Fertilizer Recommendations
Michigan State University Extension Service
Soil Science and Horticulture
Revised October 1957
48 pages

Extension Bulletin 159 (Revised) October 1957

FERTILIZER Recommendations for MICHIGAN CROPS

Prepared by Departments of Soil Science and Horticulture
MICHIGAN STATE UNIVERSITY
Cooperative Extension Service • East Lansing

CONTENTS

HOW TO USE THIS BULLETIN

To make the best use of the information presented in this bulletin, follow the instructions presented below:

1. For tree fruits, grapes, brambles, strawberries, bush fruits and blueberries—turn to pages 26 to 31.

2. For vegetables:

   A. If your soil is a loam, silt loam, or clay loam (Soil management groups 1 and 2), refer to Table 9, page 21. See items 5 and 6 below.

   B. If your soil is a sandy loam or loamy sand (Soil management groups 3, 4, and 5), refer to Table 10, page 22. See items 5 and 6 below.

   C. If your soil is muck, refer to Tables 11 and 12, pages 35, 36. See items 5 and 6 below.

3. For field crops growing on mineral soil:

   A. Where soil tests are available—

   (1) If the soil series is known, turn to the alphabetical list of series in the back of the bulletin (Table 19). It will show the table listing fertilizer recommendations for field crops. You can get soil series information from published county soil survey reports or maps prepared for individual farms by the Soil Conservation Service. Your county agricultural agent will have a copy of a soil survey map if one is available in your area. On the basis of the soil test, select the column in the fertilizer recommendations table that applies to your field; follow the suggestions in that column for crops you wish to grow.

   (2) If the soil series is not known, select the block in the chart (page 4) that best describes the upper 3 feet of your soil profile. Turn to the fertilizer recommendation table indicated there.

   (3) If the soil has been tested but neither the soil series nor the soil profile characteristics are known, use the block in the chart that best describes the texture and color of the soil sample.

(4) If only the soil test results are available, then follow the fertilizer recommendation shown in Table 5, page 17.

B. Where soil tests are not available—

(1) If the soil in a field to be fertilized has not been tested but you know the name of the soil series, turn to the alphabetical list of soil series in the back of the bulletin (Table 19). It will direct you to the proper fertilizer recommendation table. Use column 1 of the recommendation table if your soil is low or medium in productivity; use column 4 if the soil is in a high state of productivity.

(2) If you do not know the soil series, determine the soil group by texture and color characteristics—See chart below. It will direct you to the proper fertilizer recommendation table.

Soil Group identification chart for mineral soils. The Fertilizer Recommendations Table for field crops is given for each soil group.

Texture of the upper 3 feet of the profile	Natural drainage and surface color		
	Well drained, light colored a	Imperfectly drained, fairly light colored b	Poorly drained, dark colored c
1 Clay and silty clay	1a* Table 3	1b* Table 3	1c* Table 3
2 Clay loams or loam	2a* Table 5	2b* Table 5	2c* Table 4
3 Sandy loams	3a* Table 5	3b* Table 5	3c* Table 6
4 Loamy sands or sands with some finer textured layers	4a* Table 7	4b* Table 7	4c* Table 6
5 Sands	5a* Table 8	5b* Table 8	5c* Table 8
G Gravelly or stony	Ga* Table 5	Gbc* Table 5	Gbc* Table 5
R Rocky	Ra* Table 5	Rbc* Table 5	Rbc* Table 5

*Soil management group designations. These groups are described on page 44.

(3) It is not advisable to make fertilizer recommendations if the soil group is not known and the soil has not been tested.

4. For crops growing on organic soils:

   Fertilizer recommendations for muck soils depend on actual soil tests made by the "active method". Find the column listing the crop in Tables 11 and 12, then find the position of the approximate soil test in the same column above the crop listing. Follow dotted line to right from the soil test, and read figures in the far right column for the amount of P_2O_5 or K_2O required.

5. Turn to page 13 for the way to appy fertilizer on field crops. Turn to page 14 for vegetable crops growing on mineral soils. Muck crops are listed in Table 18, page 43.

6. Minor elements are often needed. If the pH is above 6.5 on mineral soils, read section on page 25. Recommendations for muck crops are reported in pages 37 to 41 and Tables 13 to 17.

7. Nitrogen recommendations on mineral soils depend upon soil management practices in use. Turn to pages 12 and 13 and Table 2 for instructions.

Fertilizer Recommendations for Michigan Crops

Prepared by staff members of the

Departments of Soil Science and Horticulture

RATIOS AND MINIMUM FERTILIZER GRADES RECOMMENDED[1]

Ratio	*Minimum grades*	*Ratio*	*Minimum grades*
0:1:1	0-20-20	1:3:9	3-9-27
0:1:2	0-15-30	1:4:0	8-32-0
0:1:3	0-10-30	1:4:2	5-20-10
0:2:1	0-20-10	1:4:4	4-16-16
1:1:1	10-10-10	1:6:3	4-24-12
1:2:1	10-20-10	2:1:1	14-7-7
1:2:2	8-16-16	2:1:2	12-6-12
1:2:4	5-10-20	2:2:1	12-12-6

(Carriers of nitrogen, phosphorus, and potassium)

Whenever possible, use higher grades of the recommended ratios. Such substitutions result in a saving of money and labor. For instance, 500 pounds of 4-16-16 fertilizer is required to furnish the plant food contained in 400 pounds of 5-20-20. Higher grades usually are cheaper per pound of plant food, and you save through lower trucking charges and less labor in the field at planting time. Table 1 compares different fertilizer grades having the same ratios.

The first figure in the grade is the percentage of total nitrogen (N). The second is the percentage of available phosphoric acid (P_2O_5). It takes 2.24 pounds of P_2O_5 to equal 1 pound of phosphorus (P). The third is the percentage of water-soluble potash (K_2O). It takes 1.2 pounds of K_2O to equal 1 pound of potassium (K).

Actually, it is impossible to place these three plant nutrients together exactly as they are expressed in the grade percentage figures. For instance, nitrogen in the pure state is a gas. It must be placed in the fertilizer as a salt containing perhaps only 20 percent nitrogen, or as ammonia containing 82 percent nitrogen. Phosphate is usually

[1]Ratio simply refers to the proportion of nitrogen, phosphoric acid, and potash in the mixture. The grade indicates the percentage of each nutrient (by weight) contained in the finished fertilizer.

TABLE 1—Amount of fertilizer required to obtain the same amounts of $N:P_2O_5:K_2O$ for a particular ratio.

Ratio	Grade	Pounds necessary for equal amounts of $N:P_2O_5:K_2O$
0:1:1	0-12-12	167
	0-20-20	100
	0-25-25	80
0:1:2	0-10-20	150
	0-15-30	100
	0-20-40	75
0:2:1	0-16-8	125
	0-20-10	100
	0-30-15	67
1:1:1	9-9-9	110
	10-10-10	100
	12-12-12	83
1:2:1	6-12-6	125
	8-16-8	100
	10-20-10	80
1:2:2	6-12-12	125
	8-16-16	100
	10-20-20	80
1:4:2	4-16-8	125
	5-20-10	100
	6-24-12	83
1:4:4	3-12-12	133
	4-16-16	100
	5-20-20	80
1:6:3	3-18-9	133
	4-24-12	100
	5-30-15	80
0:1:3	0-9-27	110
	0-10-30	100
	0-13-39	77
2:1:1	12-6-6	117
	14-7-7	100

supplied as superphosphate (monocalcium phosphate and calcium sulfate) or ammonium phosphate; while potash may be supplied as a salt, such as potassium chloride or potassium sulfate.

Thus, the "percents" not accounted for in the sum of the grade percentages are not made up with filler, but with conditioners and the other elements in the salts or compounds used as carriers for the plant nutrients. A large part is made up of calcium, sulfur, hydrogen, and oxygen. The grades of fertilizer recommended in this bulletin are not likely to contain "make weight" materials.

I. Recommendations for Mineral Soils

NO "CURE-ALL" MAGIC COMPOUNDS

Fertilizers are most effective on well-drained soils with a favorable structure which promotes deep rooting. Too much tillage can injure plant roots or destroy structure and reduce fertilizer efficiency.

The terms "texture" and "structure" are often confused when referring to soil. Texture is the coarseness or fineness of the soil, that is, the percentage in the soil of sand, silt, and clay. Structure is the way these three aggregates hang together as natural soil particles.

Another term sometimes not understood is "pH." This is used to indicate whether the soil is acid (sour) or alkaline (sweet). A soil having a pH of 7.0 is neutral—neither acid nor alkaline. A soil having a pH of 6.0 is mildly acid; pH 5.0 is 10 times as acid as pH 6.0; pH 4.0 is 100 times as acid as pH 6.0; and so on. On the other hand, pH 8.0 is mildly alkaline. Most Michigan soils, in their natural state, have a pH lower than 7.0.

Plant nutrients, particularly phosphorus, are most available in soils of pH 6.5 to 7.0. For general field crops, acid soils (indicated by a pH of 6.5 or below) should be limed. However, where the pH is 6.3 to 6.5, increasing the availability of phosphorus may not be sufficient reason for liming if satisfactory yields of alfalfa are being obtained. Avoid raising the pH above 7.0. For vegetables on sandy soils, lime to between pH 6.0 and 6.5.

High productivity is linked with a high organic matter level. Fertilizers are not a substitute for organic matter; but, under favorable management, they can help you increase organic matter levels in the soil. Animal manures and crop residues are valuable sources of

organic matter. Plan rotations to provide for soilbuilding green manure crops.

Legumes are satisfactory green manure crops because, if properly inoculated, they work with the soil organisms to fix atmospheric nitrogen. One harvest year of an alfalfa crop may add as much as 100 pounds of elemental nitrogen to the soil. That is as much nitrogen as is contained in 2,000 pounds of 5-20-10 fertilizer, or in 500 pounds of ammonium sulfate.

FARM MANURES

Manures are valuable primarily because of their fertilizer content. They also tend to improve the moisture-holding ability of light soils and loosen the structure of heavier soils.

A ton of manure will supply about 10 pounds of nitrogen, 5 pounds of phosphate, and 10 pounds of potash. Of this amount, during the first year about 40 percent of the nitrogen, 50 percent of the phosphate, and 100 percent of the potash is as available as that supplied by commercial fertilizer. Thus, for a 10-ton per acre application of manure, figure 40 pounds of nitrogen, 25 pounds of phosphate, and 100 pounds of potash as fertilizer.

BASIS FOR RECOMMENDATIONS

Fertilizer recommendations are based on many field experiments. However, to find the right amount for any crop, you must consider the crop yield desired and the rate which will result in the best profit per acre for the money spent. The fertilizer needs of a 20-ton sugar beet crop are greater than those of a 15-ton crop. The amount needed for a 120-bushel per acre corn crop is more than double the fertilizer required for a 60-bushel crop. The recommendations in this bulletin are aimed at reasonable yields when soils are under good management.

Soils are classified into series according to color, texture, organic matter content, structure, slope, thickness, chemical composition and natural drainage. Chemical and physical properties influence crop production goals and fertilizer response. Water-holding capacity is an important consideration, because lack of water often limits crop production. If you irrigate, increase fertilizer rates to reach higher production goals.

If you know the names of the Michigan soil series on your farm, you can locate the proper fertilizer recommendation table to follow

from Table 19 in which nearly 300 different series are listed alphabetically. Locate the soil series name, then refer to the particular fertilizer recommendation table indicated for specific crops.

Soil Tests Now a Valuable Aid

Only soil test results obtained by the Spurway method should be used to select fertilizer recommendations in this bulletin. (In the Spurway "reserve" method recommended for general crops on mineral soil, the extracting reagent is the No. 8 reagent, 0.13 normal hydrochloric acid.)

The recommendation tables for *mineral soils* are based on the assumption that all phosphorus tests below 50 pounds per acre are low; those above 50 are high. Make this division between "low" and "high" at 100 pounds per acre if the soil pH is above 7.0.

Potassium tests are considered to be high if they are above 150 pounds per acre; low if they are below 150. *If test results fall very close to these values, use your own judgment to determine the amount of fertilizer needed.* In general, the rates of application on mineral soils are doubled as the test results change from very "high" to very "low" in both phosphorus and potassium (P and K). In all but a few cases, well-balanced fertilizers have caused economical yield increases in field experiments. They are recommended for all crops.

