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FERTILIZER RECOMMENDATIONS for MICHIGAN VEGETABLES and FIELD CROPS

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MISPRINT! Titles for Tables 9 and 10 (pp. 12 and 13) are Interchanged

Some Conversion Factors

Home gardeners, nurserymen, and greenhouse growers often have difficulty figuring how much fertilizer to use. Some equivalent values are:

- 1 acre is equal to 43,560 square feet.
- 1 gallon of concentrated liquid fertilizer weighs about 11 pounds.
- 1 pint of water or dry fertilizer weighs about 1 pound.
- 1 pint is equal to 2 cups or 32 tablespoons.
- 1 tablespoon is equal to 3 teaspoons.
- 1 ppm means 1 part per million.
- pp2m means parts per 2 million.
- An acre of mineral soil turned to a depth of 6 2/3 inches weighs about 2 million pounds; an acre of muck soil, about 500,000 pounds.
- 0.1 ounce or 2.8 grams of fertilizer per bushel equals about 100 pounds per acre.
- 1 pound of fertilizer per cubic yard is equal to 800 pounds per acre.
- 20 bushels of soil mix equals about 1 cubic yard.
- 1 ounce or 28 grams per gallon is equivalent to 3 pounds per 48 gallons.
- 1 ounce of fertilizer per 100 gallons makes a salt solution of 75 ppm.
- 1 bushel of manure weighs about 50 pounds.

Some Equivalent Rates

Pounds per acre desired	Amount Fertilizer Needed		
	One sq. ft.	cubic yard	1,000 sq. ft. (33′ x 30′)
100	–	2 oz.	2.3 lb.
500	1 tsp.	10 oz.	11.5 lb.
1,000	2 tsp.	1.3 lb.	23 lb.

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FERTILIZER RECOMMENDATIONS

for Michigan

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How to Use This Bulletin

Fertilizer recommendations are based on the crop to be grown, soil type, past cropping and available plant nutrients as determined by a soil test. (See page 6 for a discussion of soil testing.)

Field Crops Grown on Mineral Soils

The soil management group greatly affects practical yield goals. The soil management group to which each soil belongs is shown in Table 25, pages 29 and 30. To help you estimate a practical yield goal, see Tables 26 or 27 on pages 31 and 32. Average yield goals for each soil management group are given there for southern or northern Michigan.

Nitrogen recommendations are given on page 8 and in Tables 5, 6 and 7. They are not based on a soil test, but on cultural practices, soil type, crop to be grown and yield goal.

Phosphorus recommendations are based upon soil tests and yield goals. They are shown in Table 8, page 11. See the boxed note in Table 8 for instructions on how to use.

Potassium recommendations based upon soil test and yield goal are reported in Table 9, pages 12, for loams, clay loams and clays; and in Table 10, page 13, for sandy loams, loamy sands and sands.

Fertilizer placements suggested for the various crops are given on pages 15 to 17.

Vegetable Crops Grown on Mineral Soils

Placement of typical rates of fertilizer is reported on pages 17 to 21. Follow the nitrogen recommendations given for each crop. Phosphate and potash recommendations are based on soil test levels. See Tables 13, 14 and 15, pages 18 and 19, for recommended rates.

Crops Grown on Organic Soils

Fertilizer placement for these crops is given on pages 24 and 25. Follow the nitrogen recommendations given for each crop. Phosphate and potash recommendations are based on soil test levels. See Tables 17 and 18, pages 22 and 23, for recommended rates.

Micronutrient needs for crops grown on organic soils are discussed on page 22.

Sod and Turf on Mineral and Organic Soils

Fertilizer requirements for sod on organic soils are given under the section on organic soils, page 25. Requirements on mineral soils are given in the section Sod and Turfgrasses on Mineral Soils, page 26.

Fertilizer Recommendations

All fertilizer recommendations are expressed as pounds of the actual plant food per acre. For example, if a recommendation calls for 125 pounds of nitrogen (N), 50 pounds of phosphate (P_2O_5), 75 pounds of potash (K_2O), and 5 pounds of manganese (Mn) per acre, you will need to work out a program to apply such amounts. The sections in this publication on grades and ratios, page 4, and fertilizer placements, page 15, should help do this. Your fertilizer dealer or agricultural extension agent can also help you. Several alternative programs may be possible. Use the one that best fits your farming operation at competitive costs. Consider also the cost of the plant nutrients, the cost of application, and the timeliness of the application.

General Information

Fertilizers are materials that contain elements necessary for plant growth. These essential elements, called "plant nutrients," may be divided into three groups. The major or primary plant nutrients include the elements nitrogen (N), phosphorus (P), and potassium (K). These three elements are commonly deficient in soils of low fertility.

A second group of plant nutrients commonly referred to as secondary elements includes sulfur (S), calcium (Ca), and magnesium (Mg). Normally, they are in ample supply in well-limed soils of Michigan.

The third group of essential elements is called micronutrients because they are needed in only very small amounts. These elements are sometimes called trace or minor elements. They include iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu) and molybdenum (Mo).

Major Plant Nutrients

The amounts of nitrogen, phosphorus and potassium in a commercial fertilizer are given in the analysis on the container. The first figure is the percent total nitrogen; the second, the percent available phosphate (P_2O_5), and the third, the percent water-soluble potash (K_2O). For example "5-20-20" has a guarantee of at least 5 percent nitrogen, 20 percent phosphate and 20 percent potash.

The above analysis is called the oxide basis. In recent years there has been an interest in expressing all analyses on the elemental basis. Such analyses would show percent P and K rather than percent P_2O_5 and K_2O. At present the expression of phosphorus and potassium on the elemental basis has not been adopted by Michigan control regulations. The conversion factors for the two systems are as follows:

(1) To convert P_2O_5 and K_2O to P and K, the factors are:
percent $P_2O_5 \times 0.44 =$ percent P
percent $K_2O \times 0.83 =$ percent K

(2) To convert from P and K to P_2O_5 and K_2O, the factors are:
percent $P \times 2.3 =$ percent P_2O_5
percent $K \times 1.2 =$ percent K_2O

A fertilizer having a 5-20-20 analysis on the oxide basis is equivalent in composition and value to a 5-8.8-16.6 reported on the elemental basis. Dual labeling gives the analysis in both the oxide and elemental forms.

