alfalfa for hay, which will further increase the organic matter content of the soil. The application of phosphate and potash fertilizers for sweet clover, grown for green manure purposes, is strongly recommended.

LAWN FERTILIZATION

Lawn fertilizers should contain a large proportion of nitrogen, and a medium amount of phosphoric acid and potash. The fertilizer analysis which is recommended for all general turf growing is a 10-6-4. The standard application of this fertilizer is 10 pounds per 1,000 square feet of lawn.

The first application should be made in the spring as soon as possible after the snow disappears. **Lawns which are not appreciably shaded should receive** a second application about May 15 to June 1; and a third September 1.

Shady lawns should receive the first application, as stated above, but during the season when the trees are in leaf, four pounds of fertilizer per 1,000 square feet should be applied every two weeks.

Fertilizer applications which are made when the grass is growing vigorously will cause burning of the foliage unless precautions are taken to prevent it. It is advisable to fertilize only 500 square feet at a time and wash the fertilizer off the grass leaves into the soil immediately, using a nozzle on the hose which gives a coarse spray.

In order to obtain the best results from fertilizers on lawns the cutter-bar on the lawn mower should be set to cut at a height of two inches.

When artificial watering is necessary, give the lawn a good soaking once or twice a week. Do not sprinkle lightly every night.

FERTILIZER NEEDS OF MUCK SOILS

Muck soil is naturally very low in content of several of those mineral constituents required for the production of good yields of high-quality crops. Of the ordinary fertilizing materials, it contains very much less potash and, generally, considerably less phosphate than does the average mineral (upland) soil. Only in nitrogen content does the muck excel. Muck soil is also very low in content of the lesser-known but often greatly needed elements, such as copper, manganese, sodium and boron. The lack of one of these materials in the soil, when needed by the crop, may be the factor which greatly limits the crop yield, despite the heavy application of phosphate and potash. Since the content and availability of these various constituents are quite closely associated with the reaction of the soil, the degree of acidity or alkalinity of the

muck should always be determined in deciding on the proper fertilizer mixture to be used for a particular crop.*

Lime

Lime should not be applied for any crop unless the muck is very strongly acid. When lime is needed, fertilizer, applied without liming, will be largely wasted. Owing to the fact that this very strongly acid condition of the soil generally continues to a depth of several feet, root development will be confined to the limed layer, with the result that fertilizer, washed down by rains below the lime, will be lost to the crop. In the application of any liming material, such as ground limestone, marl or sugar beet lime on such acid areas, it is therefore advisable to apply half the lime, disk it in thoroughly, then plow as deeply as possible and apply the remainder of the lime and disk it into the upturned muck. The necessary rate of application will, of course, depend on how acid a soil test shows the muck to be and what crops are to be grown (See Table 3, Column A). Since blueberries and cranberries require a very acid soil, lime should not be used where they are to be grown.

Copper Sulphate

The use of copper sulphate in the fertilizer mixture is recommended for most special and general crops on acid muck soil. Only three crops, celery, corn and rutabagas, have failed to show appreciable benefit in our experimental studies. Spinach and lettuce have been considerably benefited even on some alkaline mucks. The eight crops showing the greatest response to copper sulphate are listed in Table 3, Column B. Generally it is advisable to use from 25 to 50 pounds per acre of copper sulphate as an initial application, with from 15 to 50 pounds in succeeding years until a total of 200 to 300 pounds per acre has been applied.

Important benefits observed from the use of copper sulphate on acid muck include:

*__Sampling Muck Soil for Soil Reaction Tests__—In obtaining samples for testing, care should be taken to avoid old burnouts, places where brush or refuse has been burned, old vegetable storage pits, trenches, tile lines, ditch banks, or any other place at which some disturbing factor may have affected the soil reaction. Scrape off the surface and take the first sample at a depth of four to six inches. Since the soil reaction often changes somewhat below the plowed layer, it is advisable to take a second sample with spade or posthole auger at a depth of 18 to 24 inches. Care should be taken that none of the plowed layer falls into the second sample. Keep the samples separate and properly labeled. If part of the field has been burned over at some time or if the muck or the native vegetation varies considerably in different parts of the field, more than one set of samples may be required. If the land is properly drained and has been broken deeply for the first time, yet the properly fertilized first crop has been a failure, it is advisable to include a third sample taken just above (8 to 12 inches deep) the buried sod, since it sometimes happens that the buried surface layer is sufficiently alkaline to interfere with root development of onions, although the samples taken at depths of 4 inches and 20 inches may give no indication of this condition. Draw a map of the field and keep it for your own information; locate the points of sampling by number (1, 2, 3, etc.) and number the samples [1A (above), 1B (below), 2A, 2B, etc.] accordingly. Half-pint samples should be sent in moist condition in clean cans. Complete information regarding the muck, as to location in state, depth, years under cultivation, drainage conditions, fertilization, yields and condition of crops grown in the past years, as well as names of crops to be grown, should be sent in a letter attached to the package. Address Muck Specialist, Soils Department, M. S. C., East Lansing. In the busy part of the year, reports on the samples may be delayed from three to six weeks.