If the soil has not been tested, use the tables in this way: Use column 1 in each table if you believe the soil is in a low state of fertility; use column 4 if you believe the fertility level is high.

If you know that rock phosphate was applied on the area represented by the soil sample, use the Spurway "active" test instead of the "reserve" test. Then set different levels of phosphorus and potassium as dividing lines between "low" and "high" tests. The line for phosphorus (P) should be at 10 pounds per acre for acid soils; it should be at 15 for those with pH above 7.0. The dividing line for potassium (K) should be at 80 pounds per acre.

Greenhouse and garden soils should also be tested by the "active" method (extraction with No. 1 reagent, 0.018 normal acetic acid), because you will want to maintain much higher nutrient levels. Soils with pH value below 7.0 require 40 pounds of phosphorus per acre; above pH 7.0, use 60 pounds.

How to Take Soil Samples

The results from a soil test may be worthless (or actually misleading) unless the sample tested actually represents an entire area.

To make sure your sampling is accurate, first survey the area to determine soil-type boundaries. Use a spade or auger to check the color and textures of the surface and subsoil layers. Avoid mixing samples from different soil types in a single sample if at all possible.

Take the soil samples with a sampling tube or sharp spade which removes a core or slice to plow depth. For analysis, each sample should be a half-pint mixture of at least 10 thoroughly-mixed cores or slices from each soil type area to be tested. All tools and containers should be clean.

Nitrogen

The immediate nitrogen needs of a crop growing on a mineral soil depend more on the system of management than on the soil type or test at the time of planting. Bacteria in alfalfa and clover root nodules take nitrogen from the air to build their own bodies. The plant is able to use the nitrogen turned loose in the soil by the bacteria. Because of this "nitrogen fixation" by the legume bacteria, these crops do not usually need nitrogen fertilizer.

Animal manures are relatively high in available nitrogen, unless the product is unusually high in straw or other highly carbonaceous bedding, such as shavings or sawdust. In most cases, however, a small quantity of nitrogen at planting time is desirable, even if animal manure is used.

Table 2 estimates the total nitrogen fertilizer required for corn and other crops. If the season is cool and wet and/or the field is poorly

*TABLE 2—Guide for estimating the total pounds of nitrogen (N) fertilizer per acre needed by field crops as affected by previous management. Include in the total the nitrogen applied at planting time**

Plow down or topdress treatment	Corn Plants per acre			Sugar beets	Small grain	Late potatoes
	8,000	12,000	16,000			
Legumes† and 8 tons per acre of manure	5	5	10	10	0	25
Legumes†—no manure	10	10	40	20	10	55
8 tons per acre of manure‡	25	50	80	60	30	95
No legumes—no manure	55	80	110	90	50	125

*Add 10 pounds of nitrogen to recommendations if soils are very low in organic matter. Subtract 10 pounds if soils are high in organic matter (dark colored).

†It is assumed that sod is over 50 percent legumes and will supply about 70 pounds of available nitrogen per acre for the first year.

‡Each ton of manure is credited with supplying 4 pounds of available nitrogen during the first year.

drained, it is usually necessary to apply larger quantities of nitrogen than indicated.

Deficiency symptoms and green-tissue tests make it possible to predict, with a considerable degree of accuracy, where supplemental nitrogen applications are likely to be profitable.[2]

Deficiencies may be spotted sooner with chemical tests than by observing deficiency symptoms. After growth has started in the spring, a nitrate test will tell whether or not it will pay to topdress wheat. The same is true of oats after 6 inches of growth. Test corn, sugar beets, tomatoes, and potatoes just before each cultivation. Apply nitrogen fertilizer as soon as you notice a deficiency.

Supplemental nitrogen applications probably will not be profitable where other nutrients are lacking. Test soil for phosphorus and potassium if you have not applied adequate fertilizers at planting.

METHODS OF APPLYING FERTILIZER

Many methods of applying fertilizer have been tested at the Michigan Agricultural Experiment Station during the past 20 years. With most crops, some rather definite recommendations have emerged.

Field Crops

ALFALFA, ALFALFA-BROME, CLOVER (with or without a companion crop) — Drill through the fertilizer attachment on a grain drill. Allow legume seeds to fall on top of the soil above the fertilizer bands. To seed bromegrass, either mix the seed with oats (if oats are used as a nurse crop) or with the fertilizer.

SMALL GRAINS — The proper place to apply fertilizer for small grains is 1 inch to the side and 1 inch below the seed. Most grain drills apply the fertilizer directly in contact with the seed. This placement can cause injury when large amounts are applied or when the soil is dry. In general, do not drill **in direct contact** with the seed more than a total of 75 pounds of nitrogen and potash per acre (for example, not more than 300 pounds of a 5-20-20).

FIELD BEANS, SOYBEANS — Apply 1 inch to the side and 2 inches below the seed. Do not apply directly in contact with the seed.

SUGAR BEETS — Apply 1 inch to the side and 2 inches below the seed. Apply no more than 150 pounds in direct contact with the seed. If a side-band placement drill is not available, drill all but 150 pounds

[2]The symptoms of nitrogen starvation are illustrated in color in Michigan Experiment Station Special Bulletin 353, which also describes the methods used in making tests for nitrate in the growing plant.

of the fertilizer deeply before planting, then apply 150 pounds with the seed at planting time. Apply extra nitrogen fertilizer as soon as it appears necessary.

CORN — Apply in a single band 2 inches to the side and 2 inches below the seed level. The split-boot applicator widely used on conventional corn planters is **not** satisfactory. Plow down or sidedress nitrogen fertilizer as indicated in Table 2.

POTATOES—Apply in bands 2 inches to the side on the level or slightly below the seed piece. Plow down or sidedress with nitrogen if needed.

Vegetable Crops

Vegetables require high levels of fertility for high yields of satisfactory quality. Fertilizer can be applied to vegetables using one or more of the following methods:

(1) applied at planting time to the green manure or cover crops preceding the vegetable crop,
(2) plowed down,
(3) drilled in after plowing,
(4) placed in bands near the seed,
(5) used in starter solutions,
(6) side or topdressed, and
(7) applied on the leaves (foliar feeding).

Credit any fertilizer applied by any of the above methods to the total amounts recommended in Tables 9 and 10.

Some rules that will help you:

1. Fertilize a green manure crop with a high nitrogen fertilizer for maximum growth. The recovery of the nitrogen applied to a green manure crop will amount to about 30 percent for the first vegetable crop.

2. When using a high phosphorus fertilizer, place in bands near the seed if possible; phosphorus is essential for small seedlings, and placement reduces soil phosphorus fixation. Examples are 4-24-12, 5-20-10, 13-39-0, or 8-32-0.

3. If phosphate is to be sideplaced, drill in or plow down a fertilizer high in nitrogen and potassium. This reduces possible injury to small plants or germinating seeds, and helps decompose non-leguminous plant residues.

TABLE 3—Fertilizer recommendations for field crops growing on silt loams and clay loams of the St. Clair, Nappanee, Ontonagon, Selkirk, Hoytville, Pickford and similar series (Soil groups 1a, 1b, 1c)

Crop	Expected crop yield per acre	Recommended pounds per acre of $N+P_2O_5+K_2O$ (top figure). Example of grade and rate (lower figure). Refer to Table 1.			
		(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Alfalfa, alfalfa-brome, clover‡, sweet clover	2.8 tons	0+60+30 0-20-10 300 lb.	0+60+15 0-20-0 300 lb.	0+30+30 0-20-20 150 lb.	0+30+15 0-20-10 150 lb.
Alfalfa, after 2nd harvest year‡	2.8 tons	0+40+40 0-20-20 200 lb.	0+40+20 0-20-10 200 lb.	0+20+40 0-15-30 133 lb.	0+20+20 0-20-20 100 lb.
Grass, no legume	.....	50+25+25 14-7-7 360 lb.	50+25+0 33-0-0 150 lb. plus 0-20-0 125 lb.	50+0+25 33-0-0 150 lb. plus 0-0-60 50 lb.	50+0+0 33-0-0 150 lb.
Barley†—oats† with legume seeding	40 bu. 55 bu.	15+60+30 5-20-10 300 lb.	15+60+15 8-32-0 200 lb. or 5-20-10 300 lb.	15+30+30 8-16-16 200 lb.	15+30+15 10-20-10 150 lb.
Barley†*—oats*† without legume seeding	40 bu. 55 bu.	20+40+20 10-20-10 200 lb.	20+40+0 8-32-0 150 lb.	20+20+20 10-10-10 200 lb.	20+20+10 12-12-6 167 lb.
Field beans†	23 bu.	12.5+50+25 5-20-10 250 lb.	12.5+50+12.5 10-20-10 200 lb. or 8-32-0 150 lb.	12.5+25+25 8-16-16 150 lb.	12.5+25+12.5 10-20-10 125 lb.
Soybeans†	23 bu.	7.5+30+15 5-20-10 150 lb.	7.5+30+7.5 10-20-10 150 lb. or 8-32-0 100 lb.	7.5+15+15 8-16-16 100 lb.	None
Sugar beets†*‡	12 tons	25+100+50 5-20-10 500 lb.	25+100+25 5-20-10 500 lb.	25+50+50 8-16-16 300 lb.	25+50+25 10-20-10 250 lb.
Wheat*†—rye* with legume seeding	35 bu.	12+72+36 4-24-12 300 lb.	12+72+18 8-32-0 225 lb.	12+36+36 5-20-20 180 lb.	12+36+18 4-24-12 150 lb.
Wheat*†—rye* without legume seeding	35 bu.	15+60+30 5-20-10 300 lb.	15+60+15 8-32-0 200 lb. or 5-20-10 300 lb.	15+30+30 8-16-16 200 lb.	15+30+15 10-20-10 150 lb.
Corn*/	70 bu.	12.5+50+25 5-20-10 250 lb.	12.5+50+12.5 8-32-0 150 lb. or 5-20-10 250 lb.	12.5+25+25 8-16-16 150 lb.	12.5+25+12.5 10-20-10 125 lb.

†Where the soil pH is above 7.0, apply fertilizer containing 1 or 2 percent manganese.
‡Apply fertilizer containing ¼ percent boron if pH is above 6.5.
*Supplemental nitrogen may be needed. See Table 2.
/If land is planted to continuous corn, apply yearly to soils of low fertility, 100 pounds of nitrogen, 50 pounds of phosphate, and 50 pounds of potash per acre.

TABLE 4—Fertilizer recommendations for field crops growing on dark colored loamy (found on nearly level to depressional areas) soils of the Brookston, Sims and similar series (Soil group 2c)

Crop	Expected crop yield per acre	Recommended pounds per acre of $N+P_2O_5+K_2O$ (top figure). Example of grade and rate (lower figure). Refer to Table 1.			
		(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Alfalfa, alfalfa-brome, brome, clover‡, sweet clover	3.3 tons	0+80+40 0-20-10 400 lb.	0+80+20 0-20-0 400 lb. or 0-20-10 400 lb.	0+40+40 0-20-20 200 lb.	0+40+20 0-20-10 200 lb.
Alfalfa, after 2nd harvest year‡	3.3 tons	0+60+30 0-20-10 300 lb.	0+60+0 0-20-0 300 lb.	0+30+30 0-20-20 150 lb.	0+30+15 0-20-10 150 lb.
Grass, no legume		50+25+25 14-7-7 360 lb.	50+25+0 33-0-0 150 lb. plus 0-20-0 125 lb.	50+0+25 33-0-0 150 lb. plus 0-0-60 50 lb.	50+0+0 33-0-0 150 lb.
Barley†—oats† with legume seeding	50 bu. 70 bu.	20+80+40 5-20-10 400 lb.	20+80+20 8-32-0 250 lb. or 5-20-10 400 lb.	20+40+40 8-16-16 250 lb.	20+40+20 10-20-10 200 lb.
Barley*†—oats*† without legume seeding	50 bu. 70 bu.	30+60+30 10-20-10 300 lb.	30+60+0 33-0-0 100 lb. plus 0-20-0 300 lb.	30+30+30 10-10-10 300 lb.	30+30+15 12-12-6 250 lb.
Field beans†	32 bu.	15+60+30 5-20-10 300 lb.	15+60+15 10-20-10 150 lb.	15+30+30 8-16-16 200 lb.	15+30+15 10-20-10 200 lb.
Soybeans†	30 bu.	5+20+10 5-20-10 100 lb.	5+20+0 8-32-0 70 lb.	5+10+10 8-16-16 65 lb.	None
Sugar beets*†‡	18 tons	40+160+80 5-20-10 800 lb.	40+160+40 8-32-0 500 lb. plus 0-0-60 70 lb.	40+80+80 8-16-16 500 lb.	40+80+40 10-20-10 400 lb.
Wheat*†—rye* with legume seeding	43 bu.	16+96+48 4-24-12 400 lb.	16+96+24 8-32-0 300 lb. or 5-20-10 400 lb.	16+48+48 5-20-20 240 lb.	16+48+24 5-20-10 240 lb.
Wheat*†—rye* without legume seeding	43 bu.	15+60+30 5-20-10 300 lb.	15+60+15 5-20-10 300 lb.	15+30+30 8-16-16 200 lb.	15+30+15 10-20-10 150 lb.
Corn*/	85 bu.	20+80+40 5-20-10 400 lb.	20+80+20 8-32-0 250 lb.	20+40+40 8-16-16 250 lb.	20+40+20 10-20-10 200 lb.
Potatoes*†	300 bu.	30+120+60 5-20-10 600 lb.	30+120+30 5-20-10 600 lb.	30+60+60 8-16-16 400 lb.	30+60+30 10-20-10 300 lb.