In this publication, recommendations are expressed both as the oxide and as the element.

Grades and Ratios

Fertilizer grades refer to the guaranteed percentages of the major plant nutrients. The ratio refers to the proportion of nitrogen, phosphate and potash in the fertilizer. For example, 6-24-12 is a grade and has a ratio of 1:4:2.

A minimum grade refers to the lowest analysis suggested for a particular ratio. For example, a minimum grade for an 0:1:1 ratio fertilizer is 0-20-20. Higher analysis materials of this ratio such as 0-25-25 or 0-30-30 are encouraged if they can save money and labor.

Fertilizer recommendations in this publication are given in pounds of plant nutrients per acre. From these amounts, the buyer needs to determine the materials, or if a mixed fertilizer, the grade and amount that come closest to the recommendation. For example, if a recommendation calls for 50 pounds of nitrogen, 100 pounds of phosphate, and 50 pounds of potash, use a fertilizer having approximately a 1 to 2 to 1 ratio, such as 500 pounds of a 10-20-10.

Fertilizer Materials

Nitrogen: Nitrogen fertilizers may be divided into three classes: (1) inorganic, (2) synthetic organic and (3) natural organic. Providing proper applications are made and equivalent rates are applied, there should be little or no difference in the effect on plant growth between the various sources. These classes of nitrogen sources and their nitrogen content are given in Table 1.

Phosphorus: Phosphorus in fertilizers is present in three forms: (1) water soluble (2) available (citrate soluble) and (3) citrate insoluble. A portion of the citrate soluble phosphorus is also water soluble. Most fertilizers presently sold for row application contain at least 50 percent of the phosphorus in the water-soluble form. Table 2 gives a list of the major phosphorus fertilizers.

Potassium: Muriate of potash (KCl) is the most widely used potassium supplying fertilizer material. Other potassium materials are listed in Table 2.

Good Fertilizer Buys

Comparison of fertilizer cost and fertility value are most reliable when based on cost per unit of available plant nutrients such as cents per pound of nitrogen, phosphate or potash. Where liquid fertilizers are priced by a volume measure, the buyer must know the weight-per-unit volume as well as the analysis in order to calculate the cost per unit of nutrient.

To determine the cost per pound for a straight material, divide the cost per ton by the pounds of nutrients in one ton.

For example: Product A has 33% nitrogen and costs $66.00 per ton:

$$\frac{\$66.00}{2{,}000 \times 0.33} = \frac{66.00}{660} = \$0.10 \text{ or } 10¢ \text{ lb.}$$

When comparing materials having *the same* N-P_2O_5 and K_2O ratio, the buyer needs to calculate an average value for all nutrients before comparing prices.

For example: 5-20-20 costs $72.00 per ton; its total nutrient content is 5% + 20% + 20% or 45%.

$$\frac{\$72.00 \times 0.45}{2{,}000} = \frac{72.00}{900} = \$0.08 \text{ or } 8¢ \text{ lb.}$$

When comparing liquid and dry fertilizers, first determine the weight per gallon. Divide this figure into 2,000 to find the number of gallons per ton. Multiply the cost per gallon times the number of gallons per ton to determine the cost per ton.

For example: If a liquid 8-16-8 costs $0.50 per gallon and weighs 11.7 pounds per gallon, the cost per ton would be $\frac{2{,}000 \times \$.50}{11.7} = \$85.45$ per ton. The cost per unit of nutrient can be calculated as above.

Liquid fertilizers are equally as effective as dry fertilizers, providing comparable rates of nutrients are applied in a similar manner. So, comparison with dry

Table 1. Analysis and classes of some nitrogen (N) fertilizer materials.

Nitrogen Fertilizer Carriers	Formula	Form	Percent Nitrogen
INORGANIC			
Ammonium nitrate	NH_4NO_3	Solid	33.5
Ammonium sulfate	$(NH_4)_2SO_4$	Solid	21
Anhydrous ammonia	NH_3	Gas[1]	82
Aqua ammonia	NH_4OH	Liquid	20-25
Calcium cyanamide	$CaCN_2$	Solid	21
Calcium nitrate	$Ca(NO_3)_2$	Solid	16
Nitrogen solutions	(Varies)	Liquid	20-50
Sodium nitrate	$NaNO_3$	Solid	16
SYNTHETIC ORGANIC:			
Urea	$CO(NH_2)_2$	Solid	45
Urea formaldehyde		Solid	38
NATURAL ORGANIC:			lb/T
Animal manure		Solid	10-20
Sewage sludge		Solid	5-10

[1] Liquid under pressure

Table 2. Analysis of phosphorus (P_2O_5) and potash (K_2O) fertilizer carriers.

		Approximate Per Cent				
		N	P_2O_5			K_2O
Fertilizer Material	Formula		Total	Available (Citrate Soluble)	Per Cent Available P_2O_5 Which is Water Soluble	
PHOSPHORUS CARRIERS						
20% superphosphate	$CaH_4(PO_4)_2$ and $Ca_2H_2(PO_4)_2$	0	21	20	85	0
Concentrated superphosphate	$CaH_4(PO_4)_2$	0	47	45	85	0
Ammonium phosphate	$NH_4H_2PO_4$ mostly	11	49	48	92	0
Diammonium phosphate	$(NH_4)_2HPO_4$	18	47	46	90	0
Phosphoric acid	H_3PO_4	0	54	54	100	0
Superphosphoric acid, Polyphosphate	H_3PO_4 and $H_4P_2O_7$	0	76	76	100	0
Rock phosphate	Fluoro-and chloroapatites $3\ Ca_3(PO_4)_2 \cdot CaF_2$	0	34	3 to 8	0	0
POTASH CARRIERS						
Muriate of potash	KCl	0	0	0	0	60 to 62
Potassium sulfate	K_2SO_4	0	0	0	0	50
Potassium magnesium sulfate	$K_2SO_4 \cdot 2\ MgSO_4$	0	0	0	0	21
Potassium nitrate	KNO_3	13	0	0	0	44

fertilizer can be made on a cost-per-pound basis. However, the buyer should keep in mind the availability of materials, ease of handling, handling and transportation costs, ease of application and storage costs in addition to the cost of material.