1. Increased yields.
2. Improved vigor—a healthier crop.
3. Increased top growth with larger leaves.
4. Improved color of leaves of most crops, of bulbs of onions, and of roots of carrots.
5. No premature dying back of leaves in hot, dry weather.
6. Improved flavor of several crops, and increased sugar content of carrots and beets.

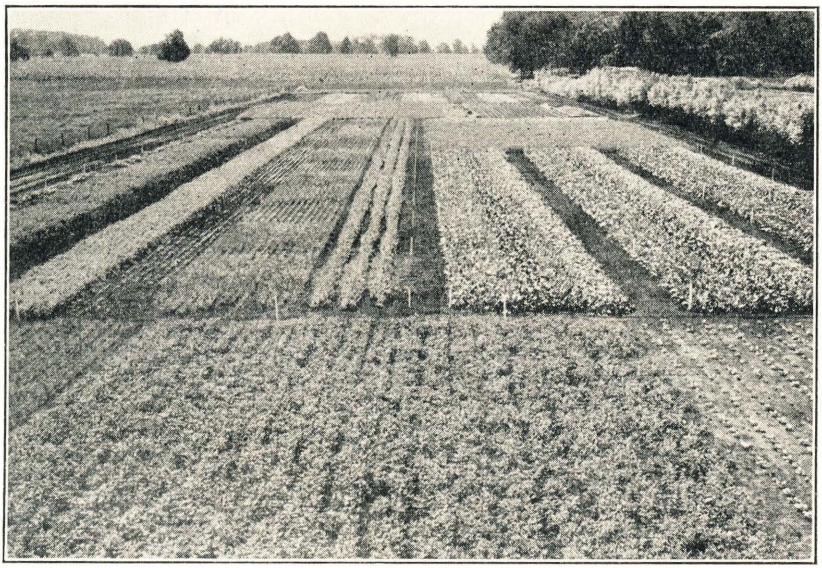

Fig. 7. Showing one (three and one-half acres) of the four sections of the Soils Department muck experimental plots on the College farm at East Lansing. The muck in this section is alkaline for about half way down the field where it becomes slightly acid. The plots on the left center show the effects of applications of sulphur and of manganese sulphate. At the right center are fertilization studies with some of the rarer elements, including boron and sodium. At the farther end of the field are comparative trials with different manures and commercial fertilizers.

Sulphur or Manganese Sulphate

In general, muck soils which are alkaline in reaction fail to produce satisfactory yields of several important crops, unless given special treatment, although an occasional alkaline muck gives good yields of all crops with ordinary fertilization. Certain crops (See Table 3, Column B) are able to tolerate this alkaline reaction without injury. If the soil is alkaline in reaction and does not produce satisfactorily, sulphur or manganese sulphate is likely to be beneficial for a number of crops (See Table 3, Column E). The amount of sulphur needed to correct the condition permanently will range from 300 to 2,000 or more pounds per acre, the amount depending on the degree of alkalinity and the depth to which the alkalinity extends. If manganese sulphate is used, from 100 to 200 pounds per acre, mixed in the fertilizer, are likely to be required each year for several years. The sulphur should be applied on

Table 3. Relative response of several special crops to different soil reactions and to certain soil treatments.