†Where the soil pH is above 7.0, apply fertilizer containing 1 or 2 percent manganese.
‡Apply fertilizer containing ¼ percent boron if pH is above 6.5.
*Supplemental nitrogen may be needed. See Table 2.
/If land is planted to continuous corn, apply yearly to soils of low fertility, 120 pounds of nitrogen, 60 pounds of phosphate, and 60 pounds of potash per acre.

TABLE 5—Fertilizer recommendations for field crops growing on light colored gently sloping to moderate sloping loams and sandy loams, of the Miami, Conover, Nester, Hillsdale, Emmet, and similar series (Soil group 2a, 2b, 3a, 3b)

Crop	Expected crop yield per acre	Recommended pounds per acre of $N+P_2O_5+K_2O$ (top figure). Example of grade and rate (lower figure). Refer to Table 1.			
		(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Alfalfa, alfalfa-brome, clover, sweet clover	3.3 tons	0+80+40 0-20-10 400 lb.	0+80+0 0-20-0 400 lb.	0+40+40 0-20-20 200 lb.	0+40+20 0-20-10 200 lb.
Alfalfa, after second harvest year‡	3.3 tons	0+60+60 0-20-20 300 lb.	0+60+30 0-20-10 300 lb.	0+30+60 0-15-30 200 lb.	0+30+30 0-20-20 150 lb.
Grass, no legume		50+25+25 14-7-7 360 lb.	50+25+0 33-0-0 150 lb. plus 0-20-0 125 lb.	50+0+25 33-0-0 150 lb. plus 0-0-60 50 lb.	50+0+0 33-0-0 150 lb.
Barley—oats with legume seeding	43 bu. 62 bu.	20+80+40 5-20-10 400 lb.	20+80+20 8-32-0 250 lb. or 5-20-10 400 lb.	20+40+40 8-16-16 250 lb.	20+40+20 10-20-10 200 lb.
Barley*—oats* without legume seeding	43 bu. 62 bu.	30+60+30 10-20-10 300 lb.	30+60+15 10-20-10 300 lb.	30+30+30 10-10-10 300 lb.	30+30+15 12-12-6 250 lb.
Field beans	28 bu.	12.5+50+25 5-20-10 250 lb.	12.5+50+12.5 8-32-0 150 lb.	12.5+25+25 8-16-16 150 lb.	12.5+25+12.5 10-20-10 125 lb.
Soybeans	25 bu.	10+40+20 5-20-10 200 lb.	10+40+10 8-32-0 125 lb.	10+20+20 8-16-16 125 lb.	None
Sugar beets*‡	14 tons	30+120+60 5-20-10 600 lb.	30+120+30 5-20-10 600 lb.	30+60+60 8-16-16 375 lb.	30+60+30 10-20-10 300 lb.
Wheat*—rye* with legume seeding	40 bu.	16+96+48 4-24-12 400 lb.	16+96+24 4-24-12 400 lb. or 8-32-0 300 lb.	16+48+48 8-16-16 300 lb.	16+48+24 5-20-10 240 lb.
Wheat*—rye* without legume seeding	40 bu.	20+80+40 5-20-10 400 lb.	20+80+20 8-32-0 250 lb. or 5-20-10 400 lb.	20+40+40 8-16-16 250 lb.	20+40+20 10-20-10 200 lb.
Corn*/	75 bu.	15+60+30 5-20-10 300 lb.	15+60+15 5-20-10 300 lb.	15+30+30 8-16-16 200 lb.	15+30+15 10-20-10 150 lb.
Potatoes*	400 bu.	40+160+160 5-20-10 800 lb.	40+160+80 5-20-10 800 lb.	40+80+160 5-10-20 800 lb.	40+80+80 8-16-16 500 lb.

‡Apply fertilizer containing ¼ percent boron if pH is above 6.5.
*Supplemental nitrogen may be needed.
/If land is planted to continuous corn, apply yearly to soils of low fertility, 100 pounds of nitrogen, 50 pounds of phosphate, and 50 pounds of potash per acre.

TABLE 6—Fertilizer recommendations for field crops growing on dark colored sandy loams or loamy sands (found on nearly level to depressional areas). Soils of the Ensley, Gay, Gilford and similar series (Soil groups 3c, 4c)

Crop	Expected crop yield per acre	Recommended pounds per acre of $N+P_2O_5+K_2O$ (top figure). Example of grade and rate (lower figure). Refer to Table 1.			
		(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Alfalfa, alfalfa-brome, clover‡, sweet clover	3.0 tons	0+80+80 0-20-20 400 lb.	0+80+40 0-20-10 400 lb.	0+40+80 0-15-30 270 lb.	0+40+40 0-20-20 200 lb.
Alfalfa, after first crop‡	3.0 tons	0+45+90 0-15-30 300 lb.	0+45+45 0-20-20 225 lb.	0+22+90 0-10-30 300 lb.	0+22+44 0-15-30 150 lb.
Grass, no legume		50+25+25 14-7-7 360 lb.	50+25+0 33-0-0 150 lb. plus 0-20-0 125 lb.	50+0+25 33-0-0 150 lb. plus 0-0-60 50 lb.	50+0+0 33-0-0 150 lb.
Barley†*—oats†* with legume seeding	40 bu. 55 bu.	15+60+60 5-20-20 300 lb.	15+60+30 5-20-10 300 lb.	15+30+60 5-10-20 300 lb.	15+30+30 8-16-16 200 lb
Barley†*—oats†* without legume seeding	40 bu. 55 bu.	25+50+50 8-16-16 300 lb.	25+50+25 10-20-10 250 lb.	25+25+50 5-10-20 250 lb.	25+25+25 10-10-10 250 lb.
Field beans†	28 bu.	15+60+60 5-20-20 300 lb.	15+60+30 5-20-10 300 lb.	15+30+60 5-10-20 300 lb.	15+30+30 8-16-16 200 lb.
Soybeans†	25 bu.	10+40+40 5-20-20 200 lb.	10+40+20 5-20-10 200 lb.	10+20+40 5-10-20 200 lb.	10+20+20 8-16-16 125 lb.
Sugar beets†*‡	14 tons	30+120+120 5-20-20 600 lb.	30+120+60 5-20-10 600 lb.	30+60+120 5-10-20 600 lb.	30+60+60 8-16-16 275 lb.
Wheat†*—rye* with legume seeding	35 bu.	20+80+80 5-20-20 400 lb.	20+80+40 5-20-10 400 lb.	20+40+80 5-10-20 400 lb.	20+40+40 8-16-16 250 lb.
Wheat†*—rye* without legume seeding	35 bu.	15+60+60 5-20-20 300 lb.	15+60+30 5-20-10 300 lb.	15+30+60 5-10-20 300 lb.	15+30+30 8-16-16 200 lb.
Corn*/	70 bu.	15+60+60 5-20-20 300 lb.	15+60+30 5-20-10 300 lb.	15+30+60 5-10-20 300 lb.	15+30+30 8-16-16 200 lb.
Potatoes*†	400 bu.	40+160+160 5-20-20 800 lb.	40+160+80 5-20-10 800 lb.	40+80+160 5-10-20 800 lb.	40+80+80 8-16-16 500 lb.

†Where the soil pH is above 6.5 apply fertilizer containing 1 or 2 percent manganese.
‡Apply fertilizer containing ¼ percent boron.
*Supplemental nitrogen may be needed. See Table 2.
/If land is planted to continuous corn, apply yearly to soils of low fertility, 100 pounds of nitrogen, 50 pounds of phosphate, and 50 pounds of potash.

TABLE 7—Fertilizer recommendations for field crops growing on light-colored, nearly level to hilly loamy sand of the Oshtemo, Boyer, Spinks, Coloma, Brady, Montcalm and similar series (Soil group 4a, 4b)

Crop	Expected crop yield per acre	Recommended pounds per acre of $N+P_2O_5+K_2O$ (top figure). Example of grade and rate (lower figure). Refer to Table 1.			
		(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Alfalfa, alfalfa-brome, clover, sweet clover	2.5 tons	0+60+60 0-20-20 300 lb.	0+60+30 0-20-10 300 lb.	0+30+60 0-15-30 200 lb.	0+30+30 0-20-20 150 lb.
Alfalfa, after first crop‡	2.5 tons	0+45+20 0-15-30 300 lb.	0+45+45 0-20-20 225 lb.	0+20+90 0-10-30 300 lb.	0+22+44 0-15-30 150 lb.
Grass, no legumes		50+25+25 14-7-7 360 lb.	50+25+0 33-0-0 150 lb. plus 0-20-0 125 lb.	50+0+25 33-0-0 150 lb. plus 0-0-60 50 lb.	50+0+0 33-0-0 150 lb.
Barley*—oats*† with legume seeding	35 bu. 50 bu.	12.5+50+50 5-20-20 250 lb.	12.5+50+25 5-20-10 250 lb.	12.5+25+50 5-10-20 250 lb.	12.5+25+25 8-16-16 150 lb.
Barley*—oats*† without legume seeding	35 bu. 50 bu.	16+32+32 8-16-16 200 lb.	16+32+16 10-20-10 160 lb.	16+16+32 5-10-20 160 lb.	16+16+16 10-10-10 160 lb.
Field beans†, soybeans†	20 bu.	10+40+40 5-20-20 200 lb.	10+40+20 5-20-10 200 lb.	10+20+40 5-10-20 200 lb.	10+20+20 8-16-16 125 lb.
Wheat†*—rye* with legume seeding	30 bu.	15+60+60 5-20-20 300 lb.	15+60+30 5-20-10 300 lb.	15+30+60 5-10-20 300 lb.	15+30+30 8-16-16 200 lb.
Wheat†*—rye* without legume seeding	30 bu.	10+40+40 5-20-20 200 lb.	10+40+20 5-20-10 200 lb.	10+20+40 5-10-20 200 lb.	10+20+20 8-16-16 125 lb.
Corn*	55 bu.	10+40+40 5-20-20 200 lb.	10+40+20 5-20-10 200 lb.	10+20+40 5-10-20 200 lb.	10+20+20 8-16-16 125 lb.
Potatoes*†.....	325 bu.	30+120+120 5-20-20 600 lb.	30+120+60 5-20-10 600 lb.	30+60+120 5-10-20 600 lb.	30+60+60 8-16-16 375 lb.

†Where pH is above 7.0 apply fertilizer containing 1 or 2 percent manganese.
‡Apply fertilizer containing ¼ percent boron if pH is above 6.5.
*Supplemental nitrogen may be needed. See Table 2.

4. Use starter solutions high in phosphorus for spring planting of transplants. Examples are 15-30-15 or 10-52-17.

5. Sidedress or topdress vegetables and fruiting crops with nitrogen as foliage color indicates.

6. Foliage application is an efficient way to correct or prevent some minor-element deficiencies and may also be useful for supplementing soil applications of the major fertilizer elements.

Here are some typical recommendations for growing vegetables on soils of low fertility (column 1 in the recommendation tables).