Soil Sampling

A soil test, to be helpful, must be made from a representative soil sample. Too much is at stake to be careless in this task.

For general rotation crops, soils should be tested at least every 3 years. Under intensive use, as in gardens and greenhouses, or for high-value field crops, soils should be tested annually.

Soil samples may be taken at any time during the year when temperature (lack of frost) and moisture conditions permit. Before sampling a field, check it for differences in soil characteristics. Consider its productivity, topography, texture, drainage, color of top soil, and past management. If these features are uniform throughout the field, each composite sample of the top soil can represent 10 to 15 acres.

Each composite sample should be made up of at least 20 sub-samples taken at random over the field. Avoid taking samples close to gravel roads, dead furrows, previous locations of brush, lime or manure piles, or burned muck areas. Be sure the sub-samples are well mixed, and place a pint of the soil in the sample container for mailing to the laboratory.

Extension Bulletin E-598, "*Sampling Soils For Fertilizer and Lime Recommendations,*" also gives instructions on how to collect soil samples.

Soil Testing

Soil tests on samples representative of a field are necessary before one may be sure of what plant nutrients to apply so that deficiencies will be eliminated as a risk in crop production. However, a lack of plant nutrients is only one of the many factors which can limit crop yields.

Soil pH of mineral soils is measured with a 1:1 soil-to-water suspension and of organic soils with a 1:2 soil-to-water suspension.

Only soil tests obtained by the Bray P_1 (absorbed) method should be used as a basis for selecting the phosphorus recommendations suggested in this publication.

The potassium recommendations in Michigan are based upon the 1.0 *N* neutral ammonium acetate extraction method.

Micronutrient levels are expressed as parts per million (ppm). Available manganese and zinc are determined upon a 0.1 *N* HCl extraction; copper on a 1.0 *N* HCl extraction (1:10 soil-extractant ratio).

All mineral soil samples submitted to the Michigan State University Soil Testing Laboratory are extracted on weighed samples. Amounts of nutrients which they contain are expressed as pounds available in two million pounds of soil. This is about the weight of an acre of loamy soil, 6 2/3 inches deep. Organic soil samples or synthetic soil mixes are measured by volume. This is necessary because such materials usually have much lower densities than mineral soils.

Many soil samples are tested in laboratories other than those supervised by the MSU Crop and Soil Sciences Department. The test results and the fertilizer recommendations made by these laboratories can be greatly different from those suggested in this publication. These differences are due to other testing methods and differences in soil test interpretations.

Basis for Recommendations

Fertilizer recommendations are based on theoretical considerations and many field experiments. In these experiments, soil test levels of the plow layer have been correlated with actual crop responses to fertilizer nutrients.

Yield goals in Tables 26 and 27 represent practical yield potentials under good management. These goals are based on years of field experience with different soil management groups. Yield potential on individual fields can vary substantially from these averages. This variation is taken into account in later tables where increasing quantities of fertilizer nutrients are recommended over a range of increasing yield goals.

Past experience and good judgment must be used in selecting the yield goal for a given field. It is a needless cost to fertilize for a yield goal that cannot be attained because of some other limiting factor or factors. The accumulation of nutrients above a level where crop response is attained leads to deleterious effects on soils and crops. It also increases environmental hazards due to potential erosion and/or leaching of nutrients into ground or surface waters.

Recommendations shown in Tables 8 to 10 call for amounts that will result in fertility buildup when soils test low. Where soils test high, the recommendations call for little or no fertilizer. For such situations, crop removal will eventually deplete the soil reserves to a point that more fertilizer will be needed. The soil test should be repeated every two or three years to check the fertility reserves in the plow layer. With high value crops, repeat soil tests every year.

Fertilizers are most effective on well-drained soils with favorable structure, which promotes deep rooting. Too much tillage can cause compaction, destroy soil structure and lower fertilizer efficiency.

Deficiency Symptoms

For better results from fertilizers, watch for plant nutrient deficiency symptoms. Plants are normally green. When another color develops, it is likely caused by a deficiency of some plant nutrient. Most deficiencies result in yellowing of leaves. The pattern of yellowing varies according to nutrient deficiency and plant species. Insect damage and plant diseases can also show similar color changes.

For many years, these deficiency symptoms have been studied under controlled conditions. The appearance of a starved plant may indicate what nutrient shortage is causing the unhealthy condition. You can become familiar with these symptoms and decide for yourself when your plants are lacking 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.

Soil Acidity and Lime Index

Soil acidity is expressed in terms of "pH." 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 more strongly acid. On the other hand, pH 8.0 is mildly alkaline. Most well-drained Michigan soils, in their natural state, have a pH lower than 7.0. This is desirable from the standpoint of availability of most nutrients.

Plant nutrients, particularly phosphorus, are most available in mineral soils having a pH between 6.0 and 7.0. For general field crops, acid soils should be limed to pH 6.5. If alfalfa is to be grown, the soil should be limed to pH 6.8.

The estimated lime requirement of acid soil samples submitted to the Michigan State University laboratory is determined by measuring the total soluble and exchangeable hydrogen and aluminum. The degree of acidity is reported as the "Lime Index." This method is more precise than estimates made from soil pH measurements alone, since it measures total acidity instead of just the active acidity of the soil. Table 3 shows the amount of recommended limestone based upon the "Lime Index" value for mineral soils. For organic soils see Table 16.

The maximum lime recommendation in any season is 5 tons per acre.

If the "Lime Index" is less than 6.5, the soil should be retested two years after application for additional lime needs.

For potatoes, the soil is generally limed to pH 6.0. If there is no history of scab, or it is not suspected because of resistant varieties, consider liming to pH 6.5. **The lime application for potatoes should not exceed 2 tons per acre at any one time and should be applied immediately following potato harvest.**

Further information on liming is discussed in Michigan Extension Bulletin 471.

Table 3. Tons of limestone needed to raise soil pH of mineral soils to 6.5 or 6.8 as determined by the "Lime Index" Method.