No.	(A) Most tolerant of a very strongly acid reaction	(B) Most responsive to copper sulphate on acid mucks	(C) Responsive to salt on most mucks	(D) Most tolerant of an alkaline soil reaction	(E) Most responsive to sulphur or to manganese sulphate on alkaline mucks	(F) May respond to borax on new muck or on alkaline mucks
1.....	Cranberries	Spinach	Table beets	Sugar beets	Onions	Celery
2.....	Blueberries	Onions	Celery	Mangels	Celery	Table beets
3.....	Potatoes*	Lettuce	Turnips	Swiss chard	Radishes	Spinach
4.....	Lettuce*	Carrots	Mangels	Cabbage	Spinach	Sugar beets
5.....	Spinach*	Tomatoes	Swiss chard	Cauliflower	Lettuce	Corn
6.....	Peas*	Potatoes	Sugar beets	Peppermint	Potatoes	Cauliflower
7.....	Squash*	Cauliflower	Celeriac	Parsnips	Carrots	Mangels
8.....	Tomatoes*	Radishes	Cabbage	Carrots	Table beets	Radishes

*Light lime and copper sulphate applications required.

the surface and disked in thoroughly after plowing. If the alkalinity extends to a depth of several inches, it is advisable in later plowings not to plow deeply, unless more sulphur or manganese sulphate is to be applied. A light sulphur or manganese sulphate application is sometimes advisable for onions, even when the soil is only very slightly acid, but where the onion crop is slow to mature.

Salt

The use of common salt, along with a fertilizer mixture high in potash, can be recommended for the eight crops listed in Table 3, Column C. An initial application of 500 to 1,000 pounds per acre broadcast before planting is generally advisable, with succeeding applications in the following years of 250 to 500 pounds in case of continuous cropping with these salt-responsive crops. The need for salt may not be so great if the land has been heavily fertilized for several years just preceding. Although yields of some other crops may be decreased if heavy salt applications are used immediately before planting, the residual effect of the salt will have no bad effect on the crop of the year following the application. Benefit from the salt application can be seen in increased yields, and, in the case of celery, in an improvement in quality.

Boron

Several crops have showed a response (Table 3, Column F) to boron, in the form of borax, on some muck areas in the state. Boron-deficiency is most likely to be seen in celery in the occurrence of Cracked-stem disease, in table beets in the occurrence of Girdle, and in sugar beets in a stunting and cross cracking of the leaf stems of the center leaves, and sometimes also in a yellowing of the outer, older leaves, in the hottest part of the summer. Cracked-stem appears as a cross cracking of the ribs on the celery stems, generally in the late growth of the

crop. It is most likely to occur on new muck, but, with heavy fertilization, disappears after a year or two unless the muck is alkaline. Girdle appears as a cracking, followed by the decaying of the table beet about at the level of the muck surface and occurs on alkaline mucks. Depressed yields of the other three crops and a premature discoloration of cauliflower heads are their chief symptoms of boron deficiency.

Complete control of these boron deficiencies in the cases of all of the crops except table beets, and great reduction of the Girdle of table beets can be secured by an initial application of borax at the rate of 25 to 50 pounds per acre and of 100 pounds if the soil is decidedly alkaline. Its application is strongly recommended on new fields which are being cropped to celery for the first time. Continued applications of 15 to 25 pounds per acre of borax in later years, whenever one of these crops is to be grown, are generally advisable, especially on alkaline mucks, but care should be exercised in using it, since borax is very toxic to plant growth when applied in excess. Since celery, table beets and sugar beets likewise respond to salt, the borax for these crops can be mixed with the salt and broadcast before planting.

Manure and Green Manure

Since muck soil contains a relatively high proportion of nitrogen, manure, with its high nitrogen content, is not a balanced fertilizer for muck land. When used alone on muck, it has a tendency to increase lodging of grain, to increase the proportion of scallions of onions and sometimes to produce distorted growth of the roots of root crops. By increasing the weed growth, manure also considerably increases the labor cost in producing vegetable crops. If there are mineral soils on the farm, it is better to use the manure on the upland and to maintain the fertility of the muck with commercial fertilizers and green manures.

On some farms, however, the manure produced on the farm must be used on the muck. Here it always should be supplemented with a commercial fertilizer high in potash but containing no nitrogen. In our muck experimental trials with different forms of manure, sheep manure has given the best results, with chicken manure generally second in yields of crops. Of the various crops, cabbage, cauliflower, celery, corn, lettuce and spinach respond well to the use of manure with commercial fertilizer.

The growing of green manure crops on muck land, which would otherwise lie fallow, is a very desirable practice. The green manure tends to retain the residual fertilizer, it prevents the blowing away of the surface muck, it gives a more granular structure to the soil as it becomes incorporated with it, and it tends to smother out the weeds. Soybeans, sweet clover, Sudan grass, oats, rye, or a mixture of corn and soybeans, are all suitable for green manure crops, with the legume crops generally giving better results. In the case of the last-named, the corn can be husked and the corn stover and soybean residue plowed under to improve the soil.