ASPARAGUS (mature beds) — For sandy soils, broadcast 500 pounds per acre of 12-12-12 early in April, before the spears emerge. After the cutting season is over, disk into the soil 700 pounds per acre of a 12-12-12 fertilizer. You can also use 5-20-20 and ammonium nitrate. For clay loams, use 5-20-10 at the rate of 1,000 pounds per acre, and

TABLE 8—Fertilizer recommendations for field crops growing on sandy soils of the Kalkaska, Plainfield, Roscommon, Granby, Newton, and similar series (Soil group 5a, 5b, 5c)

Crop	Expected crop yield per acre	Recommended pounds per acre of $N+P_2O_5+K_2O$ (top figure). Example of grade and rate (lower figure). Refer to Table 1.			
		(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Alfalfa‡,alfalfa-brome‡, clover‡,sweet clover‡	2.3 tons	0+45+90 0-15-30 300 lb.	0+45+45 0-20-20 225 lb.	0+30+90 0-10-30 300 lb.	0+22+45 0-15-30 150 lb.
Alfalfa, after first crop‡	2.3 tons	0+30+90 0-10-30 300 lb.	0+30+30 0-20-20 150 lb.	0+15+90 0-0-60 150 lb. or 0-10-30 300 lb.	0+15+45 0-10-30 150 lb.
Grass, no legumes		30+30+30 10-10-10 300 lb.	30+30+0	30+0+30	30+0+0 33-0-0 100 lb.
Barley†*—oats†* without legume seeding	30 bu. 45 bu.	16+32+32 8-16-16 200 lb.	16+32+16 10-20-10 160 lb.	16+16+32 5-10-20 160 lb.	16+16+16 10-10-10 160 lb.
Field beans†, soybeans†	15 bu.	10+20+40 5-10-20 200 lb.	10+20+20 8-16-16 125 lb.	10+10+40 3-9-27 150 lb.	10+10+20 5-10-20 100 lb.
Wheat†*—rye* without legume seeding	25 bu.	12.5+50+50 5-20-20 250 lb.	12.5+50+25 5-20-10 250 lb.	12.5+25+50 5-10-20 250 lb.	12.5+25+25 8-16-16 150 lb.
Corn*	45 bu.	10+40+40 5-20-20 250 lb.	10+40+20 5-20-10 200 lb.	10+20+40 5-10-20 200 lb.	10+20+20 8-16-16 125 lb.
Potatoes†*	250 bu.	30+60+120 5-10-20 600 lb.	30+60+60 8-16-16 375 lb.	30+30+120 3-9-27 450 lb.	30+30+60 5-10-20 200 lb.

†Where the soil pH is above 6.5 apply fertilizer containing 1 or 2 percent manganese.
‡Apply fertilizer containing ¼ percent boron.
*Supplemental nitrogen may be needed. See Table 2.

TABLE 9—Fertilizer recommendations for vegetable crops growing on loams, silt loams and clay loams (assuming no farm manure or legumes plowed down)

Crop	Recommended pounds per acre of $N+P_2O_5+K_2O$ and boron plus nitrogen sidedressing.			
	(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Asparagus, rhubarb	150+200+100	150+200+50	150+100+100	150+100+50
Lima† and snap beans†	25+100+50	25+100+25	25+50+50	25+50+25
Peas†	40+80+40	40+80+20	40+40+40	40+40+20
Carrots, horseradish, parsnips	30+120+60 + 50 N	30+120+30 + 50 N	30+60+60 + 50 N	30+60+30 + 50 N
Spinach†	70+70+70	70+70+35	70+35+70	70+35+35
Turnips, radishes†	50+50+50	50+50+25	50+25+50	50+25+25
Table beets,* rutabagas*	30+120+60 2 Boron + 50 N	30+120+30 2 Boron + 50 N	30+60+60 2 Boron + 50 N	30+60+30 2 Boron + 50 N
Broccoli,* cabbage, brussel sprouts	40+160+80 1 Boron + 75 N	40+160+40 1 Boron + 75 N	40+80+80 1 Boron + 75 N	40+80+40 1 Boron + 75 N
Cauliflower*	50+200+100 3 Boron +100 N	50+200+50 3 Boron +100 N	50+100+100 3 Boron +100 N	50+100+50 3 Boron +100 N
Sweet corn	25+100+50 + 70 N	25+100+25 + 70 N	25+50+50 + 70 N	25+50+25 + 70 N
Cucumbers, slicing	30+120+60 + 50 N	30+120+30 + 50 N	30+60+60 + 50 N	30+60+30 + 50 N
Cucumbers, pickling	12+72+36 + 40 N	12+72+18 + 40 N	12+36+36 + 40 N	12+36+18 + 40 N
Muskemelons	40+160+80 + 40 N	40+160+40 + 40 N	40+80+80 + 40 N	40+80+40 + 40 N
Home and market gardens	50+200+100 + 60 N	50+200+50 + 60 N	50+100+100 + 60 N	50+100+50 + 60 N
Tomatoes, eggplant, peppers	50+200+100 + 50 N	50+200+50 + 50 N	50+100+100 + 50 N	50+100+50 + 50 N
Lettuce†, endive†	60+120+60	60+120+30	60+60+60	60+60+30
Pumpkins, squash	20+80+40 + 40 N	20+80+20 + 40 N	20+40+40 + 40 N	20+40+20 + 40 N

*Boron generally not needed if pH is below 6.5.
†Crops may need manganese if pH is above 7.0.

topdress with 50 to 75 pounds per acre of nitrogen. If pH is above 6.5 apply another 50 pounds of potash per acre each year.

RHUBARB — In early spring, apply 5-20-20 at 750 to 1000 pounds per

acre on sandy loams. Sidedress with one or two applications of nitrogen at 2-week intervals after growth starts.

LIMA BEANS, SNAP BEANS — Apply fertilizer 2 inches to the side and 2 inches below the seed. Do not apply directly in contact with the

TABLE 10—Fertilizer recommendations for vegetable crops growing on loamy sands and sandy loams (assuming no farm manure or legumes plowed down)

Crop	Recommended pounds per acre of $N+P_2O_5+K_2O$ and boron plus nitrogen sidedressing.			
	(1) Phosphorus low Potassium low	(2) Phosphorus low Potassium high	(3) Phosphorus high Potassium low	(4) Phosphorus high Potassium high
Asparagus, rhubarb	150+150+150	150+150+75	150+75+150	150+75+75
Lima† and snap beans†	20+80+80 + 30 N	20+80+40 + 30 N	20+40+80 + 30 N	20+40+40 + 40 N
Peas†	50+50+50	50+50+25	50+25+50	50+25+25
Carrots, horseradish, parsnips	30+120+120 + 50 N	30+120+60 + 50 N	30+60+120 + 50 N	30+60+60 + 50 N
Spinach†	70+70+70	70+70+35	70+35+70	70+35+35
Turnips, radishes†	50+50+50	50+50+25	50+25+50	50+25+25
Table beets*, rutabagas*	30+120+120 2 Boron + 60 N	30+120+60 2 Boron + 60 N	30+60+120 2 Boron + 60 N	30+60+60 2 Boron + 60 N
Broccoli,* cabbage, brussel sprouts	40+160+160 1 Boron + 80 N	40+160+80 1 Boron + 80 N	40+80+160 1 Boron + 80 N	40+80+80 1 Boron + 80 N
Cauliflower*	50+200+200 3 Boron +100 N	50+200+100 3 Boron +100 N	50+100+200 3 Boron +100 N	50+100+100 3 Boron +100 N
Sweet corn	20+80+80 + 75 N	20+80+40 + 75 N	20+40+80 + 75 N	20+40+40 + 75 N
Cucumbers, slicing	25+100+100 + 50 N	25+100+50 + 50 N	25+50+100 + 50 N	25+50+50 + 50 N
Cucumbers, pickling	15+60+60 + 40 N	15+60+30 + 40 N	15+30+60 + 40 N	15+30+30 + 40 N
Muskmelons, watermelons	35+140+140 + 50 N	35+140+70 + 50 N	35+70+140 + 50 N	35+70+70 + 50 N
Home and market garden	50+200+200 + 75 N	50+200+100 + 75 N	50+100+200 + 75 N	50+100+100 + 75 N
Tomatoes, eggplant, peppers	40+160+160 + 60 N	40+160+80 + 60 N	40+80+160 + 60 N	40+80+80 + 60 N
Lettuce†, endive†	60+120+120	60+120+60	60+60+120	60+60+60
Pumpkins, squash	20+80+80 + 50 N	20+80+40 + 50 N	20+40+80 + 50 N	20+40+40 + 50 N

*Boron generally not needed if pH is below 6.5.
†Crops may need manganese if pH is above 7.0.

seed. Use 5-20-10 for clay loams and 5-20-20 for sandy loams. Apply at the rate of 300 pounds per acre. Sidedress beans with urea or ammonium nitrate a few days before flowering (if foliage is light green).

Peas — Broadcast or drill 2 inches to side of the seed 500 pounds per acre of 10-10-10 on sandy loams, or 8-16-8 on clay loams.

Carrots, Horseradish, Parsnips—Drill in before seeding or apply in a band 1 inch to side and 2 inches below the seed. Use 5-20-20 on sandy loams at the rate of 600 pounds per acre. Topdress with 50 pounds of nitrogen per acre after plants are well started.

Radishes, Turnips — Drill in 12-12-12 or 14-7-7 at the rate of 400 pounds per acre. Boron may be needed.

Table Beets, Rutabagas — Drill in before seeding or apply in a band 1 inch to the side and 2 inches below the seed. Use 5-20-10 for clay loams and 5-20-20 for sandy soils with ¼ percent boron in each. Apply at the rate of 600 pounds per acre.

Broccoli, Cabbage, Brussel Sprouts, Cauliflower — Plow down 30 to 50 pounds of nitrogen per acre with stubble or grain cover crops. For sandy soils, plow down, or drill in after plowing, 600 to 800 pounds per acre of a 5-20-20 containing ¼ percent boron. Band 200 pounds — if possible — of a 5-20-20 fertilizer near the plants or seeds. Use 5-20-10 containing ¼ percent boron for clay loams.

Use a high nitrogen starter solution for transplants (for amounts see page 24). Sidedress cauliflower two or three times with a total of 100 pounds per acre of nitrogen.

Sweet Corn — Plow down 30 to 50 pounds of nitrogen per acre with stubble, grain, or grass sod. Apply fertilizer in a single band 2 inches to the side and 2 inches below the seed. Use 5-20-10 at the rate of 500 pounds per acre for clay loams, and 5-20-20 at 400 pounds per acre for sandy loams. Sidedress with about 60 to 80 pounds of nitrogen when plants are 10 to 20 inches tall.

Cucumbers — For pickling cucumbers, plow down 30 to 50 pounds of nitrogen per acre with a stubble, grass, or grain cover crop. Drill in 400 pounds of a 3-18-9 per acre for clay loams, and 300 pounds of a 5-20-20 for sandy loams. Lower rates must be used if the fertilizer is placed in a band 2 inches to the side and 2 inches below the seed to avoid injury. Sidedress with 30 to 40 pounds of nitrogen per acre. For slicing cucumbers, drill in 600 pounds per acre of a 5-20-10 for

clay loams, and 500 pounds per acre of a 5-20-20 for sandy loams. Sidedress with 50 pounds per acre of nitrogen.

MUSKMELON, WATERMELON — At planting time, fertilize rye or rye grass used for green manure crop with 300 pounds of a 10-10-10 fertilizer per acre. For sandy soils, drill in, 3 or 4 inches deep, 700 pounds per acre of 5-20-20 fertilizer after plowing. Use a 5-20-10 at similar rates for clay loams. Lower rates—400 pounds—must be used if the fertilizer is placed in a band several inches to the side and below the seed. Sidedress with 50 pounds per acre of nitrogen three weeks after plants have emerged, or after transplanting.

TOMATOES — Plow down or drill in 3 or 4 inches deep one-half to two-thirds of the fertilizer recommended in the tables. This would amount to 800 pounds per acre of a 5-20-10 on clay loams and 600 pounds per acre of 5-20-20 on sandy loams. Apply 200 to 300 pounds per acre of similar grade in bands 3 to 4 inches to the side and several inches below at planting time, or sidedress. Use starter solutions high in phosphate on transplants. Apply additional nitrogen fertilizer when the first fruits are about the size of a half dollar.