Lime Index	Tons lime per acre (9" Plow Depth) *	
	to pH 6.5	to pH 6.8
7.0	0.5	1.0
6.9	1.0	1.5
6.8	1.5	2.0
6.7	2.5	3.0
6.6	3.5	4.0
6.5	4.5	5.0
6.4	5.5	6.0
6.3	6.0	7.0
6.2	7.0	8.0
6.1	8.0	9.0
6.0	9.0	10.0
5.9	10.0	11.0
Below 5.9	11.0	12.0

**To convert lime recommendations to depth of plowing other than 9 inches, divide above rates by 9 and then multiply by the depth of plowing.*

Sulfur Rates to Reduce Soil pH

Elemental sulfur can be used to reduce the pH level of a soil. While not practical for field crops, under special conditions sulfur may be used for this purpose. The rates given in Table 4 should be used as a guide. Both spray grade and soil grade sulfur are satisfactory.

Other materials are satisfactory. Since these materials are not as acidifying as sulfur, greater rates must be used. Listed below are materials and rates equivalent to sulfur rates in Table 4.

Material	Pounds equivalent to 1 pound of sulfur
Aluminum sulfate	7 *
Ammonium nitrate	5
Urea	3.5
Ammonium sulfate	2.6
Anhydrous ammonia	2

**For example, apply 7 times as much aluminum sulfate as sulfur.*

Table 4. Quantity of sulfur required to reduce soil pH for a depth of 7 inches.

Desired pH Change	Soil Texture					
	Sands	Loamy sands	Sandy loams	Loams	Clay loams	Organic
	..........................lb Sulfur/acre..........					
7.0-6.0	300	400	500	700	1100	1750
6.0-5.0	800	1000	1200	1400	1400	2750
5.0-4.0	800	1000	1200	1400	1800	4500
	......................lb Sulfur/100 Square feet					
7.0-6.0	0.7	1.0	1.2	1.6	2.5	3.9
6.0-5.0	1.8	2.3	2.8	3.2	3.2	6.3
5.0-4.0	1.8	2.3	2.8	3.2	4.1	10.3

Recommendations for Field Crops on Mineral Soils

Major Nutrients

Nitrogen (N) – 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 soil test made prior to planting.

When more than planting-time nitrogen is required, the grower should follow the guidelines for application given for the specific crop listed under the fertilizer placement section on pages 15 to 17.

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 released in the soil by the bacteria. Because of this "nitrogen fixation" by the bacteria, these crops do not usually need or respond to nitrogen fertilizer.

Animal manures are relatively high in available nitrogen, unless they are high in straw or other carbonaceous bedding, such as shavings or sawdust. In most cases, a small quantity of nitrogen at planting time is desirable, even if animal manure is used. Where straw or mature grass cover crops are plowed down, extra nitrogen is generally needed for orderly decomposition of the old crop residues and growth of the new crop.

Tables 5, 6 and 7 give recommendations of the nitrogen fertilizer required for corn and other crops. If the season is cool and wet and/or the field is poorly drained, it is usually necessary to apply larger quantities of nitrogen than indicated.

A number of nitrogen materials are offered for sale. Usually the materials are equally effective and should be purchased on the basis of cost per pound of actual nitrogen, convenience of application, and supply. Under special conditions, nitrate fertilizers are preferred, especially for plants growing in cold soils or on recently fumigated land.

Most nitrogen carriers leave an acidic residue in the soil. *It requires 1.8 pounds of limestone to neutralize the acidifying effect of each pound of nitrogen derived from ammonium nitrate, urea or anhydrous ammonia and 5.5 pounds if ammonium sulfate is used.*

Phosphorus (P) – Phosphorus fertilizers are mostly derived from phosphate rock located in Florida, Tennessee and the Western states. Normal superphosphate (0-20-0) is made by treating phosphate rock with sulphuric acid. Triple superphosphate (0-46-0) is made by treating the rock with phosphoric acid. Ammonium phosphates are made by neutralizing phosphoric acid with ammonia. They are either monoammonium phosphate (11-48-0) or diammonium phosphate (16-48-0, 18-46-0, 21-53-0).

Polyphosphates have recently come on the market. These materials have two or more phosphorus ions in each molecule. The production of polyphosphoric acid differs from ordinary phosphoric acid in that less water is used. The process results in higher phosphorus analysis. Field trials indicate that polyphosphates and ordinary phosphate materials are essentially equal in availability to plants.

Normal and triple superphosphate have a low salt index, but they can delay seed germination because they readily absorb soil moisture. This often happens in dry seasons when applied in direct contact with the seed, such as with a fall seeding of wheat.

Ammonium phosphates have high salt effects and must be placed away from the seed or plant. Diammonium phosphate is particularly hazardous because of the release of the ammonium ion in the soil solution.

Phosphorus fertilizers show their greatest benefits for fast growth of small seedlings, particularly when soil temperatures are low. Once a crop has developed a good root system, the plant is better able to utilize soil phosphorus. Thus, fertilizers high in phosphorus are generally recommended in starter solutions or in bands near the seed.

The recommendations in Table 8 show phosphorus rates based on soil tests, crop grown and yield goal.

Potassium (K) – The common source of potassium is potassium chloride (muriate of potash), containing 60 percent K_2O. This is the cheapest source and is highly effective for nearly all field crops. Other carriers are potassium sulfate, potassium-magnesium-sulfate and potassium nitrate. These sources are used for specialty crops such as potatoes, blueberries, greenhouse tomatoes and in potting soil mixes. They are used to help maintain low chloride levels and prevent soluble salt accumulation.

Small seedlings have less need for potassium than for phosphorus. On the other hand, once plants start to grow rapidly, they utilize large amounts of potassium. Crop removal is particularly heavy when the

Table 5. Nitrogen fertilizer guides for corn growing on soil containing 2 to 4% organic matter.

Previous crop or manure application	Yield goal per acre			
	60-89 Bu 10-14 tons	90-119 Bu 15-19 tons	120-149 Bu 20-24 tons	150-180 Bu 25-30 tons
	..............Pounds of nitrogen per acre..............			
Legume and 10 tons manure/acre	0	0	40	80
Good legume	10	40	80	120
Manure 10 tons/acre	30	60	110	160
No legumes, no manure	70	100	150	200

For Sudangrass, sudax, etc., use nitrogen rates comparable to silage productivity.

Table 6. Guide for estimating total nitrogen needed for small grains, potatoes, beans, and grassland.