The Fertilizer Requirement

Most mucks show a need for a fertilizer containing both potash and phosphate immediately after the land has been broken up, especially if

TABLE 4. FERTILIZER RECOMMENDATIONS FOR MUCK SOILS

(G) Crop. When two fertilizer analyses are given, the first is generally preferred. Read footnotes very carefully.	(H) Annual fertilizer application pounds per acre (Preferably in drills 7 inches apart and 3 to 4 inches deep.)	TYPE OF MUCK			
		High-Lime (Deep or medium depth) Properly drained, pH range 7.0—4.6		**High-Lime**	**Low-Lime** pH 4.5 or less
		(I) Newly reclaimed (1-8 years) Somewhat fibrous or woody. Heaviest fertilizer recommendation advisable for first few years after reclamation.	(J) Old Muck (Well decomposed). If well fertilized in past years, applications can be reduced to the lowest recommendations.	(K) Poorly drained muck, Alkaline muck or Shallow muck.	(L) Very strongly acid muck (Limestone, marl, sugar beet lime or wood ashes required before fertilization.)
Broccoli	400-600	0-8-24 or 2-8-16	3-9-18 or 0-8-24	3-9-18 or 3-12-12	3-9-18
Cabbage (2) Cauliflower (2) Lettuce (1) (2) Spinach (1) (2) Swiss chard (3) (4)	500-1000 800-1500 500-1000 500-800 500-1000	Apply fertilizer (7 inch drills) before planting. For cabbage and cauliflower, transplanted to field, 400 to 500 pounds per acre can be applied in row 4 inches deep if muck is well supplied with moisture. Side-dressing of available nitrogen fertilizer (75 to 100 pounds) sometimes advisable, especially for cauliflower. These crops responsive to manure, supplemented with 0-8-24 mixture.			
Celery, Early (1) (3) (4)	1000-1800	3-9-18 or 3-12-12	3-9-18 or 3-12-12	3-12-12	3-9-18
Radishes, Early (1) (2) (3) (4) Table beets, Early (2) (3) (4)	400-800 600-1000	Row application for beets and celery advisable on wet muck—500 pounds 3 inches below surface. Apply remainder in 7 inch drills or broadcast and disk in. If no manure has been applied for celery, side-dressing of available nitrogen in fertilizer is beneficial, especially in cool seasons and on wet muck, or old muck. If manure has been applied, nitrogen generally can be omitted from the fertilizer mixture.			
Celery, Late (1) (3) (4)	1200-2000				
Radishes, Summer (1) (2) (3) (4) Table beets, Late (2) (3) (4)	400-800 600-1000	0-8-24	0-8-24	3-9-18 or 2-8-16	3-9-18
Onions (1) (2)	800-1200	Row application 400 to 500 pounds 2 inches below seed advisable on moist muck. Apply remainder in 7 inch drills. Try 0-20-20 or 3-12-12 if crop tends to mature late.			
		0-10-20 or 0-20-20	2-8-16 or 0-10-20	3-9-18 or 3-12-12	3-9-18
Mint (2)	200-400	Fertilizer needed to maintain stand of mint, as well as to increase oil content. Apply broadcast fairly early in spring. Try 0-20-20 if mint is late in blossoming.			