MARKET GARDEN — Plow under 600 pounds per acre of fertilizer. Broadcast and disc in, or apply in bands 1 inch to the side and 2 inches below the seed at 400 to 600 pounds per acre. If experience has shown that extra nitrogen has been profitable in the past, make one or two applications between the rows during the growing season. Nitrogen recommendations shown in Table 2 for potatoes are a good guide.

HOME GARDEN — Apply 20 pounds of fertilizer per 1000 square feet before plowing or spading. After plowing, apply similar amounts into the soil several inches deep. Use 4-16-8, 5-20-20, or similar grades.

For tomatoes, apply one-third pound in a circular trench around the plant, about 5 inches out and 3 inches below the root cluster. This method can be used for other transplants, but the rate of application should be relative to the square feet of space taken by each plant. It is assumed that each tomato plant would occupy about 12 square feet. Sidedress the plants in the middle of the summer with 3 to 4 pounds of ammonium nitrate per 1,000 square feet.

Starter Solutions

Starter solutions can be used on your home garden. Stir one-half cup dry fertilizer, such as a 5-20-10 or 10-20-10, into 3 gallons of

water. Apply 1 cup of the solution to 10 feet of row or around transplants. (Use this solution in addition to the recommended rates of dry fertilizer.) You can buy commercial starter solution mixtures such as a 15-30-15 or 10-52-17. Follow the manufacturer's directions when using these concentrated fertilizers.

2 cups = 1 pint
1 pint = 1 pound dry fertilizer
1 cup = 16 tablespoons
1 cup = 48 teaspoons

MINOR ELEMENTS IN MINERAL SOILS

The mineral soils of Michigan may be deficient in manganese and/or boron for certain crops; particularly on soils above pH 6.5. Manganese may be needed for oats, beans, snap beans, potatoes, Sudan grass, soybeans, and spinach. In extreme cases, barley, corn, wheat, and sugar beets may respond to manganese. A deficiency of this element is most likely to be found on dark colored surface soils with grayish subsoils.

Boron is likely to be needed for sugar beets, table beets, cauliflower, celery, turnips, and rutabagas. Use 2 to 3 pounds per acre for these crops. Lettuce, alfalfa, broccoli, spinach, and cabbage may need 1 pound of boron per acre. **Never apply boron for beans, snap beans, peas, or small grains.**

Manganese and boron can be mixed with the regular fertilizer by the manufacturer. Requests for such special mixes will be limited to the percentages permitted by the state control officials. For boron, it is either ¼, ½, or 1 percent; for manganese, 1, 2, or 5 percent. Order such mixtures early because most companies do not keep them in stock.

Acid sandy soils or sandy soils limed with calcic (low-magnesium) limestone may be low in magnesium. Responsive crops are cauliflower, muskmelons, potatoes, peas, sweet and field corn. Apply magnesium limestone to correct this deficiency using up to 1,000 pounds per acre on soils where the pH is 6.0 to 6.5. Over-use of potassium fertilizers, or nitrate of soda, will promote a magnesium deficiency in crops.

HANDLE FERTILIZER PROPERLY

Properly cured fertilizer, stored in a dry place, will remain in drillable condition for several months. Store in a well-ventilated place, on boards to let air circulate beneath the pile. Do not put more than four bags of fertilizer in a stack because weight causes hardening. Repile the bags if long storage is necessary. To avoid lumpy fertilizer, build a gravel screen with a ⅜- to ½-mesh into the top of fertilizer hoppers.

PLANTS SHOW STARVATION SYMPTOMS

For better results from fertilizer, watch for starvation symptoms. Plants are normally green. When another color develops, it is very likely caused by a deficiency of some plant nutrient. Most deficiencies result in yellowing of leaves. The pattern of yellowing varies with different nutrient deficiencies and with different species of plants.

For many years these deficiency symptoms have been studied under controlled conditions. The appearance of a starved plant may indicate just what nutrient shortage is causing its unhealthy condition. You can become familiar with these symptoms and decide for yourself when your plants are lacking plant nutrients. Green plant tissue tests will verify the symptoms of starvation. There may still be time to use fertilizer profitably on that particular crop, or the information may help you select the fertilizer for the next crop.

To obtain additional information on deficiency symptoms, write for Michigan Agricultural Experiment Station Special Bulletin 353, from the Bulletin Office, Michigan State University, East Lansing, Michigan.

TREE FRUITS

(Apple, cherry, pear, peach, plum)

Nitrogen, potassium and magnesium are the most common nutrient shortages in Michigan fruit plantings. Fruit trees have not responded to phosphorus applications, however iron, manganese, and zinc may be needed in certain orchards.

Leaf analysis is the best way to determine fertilizer needs of established fruit trees. A leaf analysis service is available to Michigan fruit growers. You can obtain information on leaf analysis

from county extension offices or by writing to the Department of Horticulture, Michigan State University, East Lansing, Michigan.

In the meantime use the following guide:

Kind of fruit	Fertilizer ratio	Amount (based on 12 percent N)
Apple and pear	1:1:1 or 2:1:2	1 pound per year of tree age, up to 10 to 15 pounds per tree.
Cherry, peach, plum	1:1:1 or 2:1:2	½ to ⅔ pound per year of tree age, up to 4 to 8 pounds per tree.

Applications can be made in fall or spring.

Dolomitic lime—apply 1 to 2 tons per acre where soil pH is below 5.5. If pH is above 6.0, use 1,000 pounds. If pH is above 6.5, do not use lime.

Nutrient Sprays

Apply according to indicated need.

Magnesium — Use Epsom salts in early cover sprays. Use 10 to 20 pounds per 100 gallons.

Iron — No satisfactory spray has been established. Ferbam may be beneficial.

Manganese — Manganese sulfate in early cover sprays, or as after-harvest sprays. Use 5 pounds per 100 gallons.

Boron — Borax or other soluble borates as: (1) soil application, (2) early cover spray, or (3) after harvest spray. Use 2 to 4 ounces per tree on soil, or 2 to 3 pounds per 100 gallons in early cover sprays, or 5 pounds per 100 gallons in after harvest spray.

Zinc — Zinc oxide in early cover sprays or zinc sulfate as after harvest spray. Use 2 to 3 pounds of zinc oxide per 100 gallons in early cover sprays or 5 pounds zinc sulfate per 100 gallons in after harvest spray. Add hydrated lime in amounts equal to zinc sulfate.

Urea — May be used on apples and pears. Not recommended for cherries and peaches. Use 5 pounds per 100 gallons in early cover sprays.

Spray Compatibility

Unless compatibility with insecticides and fungicides is known, apply nutrient sprays separately. If you do want to combine them, try the combination on a small area before using it widely.

Urea—compatible with most pesticides, except karathane and lime sulfur, so that it is comparable to other nutrients.

Magnesium sulfate (Epsom salts)—compatible with DDT, BHC, glyodon, wettable sulfur, ferbam and lime. Not compatible with arsenate and copper sprays.

Boron (Borax or soluble borates)—compatible with most pesticides. Not compatible with arsenate sprays.

Iron (ferrous sulfate or ferrous citrate)—no spray program recommended.

Zinc (Zinc oxide or zinc sulfate)—compatible with most pesticides. Not compatible with captan, cryolite and rotenone. Use organomercuries with caution.

Manganese (manganese sulfate)—compatible with nabam or iron.

Solutions at Planting Time

On soils testing low for potassium, use a solution of 1 ounce of sulfate of potash per 3 gallons (2 pounds per 100 gallons). Apply 1 to 3 gallons per tree immediately after planting.

Nitrogen solutions have been beneficial on light sandy soils. Use nitrate or urea nitrogen equal to 1 ounce per 3 gallons (2 pounds per 100 gallons) of sodium nitrate or potassium nitrate. Apply 1 to 3 gallons per tree immediately after planting.

Solutions of hydrated dolomitic lime may be used on soils low in magnesium and calcium. Solutions containing 1 pound of hydrated dolomitic lime per 10 gallons may be used at a rate of 2 gallons per tree.

Cover Crop Fertilizer

Fertilizer applications to cover crops or sods should be based on soil tests. Use the following general guide for grass sods and cover crops.

Soil test result		Fertilizer ratio
Phosphorus	Potassium	
Low	Low	1:4:4
Medium	Medium	1:2:2
High	High	1:1:1
Very high	Very high	1:0:0

Apply enough of needed ratio to furnish 25 pounds of nitrogen per acre on loamy soils and 35 pounds of nitrogen per acre on sandy soils. Reduce nitrogen in relation to legume content of cover. If cover is all legume, omit nitrogen in fertilizer. For further information, consult the recommendations in this bulletin for the specific crop.

SMALL FRUITS

Grapes

Apply nitrogen fertilizer as a 1:1:1 or 2:1:2 ratio fertilizer in the spring, in amounts to supply 40 to 50 pounds of nitrogen per acre.

For normal, healthy vineyards, apply in the fall a 0:1:3 ratio fertilizer or potash fertilizer, to supply 90 to 120 pounds of potassium per acre. If a potassium deficiency is present, apply potash fertilizer in quantities to supply 150 to 200 pounds of potash per acre until the condition is corrected.

Strawberries

Before planting—Conduct a green manuring program for 1 or 2 years before planting. Such a program should include fertilizers and lime for the best growth of the green manure crops being used. Consult recommendations in this bulletin for specific crops.

If no green manuring program was conducted before planting, a 1:4:4 ratio fertilizer in amounts to supply 25 to 35 pounds of nitrogen per acre should be worked into the soil about 10 days before setting plants in the spring. If plants are set out in the fall, make this application very early in the spring (before growth starts).

Starter solutions—Apply only to plants set out early in the season (before April 15 in Southern Michigan; before May 1 in Northern Michigan). A soluble fertilizer with a ratio of about 1:5:1 is best. For more information, consult Extension Folder F-194, "Starter Solutions".

After planting—Apply a 1:1:1 ratio fertilizer about 2 weeks after setting the plants if growth is weak. Use enough to supply 30 to 35 pounds of nitrogen per acre. Repeat this application in 3 or 4 weeks if vigor is still low.

During fruiting—Applications of fertilizer are seldom needed during the spring of the first fruiting year. Too much nitrogen at this time can result in soft berries which decay rapidly. If plants lacked vigor during the previous fall, use nitrogen fertilizers in amounts carrying not over 10 pounds of actual nitrogen per acre. This can be applied through irrigation or as urea sprays. On beds of very low vigor, make two such applications 10 days apart.

After harvest—Apply a complete fertilizer when the crop is to be harvested for another year. Immediately after harvest, use a 1:1:1 ratio fertilizer to supply 60 to 100 pounds of nitrogen per acre. As fruiting season approaches, use the applications suggested above.

Blueberries

Blueberries are sensitive to nitrates and chlorides contained in certain fertilizers. Therefore, blueberry fertilizers should only contain either ammonium salts or urea as a source of nitrogen, and sulfate of potash as a source of potassium. Blueberries grow best on soils having a low pH (4.0 to 5.5), and lime should not be applied unless the pH is 3.8 or lower.

Newly-set fields—Apply fertilizer with caution. Use 1 ounce of a 1:1:1 blueberry fertilizer per plant if soil fertility is low. The fertilizer can be applied as a band 6 inches or more away from the plants.

Established fields—Apply blueberry fertilizer in sufficient amounts to supply 60 to 100 pounds of nitrogen per acre. Use a 1:1:1 ratio fertilizer on mineral soils and a 1:2:3 ratio fertilizer on organic soils. Apply as early as possible in the spring. Broadcast fertilizer, or apply it with a drill between the rows.

Mineral soils low in organic matter—Use ammonium sulfate to supplement the applications of 1:1:1 fertilizer. If plants lack vigor, use ammonium sulfate at a rate of 60 to 70 pounds per acre (1 ounce per plant) during the first and second years. Increase the amount 30 to 35 pounds per acre each year until a maximum of 240 to 280 pounds

per acre are being applied. Apply supplemental ammonium sulfate in late June.

Other Small Fruits

(Brambles, gooseberries, currants)

Apply complete fertilizer to brambles, gooseberries and currants before growth starts in the spring. Use 2 ounces of a 1:1:1 ratio fertilizer around newly-set plants. In the second year, use enough 1:1:1 ratio fertilizer to supply 25 to 30 pounds of nitrogen per acre. In following years, use enough 1:1:1 ratio fertilizer to supply 50 to 60 pounds of nitrogen per acre.