Manure application	Barley Oats Rye	Wheat*	Pea Beans or Soybeans	Grass (pasture or hay) Low Level Management	Grass (pasture or hay) High Level Mgmt.	Potatoes-cwt/acre** 250-349	Potatoes-cwt/acre** 350-449	Potatoes-cwt/acre** 450-550
	.... Pounds of nitrogen per acre..........................							
Legume and 10 tons of manure/acre	10	10	0	0	0	20	60	80
Good legume	10	10	10	0	0	60	100	120
Manure 10 tons/acre	10	30	10	0	50	90	130	160
No legume or manure	40	60	40	60	100	130	160	180

**If wheat is apt to lodge, follow amounts suggested for oats.*
***Russet Burbanks will generally require an additional 30 to 40 pounds of nitrogen to obtain the same yield goal as other late season varieties.*

whole plant is harvested, as with hay, summer forages, corn for silage or celery.

The effectiveness of potassium applied in the row is equal or superior to that applied broadcast. However, there is often a limit on the amount of potassium that can be applied near the seed because of possible salt injury to the seed. For this reason, broadcast application is often recommended.

The potassium-supplying ability of a soil is related to the types and amounts of clay minerals present.

Table 7. Nitrogen recommendations for sugar beets grown under different management systems.

Previous Management	Maximum Yield of Roots	Maximum Yield of Sugar
	Pounds of N/Acre	
No nitrogen applied previous year		
Legume and 10 tons manure/acre	10	0
Good legume	10	10
Manure (10 tons/acre)	50	30
Nitrogen applied previous year plus manure and/or legume		
Legume and 10 tons manure/acre		
All rates of N applied previous year	10	0
Good legume		
All rates of N applied previous year	10	0
Manure 10 tons/acre		
Less than 50 lb N/A applied Previous year	50	30
50-100 lb N/A applied Previous year	50	10
More than 100 lb N/A Applied previous year	50	0
Nitrogen applied previous year without legume or manure		
More than 150 lb N/acre applied previous year	90	0
100-150 lb N/acre applied previous year	90	20
50-100 lb N/acre applied previous year	90	40
Less than 50 lb N/acre applied previous year	90	60

Table 8. Phosphate – phosphorus recommendations for field crops on mineral soils.

Available Soil Phosphorus ----pounds of Phosphorus (P) per acre						Pounds per Acre Annually Recommended P_2O_5	P
					0-39	250	110
				0-39	40-79	200	88
				40-59	80-99	150	66
			0-19	60-79	100-119	125	55
		0-19	20-39	80-99	120-139	100	44
	0-19	20-39	40-59	100-119	140-159	75	33
0-19	20-39	40-59	60-79	120-139	160-179	50	22
20-39	40-59	60-79	80-99	140-159	180-199	25	11
40+	60+	80+	100+	160+	200+	0	0
Alfalfa 3-4T topdressing Buckwheat Clover Corn 60-89 bu Cover crops Field beans 15-29 bu Grass pasture (Unimproved) Grasses Timothy Orchard, Brome Kidney beans 15-29 bu Millet Oats 50-79 bu Rye Soybeans 25-40 bu	Alfalfa 5-6T topdressing Alfalfa 3-4T seeding Barley 40-69 bu Birdsfoot Trefoil Corn 90-119 bu Corn silage 10-14T Field beans 30-50 bu Kidney beans 30-50 bu Oats 80-120 bu Soybeans 40+ bu Sorghum Sudangrass Wheat 25-39 bu	Alfalfa 7+ T topdressing Alfalfa 5+ T seeding Barley 70-100 bu Corn 120-149 bu Corn silage 15-19T Wheat 40+ bu	Corn 150+ bu Corn silage 20-30T Sugar beets 18-23T	Sugar beets 24-28T Potatoes 250-350 cwt	Potatoes 350+ cwt		

To use this table, look for the crop to be grown showing the yield potential nearest your expected yield goal. Then find the position of the soil test range in the overlying column of figures. To determine the phosphate (P_2O_5) needed, follow dashed line to the appropriate column on the right side.
EXAMPLE: Crop to be grown - corn, yield goal 110 bu. per acre
Soil test - 28 pounds of P/A
Recommendation - 50 pounds of P_2O_5

The present soil test used for potassium can adequately predict the potassium-supplying ability of most Michigan soils. However, some soils fix potassium in forms which are not readily available to plants. Remember that routine soil testing does not determine various types of clay minerals or the fixing ability of a soil. If applications of 300 to 500 pounds of K_2O do not increase the soil test substantially, you can assume the soil has considerable fixing capacity. A corrective application of an additional 1,000 pounds K_2O should be made. Once such soils have a good test, they will continue to supply potash for some time even though crop removal may be considerable.

The recommendations in Tables 9 and 10 show the potassium rates based on soil tests, crop grown, yield goal and soil texture.

Secondary Nutrients

Magnesium (Mg) – Magnesium deficiency is most likely to occur in acid soils with a sandy loam, loamy sand or sand plow layer with a subsoil as coarse or coarser than the plow layer (see Table 26 or 27) and in similar soils limed with calcic limestone or marl. Responsive crops are cauliflower, celery, muskmelons, potatoes, peas, oats and corn. Magnesium deficiency is a common disorder in greenhouse tomatoes.

Present soil test criteria for recommending magnesium in Michigan are: (1) if the exchangeable magnesium level is less than 75 pounds per acre, or (2) if as a percent of the total bases (calcium plus magnesium plus potassium expressed as milliequivalents per 100 grams of soil), potassium exceeds magnesium or (3) if the soil magnesium (as a percent of total bases) is less than 3 percent.

On acid soils where magnesium need is indicated, at least 1,000 pounds of dolomitic limestone should be applied. On soils which are not acid and need magnesium, soluble sources are suggested. Magnesium sulfate (epsom salts), sulfate of potash-magnesium or finely ground magnesium oxide are all satisfactory sources of magnesium.

Magnesium can be applied as a foliar spray. Suggested rates per acre are 10 to 20 pounds of magnesium sulfate (epsom salts) in 100 gallons of water.