Barley, Oats (2), Rye — With or without seeding	250-400 250-400 200-350	To secure satisfactory results from fertilizers, grow grain varieties adapted to muck land, such as Gopher oats, Peatland barley, and Rosen rye.			
		0-8-24 or 0-8-32	0-8-32 or 0-8-24	0-8-24 or 0-10-20	3-9-18 or 0-8-24
Mangels (3) (4) Sugar beets (2) (3) (4)	300-500 300-600	Row application advisable for sugar beets, not more than 150 pounds per acre with seed, or not more than 300 pounds 2 to 3 inches below seed. Apply remainder in 7 inch drills 4 inches deep before planting.			
Field corn Sweet corn Sunflowers	250-350 400-800 250-400	If row application is made for corn, do not use more than 200 pounds per acre for field corn and 400 pounds for sweet corn, preferably at least 2 inches below seed.			
Potatoes (1) (2)	500-800	Row application sometimes advisable for potatoes but not more than 400 pounds per acre preferably in furrow 2 to 4 inches below seed. If mixed with muck with machine planter, 600 pounds can be safely applied. Plant close to avoid hollow heart and to minimize frost danger.			
Permanent pasture Timothy and alsike Sweet clover Reed canary grass Hungarian millet (1) (2) Soybeans Sudan grass (1) (2) Asparagus Parsnips Rutabagas and Turnips (3) Stock carrots Table carrots (2)	75-150 200-350 200-350 300-400 200-300 200-350 200-300 400-800 600-1000 300-500 300-500 400-800	Apply fertilizer broadcast on pasture in spring. Growth increased and palatability and nutritive value of grass much improved by proper fertilization.			
		Seeding hay without nurse crop often advisable. Early seeding necessary to beat weed growth.			
		0-8-32 or 0-8-24	0-8-32	0-8-24	3-9-18 or 0-8-24
		For root crops, apply with fertilizer drill, or broadcast and disk in before seeding.			
Beans (1) (2) Cucumbers and Melons Pumpkins and Squash Tomatoes (2)	250-500 400-800 300-600 500-1000	0-10-20 or 0-8-24	0-8-24	0-10-20	0-10-20
		These crops easily killed by frost, therefore generally not safe on muck soil. Keep soil compact and well supplied with moisture to help prevent frost injury.			
Blueberries (2)	500-800	Blueberries require very strongly acid soil. On slightly acid muck, crop can be improved by application of 1000 to 3000 pounds of sulphur per acre. Crop not recommended on mucks of high pH.			
		0-8-24 or 0-20-20	0-8-24 or 0-20-20	0-10-20	3-9-18
Raspberries (1) (2)	500-800	Raspberries adapted to acid mucks. Light applications of sulphur sometimes beneficial.			
Strawberries (1) (2)	200-600	For berry production on strawberries, use 100 to 200 pounds 0-20-20 per acre; for plant production, apply 500 to 600 pounds 0-8-24.			

(1) These crops likely to show marked response to sulphur or manganese sulphate when grown on alkaline muck.
(2) These crops very likely to respond to copper sulphate when grown on acid muck (pH 6.0 or less).
(3) These crops are likely to respond to salt in fertilizer mixture.
(4) These crops occasionally benefited by light application of borax, especially on previously unfertilized muck.

several crops of wild hay were removed, or the muck was used for pasture for many years, before breaking, or if certain special crops, such as celery or onions, are grown immediately. In the maintenance of fertility of muck soils, the fertilizer should be applied each year, at a rate sufficient for the needs of the crop to be grown that year. After

Fig. 8. Sugar beets on muck land. The beets in the upper picture received phosphate only while those in the lower picture received phosphate and potash. Yields: Phosphate only, 3.8 tons; phosphate and potash, 10.6 tons per acre.

the muck has been fertilized for a few years, some reserve of fertility will have been built up in the soil, at which time the rate of application can be slightly reduced.

Table 4 gives the recommended fertilizer mixtures for the various crops (Column G) on different types of muck, together with the rates of application (Column H) which should produce satisfactory yields. Although a high proportion of potash in the fertilizer mixture is gen-

erally advisable (Columns I and J), a little more phosphate may be beneficial to the crop, if the soil is shallow, or is alkaline, or is poorly drained (Column K).

If the muck is extremely acid (Column L), or, if it is shallow or is poorly drained, or, if the muck has been farmed for a long period of years, until it has reached a highly decomposed condition, the inclusion of nitrogen in the fertilizer mixture, or the application of it during growth, is likely to be decidedly beneficial to a number of crops. Of these, cabbage, cauliflower, celery, corn, lettuce, onions, peppermint, radishes, spearmint, spinach, and Swiss chard should be mentioned. If the muck is new and well-drained (Column I), the nitrogen can frequently be left out of the fertilizer, without decreasing the yields.

Fig. 9. This muck had been well fertilized for onions each year for the six years preceding this crop, while the seventh application had been made and disked in just before the crop was sown. The six rows at the left of the center stake received no further treatment while the six at the right received a 500-pound application in the row two inches below the seed.

The rate of application that should be made for a given crop will depend on how well the muck has been fertilized in the years just past, how close the crop rows will be spaced, how high the analysis of the fertilizer is and what method of application is used. In general the application of the fertilizer with a regular drill, with the fertilizer drilled in rows seven inches apart and at least three inches deep, is advisable for most crops. If the muck is well supplied with moisture and is not likely to become drouthy later in the season, application of the fertilizer in the row, at a depth of at least two inches directly below the seed, is advisable for onions, sugar beets and sometimes other crops. The amount of fertilizer that can be applied safely in the row depends on the crop, and can be determined by referring to the discussions in Table 4. On a drouthy muck, a row application may injure the germination and growth of the crop.

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