If leaf scorch (potassium deficiency) appears, apply enough potash fertilizer to furnish 150 to 200 pounds of potash per acre. Repeat annually until leaf scorch disappears. Gooseberries and currants need sulfate of potash to avoid possible chloride injury.

For further information on fruit crops, see Extension Folder F-224, "Fertilizers For Fruit Crops."

II. Recommendations for Muck Soils

Muck soils—as distinguished from mineral soils in Michigan—include all soils very high in organic matter, even though they are peaty in nature. In several county soil surveys, these organic soils are classified either as mucks or peats. CARLISLE, HOUGHTON, KERSTON, LUPTON and CARBONDALE mucks and RIFLE and GREENWOOD peats represent the more important types.

Within each of these types, the acidity or alkalinity varies somewhat, except that Greenwood peat is always very acid. Muck soil usually does not benefit from liming unless the soil pH is below 5.0. Application of lime on muck when it is not needed is likely to lower crop yields. Greenwood peat must be limed for the production of all crops except blueberries. Even blueberries may benefit from limestone if the soil pH is below 4.0.

Sometimes the pH of the surface foot of soil is around 5.0, but the second foot of soil may have a pH around 4.0. In this case, lime after deep plowing. When muck soil requires lime, the magnesium content of the soil is generally low, so the use of dolomitic limestone is advisable.

The fact that part of a muck area requires lime is not proof that the whole area does. Sometimes, one part may be too acid and another part too alkaline for best crop yields.

The amount of ground limestone required for muck soils with pH below 5.0 will depend on the pH and the depth to which the extreme acidity extends. With the pH between 4.6 and 5.0, an application of 2 to 3 tons per acre of agricultural dolomitic limestone is likely to be needed for most crops; with a pH ranging from 4.3 to 4.5, from 3 to 5 tons of limestone; and with pH 3.8 to 4.2, from 7 to 10 tons.

If the pH is higher in the second foot of soil, less limestone may be required; if lower, more will be needed. With lower pH readings, more limestone is likely to be needed after a few years of farming. If a well-pulverized, high-test marl or other liming material is used, use from 1½ to 2 cubic yards for each ton of limestone recommended. Avoid excessive applications of marl.

THE SOIL TEST

Since both very alkaline and very acid muck soils are unproductive for most crops, a soil-reaction test is very important. Most newly reclaimed mucks are low in available phosphorous and available potassium. After the muck has been farmed for several years, either phosphorus or potassium (or both) may have increased from fertilizer used, thus, the tests may become considerably higher. At that time, it is wise to modify the fertilizer grade and the rate of fertilizer application.

Fertilizer recommendations for muck soils are based on the available soil tests, using Spurway "active" extracting agent (0.018 N acetic acid).

The use of the reserve extracting solution usually removes about four to five times more phosphorus than the "active" extracting solution. At times the reserve solution removes much greater quantities. This is particularly noticeable on slightly acid or alkaline soils or where rock phosphate has been applied. Field tests and observations show that the "active test" is the best index of the phosphorus requirement of vegetable crops. The "reserve" test, however, is equally as good as the "active" test for determining potassium.

Directions for Sampling Muck Soils

Since muck soils which have never been fertilized are almost always low in phosphorus and potassium, make only the pH test, on the plowed layer. Also test the underlying soil at a depth of 18 to 24 inches. After the muck has been well fertilized for 2 or 3 years, determine the available phosphorus and potassium, along with the pH, in a sample taken at a depth of 3 to 6 inches. Since the applied fertilizer remains largely in the plowed layer, only the pH test is necessary at the 18- to 24-inch depth. Rechecking of the soil tests every few years is advisable.

In getting samples for testing, avoid places where brush or refuse has been burned, old vegetable storage pits, trenches, tile lines, ditch banks, or any other place where some disturbing factor may affect the soil reaction. Composite samples from areas where the soils are widely different are never advisable. Be sure that none of the surface layer falls into the lower sample.

Keep the samples separate and properly labelled. If part of the field has been burned at some time—or if the muck or the native vege-

tation varies considerably in different parts of the field—more than one set of samples may be required.

Draw a map of the field and keep it for your own information. Locate the points of sampling on the map by number (1, 2, 3, etc.) and number the samples (1 top, 1 sub, 2t, 2s, etc.) accordingly. Send in approximately half-pint samples, in clean cans or ice cream cartons. Avoid contaminating or handling the soil with your hands.

Fill in complete information regarding the muck: depths, years under cultivation, drainage condition, fertilization, use of minor elements, yields and conditions of crops grown in the past years, and crops to be grown on each field next year. Attach this letter to the package, address to the Soil Science Department, Michigan State University, East Lansing, Michigan, or to one of the county soil testing laboratories.

Effect of Time of Sampling

In the case of newly reclaimed mucks, or mucks which have not been heavily fertilized, there is little change in the soil test from one time of the year to another. With mucks that have been heavily fertilized, however, consideration should be given to the time of obtaining the samples. Up to 50 percent of the potassium may be leached out of the soil between early fall sampling and time for cropping in the spring if there is heavy rainfall in the meanwhile. Determination of the muck's available nitrogen generally is not worthwhile except during the growing season. Even then, the test should be made within a very few days after sampling.

FERTILIZER RECOMMENDATIONS FOR MUCK SOILS

The pounds of phosphate and potash fertilizer recommended as indicated by the soil test are shown in Tables 11 and 12. You will need to determine the recommended grade and rate as well as the quantity of nitrogen and minor elements needed.

In Table 11, notice that there is no "0" recommendation for phosphorus. This applies only to new seedlings and to young transplants. It is not necessary to use phosphorus at the 10 pound per acre rate for established plantings such as pastures, mint, or asparagus.

Soils of low fertility usually test about 4 to 8 pounds of phosphorus and 80 to 100 pounds of potassium per acre. Use fertilizer recommendations for these values if you do not have a soil test made and the soil is low in fertility. The information in the tables does

not recommend a typical grade. The person making recommendations must determine what grade of fertilizer and how it is to be applied. Follow the recommendations on placement shown in Table 18.

Usually, most muck crops will need the use of 5-20-20, 5-10-20, 0-10-30, or 3-9-27 fertilizer. Potash can be plowed down or drilled in, and a high phosphate fertilizer can be used near the row.

TABLE 11—Phosphate fertilizer recommendations for muck crops based upon available soil phosphorus using Spurway "active" method. (If soil tests were made by reserve Spurway method, divide the results by 5 before using this table.)

Available soil phosphorus Pounds per acre				Pounds P_2O_5 per acre recommended
			1.....	250
			4.....	200
			8.....	175
		1.....	.....12.....	150
		5.....	.....16.....	125
	1.....	.....10.....	.....20.....	100
1.....	..... 5.....	.....15.....	.....24.....	 80
5.....	.....10.....	.....20.....	.....28.....	 60
10.....	.....15.....	.....24.....	.....32.....	 40
15.....	.....20.....	.....28.....	.....36.....	 20
20+....	.....25+....	.....32+....	.....40+....	..... 10*
Barley	Alfalfa	Asparagus	Cauliflower	
Blueberries	Beans	Broccoli	Celery	
Clover	Carrots	Cabbage	Onions	
Corn	Cucumbers	Endive		
Grass	Horse radish	Lettuce		
Oats	Mint	Potatoes		
Rye	Parsnips	Pumpkins		
Soybeans	Peas	Spinach		
Sudan grass	Radishes	Squash		
Wheat	Sugar beets	Table beets		
Pasture	Sweet corn	Tomatoes		
	Turnips			

*Starter fertilizer for transplants and new seedings only.

To use this table, look for the crop grown. Then find position of the approximate soil test in the same column above crop listing. To determine amount of phosphate fertilizer needed, follow line to right column and read figure just opposite soil test.

Example: Recommend 80 pounds per acre of phosphate for broccoli if soil test is 15 pounds per acre.

If no soil test is made and soils are low in fertility, use amounts suggested for 5 pounds of available phosphorus.

Recommendations in this table assume you will use the proper placement of fertilizer

Examples of a high phosphate fertilizer would be a 5-20-10, 4-24-12, or 8-32-0.

Nitrogen requirements are related to drainage, soil temperature, and depth of the muck. A high water table or a low soil temperature limits decomposition of the organic matter. Crops growing under these conditions may require the use of nitrogen: (1) mucks less than 18 inches deep, (2) soil with a pH less than 5.0, (3) periods after heavy rainfall. Spring-planted crops growing on most well-drained soils require 25 to 50 pounds of nitrogen per acre. Crops planted

TABLE 12—Potash fertilizer recommendations for muck crops based upon soil test using "active" method. (If soil tests were made by reserve Spurway method, divide the results by 2 before using this table.)

Available soil potassium Pounds per acre of "K"					Pounds per acre Potash (K_2O) fertilizer recommended
				50....	600
				125....	500
			25....	.....200....	400
			100....	.....250....	300
		50....	.....130....	.....300....	250
		90....	.....175....	.....350....	200
	25....	.....125....	.....200....	.....400....	160
25....	..... 50....	.....150....	.....225....	.....450....	130
50....	..... 75....	.....175....	.....250....	.....500....	100
75....	.....100....	.....200....	.....280....	.....520....	 80
100....	.....130....	.....225....	.....310....	.....540....	 60
130....	.....160....	.....250....	.....340....	.....560....	 40
160....	.....200....	.....280....	.....370....	.....580....	20
200+..	.....240+..	.....320+..	.....400+..	.....600+..	 0
Barley	Beans	Alfalfa	Asparagus	Celery	
Blueberries	Clover	Cabbage	Broccoli		
Grass	Corn	Carrots	Cauliflower		
Oats	Mint	Cucumbers	Onions		
Rye	Peas	Endive	Potatoes		
Pasture	Sudan grass	Horseradish	Sugar beets		
Soybeans	Sweet corn	Lettuce	Table beets		
	Turnips	Parsnips	Tomatoes		
	Wheat	Pumpkins			
		Radishes			
		Spinach			

If no soil test is made and soils are low in fertility, use the amounts of potash suggested for 100 pounds of available potassium per acre.

Test soil annually if little or no potash is recommended, because potash reserve can change greatly. Leaching may be serious following flooding or heavy rainfall.

in late spring or early summer usually do not need nitrogen fertilization.

Several crops may require a small amount of nitrogen for early growth on well-drained muck, but they do not need nitrogen in the broadcast portion of the fertilizer. Thus sugar beets, table beets, potatoes, and corn are likely to respond to a 5-20-10 or 3-9-27 mixture as a row application, and to a 0-10-30 or 60 percent potash drilled over the field at a depth of 3 to 4 inches before planting.

MINOR ELEMENTS

Muck soils are often low in manganese, boron, copper, and zinc. Consider an application of minor elements as good insurance against the possibility of a deficiency. High value crops, particularly, should be fertilized with minor elements if conditions indicate possible need.

Since most rapid soil test methods for minor elements are not sensitive enough to measure critical deficiency levels, you should base quantity used on the crop to be grown, soil pH, and, in the case of copper and zinc, past treatment. At present, the quantity of minor elements that can be used in mixed fertilizer is:

(1) manganese—1.0, 2.0, or 5.0 percent
(2) boron—0.25, 0.5, or 1.0 percent
(3) copper—0.5, 1.0 or 2.0 percent
(4) zinc—0.5, or 1.0 percent

In estimating the amount required in a mixed fertilizer, follow the recommendations shown in Table 13.

Minor elements can be absorbed through the leaves of plants. Where spray equipment is available, cost of material used is greatly reduced. If compatible, the minor elements can be mixed in a fungicide or insecticide spray. Suggested minor element rates as sprays are:

2 to 5 pounds per acre of water-soluble manganese sulfate
1 to 3 pounds per acre of basic copper sulfate
1 to 2 pounds per acre of zinc sulfate or neutral zinc
½ to 2 pounds per acre of borax or "Polybor-2".

Growers often find it handier and cheaper to apply minor elements directly to the soil, because of convenience and the saving in labor and equipment.