Magnesium deficiency may be induced by high rates of potassium. In some states, agronomists strive to have at least 10 percent magnesium of the total exchangeable bases (equivalent basis). These high rates are aimed at preventing "grass tetany" disorders in livestock which feed on lush grass. Anyone concerned with "grass tetany" should avoid excessive rates of potassium fertilizer. Legume hay, which is generally high in magnesium, should also be fed. Some magnesium carriers which can be mixed with grain or salt rations may also be considered. Contact your animal feed specialist for amounts and sources.

Calcium (Ca) – Calcium is an essential nutrient for plant growth. Well-limed soils are rich in calcium. Even soils needing lime to correct acidity generally contain sufficient calcium for plants. The poor growth of plants on acid soils is usually due to excess soluble manganese, iron and/or aluminum.

Research at Purdue University found that the soil water for Indiana varied between 8 to 450 ppm calcium. The average content was 30 ppm. Assuming a ratio of 400 to 1 as the amount of water needed to produce one pound of dry matter, even the lowest reading of 8 ppm would be sufficient calcium to reach plant roots.

Disorders such as blossom end rot in peppers and tomatoes, black heart in celery, internal tip burn in cabbage and cavity spot in carrots are attributed to calcium deficiency. These disorders can occur even in plants grown on soils high in calcium. Florida workers report that calcium deficiency in vegetables most likely occurs when the calcium content of the soil water (at saturation) is less than 10 percent of the total soluble salts. If calcium is low, then potassium, ammonium and/or sodium are high.

Sulfur (S) – Sulfur is an essential nutrient found in about the same amount in plants as phosphorus. One might suspect that sulfur deficiency could be widespread because of more intensive cropping and the increased use of fertilizers low in sulfur. Field trials, however, have not shown any need for sulfur as a plant nutrient. Soil mineral sources and sulfur fallout from industrial smoke and gasoline combustion are believed to exceed plant requirements.

If sulfur deficiency in crops should appear, the soils most likely to first show a need are the sandy soils of northern Michigan.

Table 9. Potash – potassium recommendations for field crops on loams, clay loam and clays.

Available soil potassium - pounds of K per acre					Pounds per Acre Annually Recommended K_2O	K
				0-59	300	249
			0-59	60-119	250	208
		0-59	60-119	120-179	200	166
	0-59	60-119	120-169	180-239	150	125
0-59	60-119	120-169	170-209	240-279	100	83
60-119	120-169	170-209	210-239	280-309	75	62
120-169	170-209	210-239	240-269	310-339	50	42
170-209	210-239	240-269	270-299	340-359	25	21
210+	240+	270+	300+	360+	0	0
Barley 40-69 bu Buckwheat Corn 60-89 bu Cover crops Field beans 15-29 bu Grass pasture (Unimproved) Grasses Timothy, Orchard, Brome Kidney beans 15-29 bu Millet Oats 50-79 bu Rye Soybeans 25-40 bu	Barley 70-100 bu Clover Corn 90-119 bu Corn silage 10-14T Field beans 30-50 bu Kidney beans 30-50 bu Oats 80-120 bu Soybeans 40+ bu Sorghum Sundangrass Wheat 25-40 bu	Alfalfa 3-4T topdressing Birdsfoot Trefoil Corn 120-149 bu Corn silage 15-19T Sugar beets 18-23T Wheat 40+ bu	Alfalfa 5-6T topdressing Corn 150+ bu Corn silage 20-30T Potatoes 250-350 cwt Sugar beets 24-28T	Alfalfa 7+ T topdressing Potatoes 350+ cwt		

Micronutrients for Mineral Soils

Manganese (Mn) – Mineral soils of Michigan may be deficient in manganese for the production of oats, beans, potatoes, sudangrass, sugar beets and spinach. In extreme cases, barley and most vegetables will respond to manganese. A deficiency is most likely to occur on dark-colored surface soils in lake bed or glacial outwash areas. Apply 5 to 10 pounds of manganese per acre in a band with the fertilizer near the seed. Suitable carriers are manganese sulfate, chelated materials and finely ground manganous oxide. Broadcast application is not recommended. Neither granular manganese oxide nor any of the manganic forms are acceptable manganese materials in blended materials.

Boron (B) – Two to three pounds of boron per acre may be needed for sugar beets, table beets, cauliflower, celery, turnips and rutabagas. Use 1 to 2 pounds per acre for alfalfa on sandy loams and sandy soils. Lettuce, broccoli, spinach and cabbage may need 1 pound of boron per acre. Never apply boron for beans, cucumbers, soybeans, peas or small grains.

Zinc (Zn) – Zinc is needed for beans and corn grown on alkaline soils of lake bed areas of eastern Michigan. The deficiency is especially noted on crops growing on soil banks, over the tile lines where calcareous subsoil is mixed-in or where soils test high in phosphorus.

For treatment on known deficient soils, apply in the band fertilizer 3 to 4 pounds of zinc from inorganic salts or 0.5 to 0.8 pounds from organic salts (chelates) per acre. Suggested rate as a preventive program is 2 pounds of zinc from an inorganic salt per acre. Granular forms of zinc oxide have not been effective. Foliar sprays have corrected the deficiency on beans and onions.

Foliar Application – Micronutrients can be absorbed through the leaves of plants from foliar applications. Where spray equipment is available, cost of material used is greatly reduced. If compatible, the micronutrients can be added to a fungicide or insecticide spray. Suggested micronutrient sources and rates per acre as sprays follow (page 14).

Table 10. Potash – potassium recommendations for field crops on sandy loams and loamy sands.