TABLE 13—Percentage of minor element required in mixed fertilizer as related to the amount of fertilizer applied and minor element needed

Fertilizer application pounds/acre	Pounds per acre of minor element desired									
	Manganese				Copper			Boron		
	5	10	20	40	4	8	12	1	3	5
100	5%	*	*	*	*	*	*	1%	*	*
200	2%	5%	*	*	2%	*	*	½%	1%	*
400	1%	2%	5%	*	1%	2%	*	¼%	½%	1%
600	1%	2%	5%	*	1%	1%	2%	¼%	½%	1%
800	†	1%	2%	5%	½%	1%	2%	¼%	¼%	½%
1,000	†	1%	2%	5%	½%	1%	1%	†	¼%	½%
1,250	†	1%	2%	5%	†	½%	1%	†	¼%	½%
1,500	†	†	1%	2%	†	½%	1%	†	†	¼%
2,000	†	†	1%	2%	†	½%	½%	†	†	¼%

*Amount required greater than that possible in mixed fertilizers by Michigan law. Make home-mix or apply straight minor element materials.

†Farmers can use some fertilizer without minor element or, in the case of manganese and copper, use the minimum percentage in all the applied fertilizer.

Manganese

Manganese deficiency is likely to occur on alkaline or near alkaline mucks, and is most severe on cold wet soils. Such a deficiency can be corrected by the application of manganese salts or by the addition of enough sulfur to acidify the soil. Use manganese salts for immediate results; sulfur, for a more lasting effect. Because of the quantity required, sulfur is not advisable for soils containing considerable free lime or marl.

Recent experiments and field observations have shown that one can expect a manganese deficiency on soils with pH as low as 6.0. Very acid soils that have been limed usually show a greater need for manganese fertilization than do soils naturally high in lime.

Crops listed in Table 14 are grouped according to the degree of response to treatment with manganese.

The amount of manganese suggested for crops as affected by pH is shown in Table 15. Soil fixation can be very great, particularly when the fertilizer is broadcast. To increase availability to crops, place the manganese in bands near the seed. Broadcast applications may require amounts greater than those suggested in Table 15. Manganese must be applied yearly, since often there is no carryover in the available form.

Boron

The need for fertilizing with boron on muck soils depends on the crop grown (see Table 14). It is generally applied broadcast or drilled in before seeding and should not be banded near the seed. Corn, barley, and beans are frequently injured by boron.

The availability of boron in the soil is affected by the lime content. For this reason, the amounts suggested in Table 16 are greater on high-lime soils. In estimating boron needs, expect some residual effect for the succeeding crop. However, this will not injure sensitive crops if recommended rates are applied. It may be necessary

TABLE 14—Crop response to minor elements (muck soil)

Crop	Minor element response			
	Manganese	Boron	Copper	Others
Alfalfa	Low	High	High	
Asparagus	Low	Medium	Low	
Barley	Medium	None	Medium	
Beans	High	None	Low	
Blueberries	None	None	Medium	
Broccoli	Medium	Medium	Medium	
Cabbage	Medium	Medium	Medium	
Carrots	Medium	Medium	High	
Cauliflower	Medium	High	Medium	
Celery	Medium	High	Medium	Salt
Clover	Medium	Medium	Medium	
Cucumbers	Low	Low	Medium	
Corn	Medium	Low	Medium	Zinc
Grass	Medium	None	Medium	
Lettuce	High	Medium	High	
Oats	High	None	High	
Onions	High	None	High	Zinc
Parsnips	Low	Medium	Medium	
Peas	High	None	Low	
Peppermint	None	None	Low	
Potatoes	High	Low	Low	
Radish	High	Medium	Medium	
Rye	None	None	None	
Spearmint	Medium	None	Low	
Soybeans	High	None	Low	
Spinach	High	Medium	High	
Sudan grass	High	None	High	
Sugar beets	Medium	High	Medium	Salt
Sweet corn	Medium	Low	Medium	
Table beets	Medium	High	High	Salt
Turnips	Medium	High	Medium	
Wheat	High	None	High	

*TABLE 15—Manganese needed for muck soils—elemental basis**

Crop response	Pounds per acre		
	pH 6.0-6.6	pH 6.7-7.2	pH 7.3-8.0
High.....	10	20	40†
Medium.....	5	10	20
Low.....	0	5	10

*To convert elemental manganese to manganese sulfate, multiply by 4.0.

†More practical to disc in 500 pounds per acre of sulfur and use 20 pounds of manganese per acre.

*TABLE 16—Boron recommendations for muck soils—elemental basis**

Crop response	Pounds per acre	
	pH 5.0-6.4	pH 6.5-8.0
High.....	3	5
Medium.....	1	3
Low.....	0	1

*To convert from boron to borax, multiply figures by 9.0.

TABLE 17—Copper recommendations for muck soils—elemental basis (Native soil pH)*

Crop response	Pounds per acre		
	pH 5.4 or less	pH 5.5-6.4	pH 6.5 or higher
High.....	12	8	4
Medium.....	8	4	0
Low.....	4	0	0

*To convert elemental copper to copper sulfate multiply by 3.9.

to use quantities greater than those suggested in Table 16 for table beets, celery, and cauliflower.

Copper

Acid peaty soils are usually low in copper but liming will not decrease its need. The carriers used for fertilizers are usually either copper sulfate or copper oxide. Copper applied to organic soils

is not easily leached, nor is it much used by the crop. For this reason, no further copper fertilization is needed if a total of 20 pounds per acre has been applied to low or medium responsive crops and 40 pounds per acre for high responsive crops.

Additional copper will be needed if soil erosion is serious or the field is plowed deeply. In many instances, the copper level in the soil is ample because of repeated applications of copper fungicide dust or spray. Crops listed in Table 14 show the degree of response to copper fertilization, and data in Table 17 show copper recommendations.

Zinc

Zinc deficiency occurs on newly-broken muck. Onions and corn are affected under Michigan conditions as most of the zinc is in the surface layer. When sod is turned down to a depth of 14 to 18 inches, deficiency is likely to continue until the land is plowed again or zinc fertilizer is used. Apply 3 to 5 pounds of zinc annually for 2 or 3 years until sod is worked back into the surface soil. Zinc is more of a problem on peats having a slightly acid or alkaline reaction.

Sodium-Magnesium

Sodium and magnesium are secondary elements that may be deficient in muck crops. Sodium applied in the form of ordinary salt helps sugar beets, table beets, and celery. Salt is especially beneficial when the soil is low in available potash. It is, however, necessary to include potash in the fertilizer. Suggested rates of salt are 500 pounds per acre.

Magnesium deficiency is a problem in certain celery varieties. For these varieties, apply Epsom salts (magnesium sulfate) weekly to the foliage of the plant at the rate of 5 to 10 pounds per acre. Soil applications are not effective. Magnesium deficiency has seldom been noted on other crops growing on muck soils. It could be a problem where naturally very acid soils are limed with calcic limestone, or where excess amounts of potash fertilizer have been used.

FERTILIZER PLACEMENT

The best methods of applying fertilizer for optimum returns are indicated in Table 18. Onions, table beets, sugar beets, spinach, head lettuce and parsnips generally give higher yields with an under-the-row application.

The amount of fertilizer that can safely be applied under the row depends upon the row spacing, the fertility of the soil, salt index of the fertilizer material, and the moisture condition of the soil. Usually, 600 to 700 pounds per acre is the maximum that can be safely used 2 to 3 inches below the seed in 18-inch rows. If it is necessary to split the fertilizer application, use a high phosphate fertilizer grade under the seed and drill in or plow down a high potash fertilizer.

Sidedressing of widely spaced crops (such as cucumbers, pumpkins and squash, or transplanted tomatoes) generally will require one-third to one-half the amount of fertilizer needed for broadcast applications. Apply in bands 3 to 4 inches to the side of the row, at seeding time or immediately after transplanting. *Fertilizer recommendations given in Tables 11 and 12 assume the fertilizer is placed as indicated in Table 18.*

SUPPLEMENTAL FERTILIZATION

The need for adding more fertilizer is mainly the result of continued wet or cold weather. Nitrogen, applied as a sidedressing, may also be needed on areas with a high water level, and on some crops even under normal drainage conditions. Thus, a sidedressing of 30 to 60 pounds per acre of nitrogen (about 100 to 200 pounds ammonium nitrate), for spinach 2 to 3 weeks before harvest, and for cauliflower about the time when heads first start to form, is likely to increase yields considerably.

A sidedressing of 40 to 60 pounds of nitrogen is recommended at the last cultivation of sweet corn; at the start of heading of cabbage and, sometimes, head lettuce; and as a sidedressing or topdressing in June on mint that has a reddish cast or small leaves. Be careful not to use too much nitrogen on head lettuce and celery because of the danger of increasing tipburn or puffiness of lettuce and black heart of celery in hot weather. In continued wet weather, increase the above amounts 50 percent. Use nitrogen as a sidedressing on all leafy crops and onions, and sometimes on potatoes and other crops, if the leaves are rather yellow. If a soil test after leaching rains indicates low phosphorus and potassium, a 10-10-10 at around 300 to 500 pounds per acre may give better results as a sidedressing than a straight nitrogen fertilizer.

TABLE 18—Fertilizer placement for muck crops

Crop	Remarks
Broccoli Cabbage Cauliflower Spinach Swiss chard Leaf lettuce	Drill in 7" bands, 4" deep before seeding or transplanting. For cabbage or cauliflower on muck well supplied with moisture, 400 to 500 lbs. per acre can be applied in row 4" deep before or at transplanting. Spinach responsive to row fertilization. All crops responsive to nitrogen side-dressing.
Head lettuce	Place fertilizer 2" to 3" below seed. Heavy fertilization increases tip-burn. Use little phosphate-potash fertilizer if well fertilized previous years.
Celery Radishes Table beets	Broadcast and disc in or drill in fertilizer. Celery usually requires 0-10-30 supplemented with nitrogen.
Onions	Drill in or broadcast and disc in a fertilizer high in potash such as 0-10-30 or 60% potash. Apply in row up to 800 lbs. per acre 2" below seed of a high phosphate fertilizer such as 5-20-10. Topdress with nitrogen if needed when foliage is dry.
Mint	Fertilizer needed to maintain stand, as well as to increase oil content. Heavy fertilization and deeper plowing down of peppermint advisable where wilt is prevalent. Fertilizer usually applied broadcast or drilled in. Top-dress with pelleted nitrogen if needed when foliage is dry.
Potatoes	Drill in 7" bands, 4" deep or place up to 800 lbs. per acre beside row at planting time. Usually 3-9-27 or 0-10-30 made from sulfate of potash is recommended.
Carrots Parsnips	Drill in in 7" bands, 4" deep or in row 2" to 3" below seed, 600 to 800 lbs. per acre.
Field corn Sweet corn	Apply in a single band 2" to the side and 2" below the seed level. Maximum possible with a split boot applicator is about 250 lbs. per acre. Also possible to plow down or drill in a fertilizer high in potassium and use in the row a material high in phosphorus.
Grain Soybeans	Apply fertilizer in 7" bands, 4" deep.
Meadows Permanent pasture	Fertilize broadcast before seeding or topdress in spring.
Reed canary	Adapted only for fair drained or wet soils. On wet soils use 600 lbs. per acre of 10-10-10 fertilizer.
Sugar beets	Apply 1 inch to the side and 2" below the seeds. Plow down or drill in salt. Also possible to plow down or drill in part of potash.
Beans Cubumbers Squash Tomatoes	Drill in 7" bands, 4" deep or apply in bands 2" to the side and 2" below seed.

III. Soil Management Groups

Soil management groups have been worked out cooperatively by the Soil Conservation Service of the United States Department of Agriculture, with both the Cooperative Extension Service, and the Agricultural Experiment Station, Michigan State University, East Lansing, Michigan. These are basic interpretive soil groupings. They are based on texture, and reaction of the profile, slope, erosion, etc. and can be grouped into Land Capability Classes, or subdivided into Land Capability Subclasses or Land Capability Units.

The grouping can be useful for such specific purposes as forestry planting, irrigation design, drainage, and fertilizer and lime recommendations. The number and letter designations assigned to each group indicate the major properties and the interrelationships of these soil groups (See chart, page 4 and Table 19).

The numbers indicate the relative coarseness of the mineral materials from which the soils were formed; from 0 for the finest texture, clays, to 5 for the coarsest texture, sands. The small letter following this number indicates the natural drainage under which the mineral soil developed 'a' for the best drained, 'b' for imperfectly drained, and "c" for the most poorly drained conditions.