Available soil potassium - pounds of K per acre					Pounds per Acre Annually Recommended	
					K_2O	K
				0-59	250	208
			0-59	60-119	200	166
		0-59	60-119	120-169	150	125
	0-59	60-119	120-169	170-209	100	83
0-59	60-119	120-159	170-209	210-239	75	62
60-119	120-159	160-199	210-249	240-279	50	42
120-179	160-209	200-239	250-269	280-299	25	21
180+	210+	240+	270+	300+	0	0
Barley 40-69 bu Buckwheat Corn 60-89 bu Cover crops Field beans 15-29 bu Grass pasture (unimproved) Grasses Timothy, Orchard, Brome Kidney beans 15-29 bu Millet Oats 50-79 bu Rye Soybeans 25-40 bu	Barley 70-100 bu Clover Corn 90-119 bu Corn silage 10-14T Field beans 30-50 bu Kidney beans 30-50 bu Oats 80-120 bu Soybeans 40+ bu Sorghum Sudangrass Wheat 25-40 bu	Alfalfa 3-4T topdressing Birdsfoot Trefoil Corn 120-149 bu Corn silage 15-19T Sugar beets 18-23T Wheat 40+ bu	Alfalfa 5-6T topdressing Corn 150+ bu Corn silage 20-30T Potatoes 250-350 cwt Sugar beets 24-28T	Alfalfa 7+ T topdressing Potatoes 350+ cwt		

Rate per acre	Suggested source
1 to 2 pounds of manganese	water soluble manganese sulfate
½ to 1 pound of copper	basic copper sulfate
0.3 to 0.7 pounds of zinc	zinc sulfate
0.1 to 0.3 pounds of boron	soluble borate
1 ounce of molybdenum	found in 2 ounces of sodium molybdate

Use a minimum of 30 gallons of water per acre. All micronutrient rates are expressed as the element.

The micronutrients can be mixed in liquid or dry fertilizer by the manufacturer. At present the minimum percentages that may be sold with a claim are:

Element	Percent
Manganese	1.0
Boron	0.125
Copper	0.5
Zinc	0.5 (inorganic) or 0.125 (organic)
Molybdenum –	0.04
Iron	0.1
Sulfur	1.0

Animal Manures and Other Wastes

Manures are valuable primarily for their plant-nutrient content. They also serve as an excellent source of organic matter for improving soil physical condition. Table 12 gives some average plant nutrient figures for several kinds of common animal manures. During the first year, about 50 percent of the nitrogen and nearly all of the potassium are available. Presently, 4 pounds of nitrogen, 2 pounds of phosphate (P_2O_5) and 8 pounds of potash (K_2O) for each ton of cattle manure applied per acre are deducted from fertilizer recommendations given in preceding tables. Sheep and chicken manures add an additional 10 pounds of nitrogen per ton. Chicken manures add an additional 10 pounds of phosphate and sheep manures an additional 10 pounds of potash per ton above that for cattle manure.

Due to changes in farming practices, more manure is being spread per acre than in the past. Present research indicates that rates in excess of 15 tons per acre annually lead to nutrient imbalances. Soils receiving manure should be soil tested frequently and manure and fertilizer rates adjusted accordingly.

Municipal sewage effluents are also a rich source of nutrients, as well as a source of water for irrigation

Table 11. Micronutrient response and fertilizer needs as indicated by soil tests. (For responsive crops growing on known deficient soil types.)

MANGANESE (0.1 N HCl EXTRACTION)

Soil Test ppm Mn	Mineral Soils: Above pH 6.5 Response	Mn-lbs/A	Mineral Soils: pH 6.0-6.5 Response	Mn-lbs/A	Organic Soils: Above pH 6.4 Response	Mn-lbs/A	Organic Soils: pH 5.8-6.4 Response	Mn-lbs/A
Below 5	Probable	8	Probable	6	Certain	16	Certain	12
5-10	Probable	6	Possible	4	Certain	12	Probable	8
11-20	Possible	4	None	0	Probable	8	Possible	4
21-40	None	0	None	0	Possible	4	None	0
Above 40	None	0	None	0	None	0	None	0

ZINC FOR MINERAL AND ORGANIC SOILS (0.1 N HCl EXTRACTION)

Soil Test ppm Zn	Above pH 7.5 Response	Zn-lbs/A*	pH 6.7 to 7.4 Response	Zn-lbs/A*	Below pH 6.7 Response	Zn-lbs/A*
Below 2	Certain	5	Probable	3	Possible	2
3-5	Probable	3	Possible	3	None	0
5-10	Probable	3	Possible	2	None	0
11-15	Possible	2	None	0	None	0
Above 15	None	0	None	0	None	0

COPPER FOR ORGANIC SOILS

1.0N HCl EXTRACTION

Soil Test ppm Cu	Plant Response	Copper lbs/A
Below 9	Probable	6
10-20	Possible	3
21-40	None	0
41-80	None	0
81-160	None	0
Above 160	Excessive	0

Rates for inorganic salts such as zinc sulfate. Use one-fourth this rate for chelated materials.

Table 12. Average amounts of nitrogen, phosphorus, and potassium and the combined value of manures from different farm animals.

Kind of manure	Per-cent water	Pounds per ton of manure					Value per ton*
		N	P	P_2O_5	K	K_2O	
Chicken--							
a. From dropping boards, without litter	54	31	8	18	7	8	6.90
b. With old floor litter**	61	34	12	28	13	15	8.65
Dairy cattle	79	11	2	5	10	12	2.75
Fattening cattle	80	14	4	9	9	11	3.55
Hog	75	10	3	7	8	10	2.70
Horse	60	14	2	5	12	14	3.30
Sheep	65	28	4	9	20	24	6.30

**Calculated on the assumption that the present retail costs per pound are as follows: N, 15 cents; P_2O_5, 10 cents; and K_2O_5, 5 cents.*

***Probably contained some feed residues.*

SOURCE: Michigan State University Circular Bulletin 231, ANIMAL MANURES.

purposes. Systems for using municipal effluents in agricultural production are under intensive study. Numerous design, management, economic and other principles have to be worked out. The grower who has the opportunity to use municipal or industrial effluents should consult the local Soil Conservation Service and Cooperative Extension Service specialists.

Suggested Fertilizer Placement for Field Crops

Alfalfa, Alfalfa Brome, Clover, Birdsfoot Trefoil – The fertilizer recommendations for alfalfa seedings given in Tables 8 to 10 are for spring or summer clear seedings. Apply fertilizer at rates up to 100 pounds of phosphate plus 50 pounds of potash per acre through the grain drill. Fertilizer in excess of this amount should be broadcast and plowed down or disked in ahead of seeding. This fertilizer recommendation is sufficient to establish the legume and for growth until the first crop is removed. Beyond that point, additional fertilizer is required.

At planting, allow the legume seed to fall on top of the soil above the fertilizer band and cover ½ inch deep. To seed bromegrass, either mix the seed with a small grain or with the fertilizer.

Boron is needed annually on alfalfa at the rate of one to two pounds per acre. It should not be applied in combination seedings containing grass or small grain because of injury to these plants. Boron for the legume should be applied as a topdressing after the grass has become well established or the grain crop has been harvested.