A combination of two small letters, such as 'bc', indicates a range in natural drainage conditions from imperfectly (b) to poorly drained (c). Where a small letter precedes the number or a capital letter it has a different meaning. Thus a small 'a' preceding a capital M (for mucks) represents very **acid** soils and 'b' stands for soils well supplied with **bases** and less acid in reaction. A small 'h' preceding a number or capital letter indicates that the subsoils of that group are **hardened** or **compacted** so as to interfere with root penetration and water movement.

The capital letters indicate other soil characteristics quite important to their use and may be used with or without the numbers. For example, G is for **gravelly** or stony soils; L is for **lowlands** subject to seasonal overflow; M is for **mucks** and peats; and R is for **rocky** soils, where bedrock is close to the surface.

Thus, the L4a soil management group includes lowland soils, of loamy sand to sand textures throughout the profile, that were formed under well drained conditions. The 3b soil management group in-

TABLE 19—Fertilizer recommendation tables to use for soil series in Michigan

Soil series	Soil management group	Fertilizer table		Soil series	Soil management group	Fertilizer table	
		Field crops	Vegetables			Field crops	Vegetables
Abscota	L4a	7	10	Bridgman	5a	8	10
Adolph	2c	4	9	Brimley	3b	5	10
Adrian	M4	11,12	11,12	Bronson	4a	7	10
Ahmeek	3a	5	10	Brookston	2c	4	9
Alcona	3a	5	10	Bruce	3c	6	10
Algansee	L4bc	7	10	Brule	L3bc	5	10
Alger	3a	5	10	Burleigh	4c	6	10
Allendale	4b	7	10	Burt	Gbc	5	10
Allouez	Ga	5	10	Butternut	2c	4	9
Alpena	Ga	5	10				
Amasa	3a	5	10	Cadmus	3a	5	10
Angelica	2c	4	9	Capac	2b	5	9
Antrim	4a	7	10	Carbondale	bM	11,12	11,12
Arenac	5b	8	10	Carlisle	bM	11,12	11,12
Au Gres	5b	8	10	Casco	4a	7	10
Au Train*	5a	8	10	Celina	2a	5	9
				Ceresco	L3bc	5	10
Bach†	3c	6	10	Champion	3a	5	10
Bannister	4c	6	10	Channing*	h5b	8	10
Baraga	Ga	5	10	Charity†	1c	3	9
Barker	2a	5	9	Chatham	3a	5	10
Bark River	2a	5	9	Cheneaux	4b	7	10
Barry	3c	6	10	Chesaning	4b	7	10
Belding	3b	5	10	Cohoctah	L3bc	5	10
Bellefontaine‡	3a	5	10	Coldwater	3b	5	10
Bentley	4a	7	10	Coloma	4a	7	10
Bergland	1c	3	9	Colwood	3c	6	10
Berrien	5a	8	10	Conover	2b	5	9
Berville	3c	6	10	Constantine	4a	7	10
Bibon	5a	8	10	Coral	3b	5	10
Blount	2b	5	9	Coventry	3a	5	10
Blue Lake	4a	7	10	Crosby	2b	5	9
Bohemian	3a	5	10	Croswell	5a	8	10
Bono	1c	3	9	Crystal Falls	Ra	5	10
Bowers	2b	5	9				
Boyer	4a	7	10	Dawson	aM	11,12	11,12
Brady	4b	7	10	Deer Park*	5a	8	10
Brant	4a	7	10	Deford	4c	6	10
Breckenridge	3c	6	10	Detour	Gbc	5	9
Brevort	4c	6	10	Diana	Gbc	5	10

*Practicability of fertilization doubtful because of droughtiness of these soils.
†Contains free lime in the surface soil.
‡Now correlated as Fox, rolling.

TABLE 19—Continued

Soil series	Soil management group	Fertilizer table		Soil series	Soil management group	Fertilizer table	
		Field crops	Vegetables			Field crops	Vegetables
Dighton	2a	5	9	Hettinger	2c	4	9
Dillon	5c	8	10	Hiawatha	5a	8	10
Dowagiac	3a	5	10	Hillsdale	3a	5	10
Dresden	3a	5	10	Hodunk	3a	5	10
Dryden	3a	5	10	Houghton	bM	11,12	11,12
Duel	4a	7	10	Hoytville	1c	3	9
				Huron	1a	3	9
East Lake	5a	8	10				
Eastport	5a	8	10	Ingalls	4b	7	10
Echo	5a	8	10	Ionia	3a	5	10
Edmore	4c	6	10	Iosco	4b	7	10
Edwards†	M2	11,12	11,12	Iron River	3a	5	10
Eel	L3a	5	10	Isabella	2a	5	9
Elmdale	3a	5	10				
Elo	2a	5	9	Jeddo	2c	4	9
Emmert	Ga	5	10	Johnswood	Ga	5	9
Emmet	3a	5	10				
Ensley	3c	6	10	Kalamazoo	3a	5	10
Epoufette	4c	6	10	Kalkaska	5a	8	10
Essexville†	4c	6	10	Karlin	4a	7	10
Ewen	L3a	5	10	Kawkawlin	2b	5	9
				Kendallville	3a	5	10
Fabius	4b	7	10	Kent	1a	3	9
Fox	3a	5	10	Kerston	L4bc	7	10
Freesoil	3a	5	10	Keweenaw	4a	7	10
Froberg	1a	3	9	Kibbie	3b	5	10
Fulton	1a	3	9	Kinross	5c	8	10
				Kiva	Ga	5	10
Gaastra	3b	5	10	Kokomo	2c	4	9
Gagetown	3a	5	10				
Gay	3c	6	10	Lacota	3c	6	9
Genesee	L3a	5	10	Lake Linden	2b	5	9
Gilchrist	4a	7	10	Lapeer	3a	5	10
Gilford	4c	6	10	Leelanau	4a	7	10
Gladwin	4b	7	10	Lenawee	2c	4	9
Glendora	L4bc	7	10	Linwood	M3	11,12	11,12
Gogebic	3a	5	10	Locke	3b	5	10
Granby	5c	8	10	London	2b	5	9
Grayling*	5a	8	10	Longlois	2a	5	9
Greenwood	aM	11,12	11,12	Longrie	3a	5	10
Griffin	L3bc	5	10	Lorenzo	4a	7	10
Guelph	2a	5	9	Lupton	bM	11,12	11,12
Hagener	5a	8	10	Mackinac	2b	5	9
Hartwick§	5a	8	10	Macomb	3b	5	10
Hessel	Gbc	5	10				

†Contains free lime in the surface soil.
*Practicability of fertilization doubtful because of droughtiness of these soils.
§Now correlated as Kalkaska.

TABLE 19—Continued

Soil series	Soil management group	Fertilizer table		Soil series	Soil management group	Fertilizer table	
		Field crops	Vegetables			Field crops	Vegetables
Mancelona	4a	7	10	Palms	M3	11,12	11,12
Manistee	4a	7	10	Palo	3b	5	10
Marenisco	4a	7	10	Parkhill	2c	4	9
Markey	M4	11,12	11,12	Parma	3a	5	10
Marlette	2a	5	9	Paulding	0c	3	9
Matherton	3b	5	10	Pelkie	L3bc	5	10
Maumee	5c	8	10	Pence	4a	7	10
McBride	3a	5	10	Perrin	4a	7	10
McGregor†	3b	5	10	Perth	1b	3	9
Melita	5a	8	10	Peshekee	Ra	5	9
Menominee	4a	7	10	Pewamo	2c	4	9
Metamora	3b	5	10	Pickford	1c	3	9
Metea	3a	5	10	Pinconning	4c	6	10
Miami	2a	5	9	Plainfield	5a	8	10
Montcalm	4a	7	10	Pleine	3c	6	10
Moran	2a	5	9	Posen	3a	5	10
Morley	2a	5	9	Poygan#	2c	4	9
Morocco	5b	8	10				
Moye	4b	7	10	Randville	4a	7	10
Munising	3a	5	10	Richter	4b	7	10
Munuscong	3c	6	10	Rifle	bM	11,12	11,12
Mussey	4c	6	10	Rimer	3b	5	10
				Rodman	Ga	5	10
Nappanee	1b	3	9	Rollin	M2	11,12	11,12
Negaunee	3a	5	10	Ronald	3c	6	10
Nekoosa	5a	8	10	Roscommon	5c	8	10
Nester	2a	5	9	Roselawn*	5a	8	10
Newaygo	3a	5	10	Rousseau	4a	7	10
Newton	5c	8	10	Rubicon*	5a	8	10
Nunica	2a	5	9	Rudyard	1b	3	9
				Ruse	3c	6	10
Oakville	5a	8	10				
Ockley	2a	5	9	Saganing	4c	6	10
Ocqueoc	4a	7	10	Sanilac	3b	5	10
Ogden	M1	11,12	11,12	Satago	2c	4	9
Ogemaw*	h5b	8	10	Sauble*	5a	8	10
Ogontz	3c	6	10	Saugatuck*	h5b	8	10
Omega*	5a	8	10	Saverine	3b	5	10
Onaway	2a	5	9	Sebewa	3c	6	10
Onota	3a	5	10	Selkirk	1b	3	9
Ontonagon	1a	3	9	Seward	3a	5	10
Orienta	5b	8	10	Shelldrake*	5a	8	10
Oshtemo	4a	7	10	Shoals	L3bc	5	10
Otisco	4b	7	10	Sigma	4b	7	10
Ottawa	5a	8	10	Sims	2c	4	9
Ottokee	5a	8	10				

†Contains free lime in the surface soil.
*Practicability of fertilization doubtful because of droughtiness of these soils
#Now correlated with Sims.

TABLE 19—Continued

Soil series	Soil management group	Fertilizer table		Soil series	Soil management group	Fertilizer table	
		Field crops	Vegetables			Field crops	Vegetables
Sisson	3a	5	10	Tula	3b	5	10
Skanee	3b	5	10	Tuscola	3a	5	10
Sleeth	2b	5	9	Twining	2b	5	9
Sloan	L3bc	5	10	Tyre	4a	7	10
Spalding	aM	11,12	11,12				
Sparta	5a	8	10	Ubly	3a	5	10
Spinks	4a	7	10				
Stambaugh	3a	5	10	Volinia	3a	5	10
St. Clair	1a	3	9	Vilas*	5a	8	10
St. Ignace	Ra	5	9				
Strongs§	5a	8	10	Wainola	4b	7	10
Summerville	Ra	5	10	Waiska	Ga	5	10
Sumner	4a	7	10	Wakefield	2a	5	9
Sunfield	3a	5	10	Wallace*	h5a	8	10
Superior	1a	3	9	Wallkill	L4bc	7	10
				Warners†	M2	11,12	11,12
Tahquamenon	aM	11,12	11,12	Warsaw	3a	5	10
Tappan†	2c	4	9	Wasepi	4b	7	10
Tawas	M4	11,12	11,12	Washtenaw	2c	4	9
Tedrow	5b	8	10	Watton	2a	5	9
Thackery	2a	5	9	Wauseon	3c	6	10
Thomas†	2c	4	9	Wea	2a	5	9
Tobico†	5c	8	10	Weare§	5a	8	10
Toledo	1c	3	9	Westland	2c	4	9
Tolfree	2c	4	9	Wexford§	5a	8	10
Tonkey	4c	6	10	Whittemore†	2c	4	9
Traunik	5b	8	10	Willette	M1	11,12	11,12
Traverse	3a	5	10	Winegars	4b	7	10
Trenary	2a	5	9	Wisner†	2c	4	9
Trout Lake*	h5b	8	10				

§Now correlated as Kalkaska.
†Contains free lime in the surface soil.
*Practicability of fertilization doubtful because of droughtiness of these soils.

cludes upland mineral soils formed from sandy loam materials, under imperfectly drained conditions. The M1 soil management group includes shallow organic soils (peats or mucks) on silty clay or clay within 12 to 42 inches of the surface, and the bM soil management group includes deep organic soils well supplied with calcium.

Cooperative extension work in agriculture and home economics. Michigan State University and the U. S. Department of Agriculture cooperating. Paul A. Miller, Director, Cooperative Extension Service, Michigan State University, East Lansing. Printed and distributed under Acts of Congress, May 8 and June 30, 1914.

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