Topdressing of alfalfa is suggested in early spring while the plants are dormant or immediately after a hay harvest.

Planting-time nitrogen is not suggested for spring or summer clear seeded alfalfa.

Small Grain, Legume Seeding – The recommendations in Tables 8 to 10 are for legumes seeded in small grain. This recommendation should be sufficient to carry the legume through the first cutting. A topdressing of additional fertilizer is suggested either early spring after the small grain is harvested (late fall on level fields) or after the first cutting.

At planting time, on sandy soils, do not exceed 100 pounds of plant nutrients ($N + P_2O_5 + K_2O$) per acre in direct contact with the seed. On fine textured soils do not exceed 140 pounds per acre. If larger amounts are required, apply in a separate operation. See the discussion on some grain drills in the next section.

Barley, Oats, Wheat, Rye – The proper place to apply fertilizer for small grains is one inch to the side and one inch below the seed. Many grain drills apply the fertilizer directly in contact with the seed. This placement can cause injury when large amounts are applied, especially when the soil is dry. Do not drill in direct contact with the seed more than a total of 100 pounds of plant nutrients ($N + P_2O_5 + K_2O$) for sandy soils and 140 pounds per acre for fine-textured soils. If additional amounts are needed, apply in a separate operation.

On winter grains, nitrogen in excess of planting time fertilizer should not be fall applied on sands, loamy sands or sandy loams. Similarly, it should not be applied on frozen ground on soils with greater than 3% slope.

Small grains, especially barley, growing on certain soils are likely to lodge. On these areas, use little or no nitrogen.

Manganese is recommended in the band fertilizer for wheat, oats, and barley growing on lake bed soils and dark colored flats where pH is above 6.5. Use 5 to 8 pounds of manganese per acre for soils with pH 6.5 to 7.2 and 8 to 10 pounds per acre for soils having pH 7.3 to 8.5.

Field Beans, Soybeans – Beans are very sensitive to fertilizer applied in contact with the seed. Apply fertilizer in the row 1 inch to the side and 2 inches below the seed. These crops often need manganese when grown on organic soils and dark colored sandy soils with a pH higher than 5.8, and lake bed soils and depressional areas having gray subsoil color with pH's above 6.5.

To prevent manganese deficiency, apply 4 to 8 pounds of manganese on mineral soils. Manganese is usually mixed with fertilizer and applied in a band near the seed. Foliar applications are also effective and are often preferred, especially in the production of soybeans.

Field beans, especially the Sanilac variety, have proven highly responsive to zinc fertilizer when grown on soils with pH of 7.2 or higher. The deficiency is particularly noticeable on land previously planted to sugar beets, or where calcareous subsoils are exposed by land leveling or after tiling. To prevent the deficiency, apply 3 to 4 pounds of zinc per acre in the row fertilizer. If organic forms such as zinc chelates are used, apply 0.5 to 0.8 pounds of zinc per acre.

Corn, Corn Silage – Phosphorus and potassium fertilizers in excess of the row fertilizer may be plowed down. Nitrogen can be sideplaced or plowed down. Row fertilizer should be placed two inches to the side and 2 inches below the seed. At this placement the fertilizer can include all of the phosphate and up to 100 pounds of the potash and 60 pounds of nitrogen per acre. The row fertilizer is usually high in phosphate, so as to stimulate rapid, even growth of corn during late spring.

Corn harvested for silage removes large amounts of plant nutrients. In a Michigan study, corn yielding 140 bushels of grain when harvested by a sheller removed 120 pounds of nitrogen, 52 pounds of phosphate, and 27 pounds of potash per acre. The same crop if harvested for silage removed 196 pounds of nitrogen, 69 pounds of phosphate, and 206 pounds of potash per acre. A comparison of the two practices illustrates that nutrient removal, especially potash, is great when silage is harvested.

Nitrogen should not be plowed down in the fall on sands, loamy sands or sandy loams. Similarly, it should not be broadcast on frozen ground with greater than 3 percent slope. Care should be used when applying anhydrous ammonia to completely trap the gas in the soil. Broadcast or spray applications of liquid nitrogen should not exceed 10 pounds per acre after emergence of the corn. Applications of greater than 10 pounds per acre can cause leaf burn. Broadcast or spray applications of liquid fertilizers containing phosphorus and potassium are not recommended because of the inefficient use of these nutrients. Many solutions are compatible with herbicides and this provides a convenient means for applying a pre-emergence herbicide and supplemental nitrogen.

Grass (pasture or hay) – Grass usually needs high-nitrogen fertilizer such as 2-1-1 or 4-1-2 ratio. This fertilizer may be topdressed in winter or early spring. Under intensive cropping, additional topdressings are applied during the growing season. When a new seeding is started, more liberal rates of phosphorus and potassium are applied. These materials are applied broadcast after plowing and then are disked into the top 3-4 inches of soil. Tables 8-10 report suggested fertilizer amounts based upon soil tests.

Potatoes – Apply up to 60 pounds of nitrogen, 200 pounds of phosphate, and 100 pounds of potash per acre in bands two inches to the side and level with or slightly below the seed pieces. Plow down or disc-in additional amounts when needed. Supplemental nitrogen can be either plowed down, sidedressed or applied in the irrigation water. Nitrogen applications made after plant emergence are generally more efficient than nitrogen plowed down. For suggested nitrogen rates, see Table 6. No more than 50 pounds of nitrogen per acre should be applied in the fall to cover crops grown on sands, loamy sands or sandy loams. No nitrogen should be applied on these textures if the soil is left bare. Similarly, nitrogen should not be broadcast on frozen soils with a slope greater than 3 percent.

Manganese may be needed when mineral soils test above pH 6.5. A soil test can help determine the available amounts of manganese. See Table 11 for micronutrient recommendations. Manganese may be applied as a foliar spray.

Fall applications of potash for the cover crop or plow-down applications in the spring are suggested for large rates of potassium chloride. Potassium sulfate and potassium nitrate are preferred potash carriers for late treatments, but are more expensive.

Potato varieties show differences in fertility requirements. Russet Burbanks show a greater need for nitrogen and potassium than Sebagos and Katahdins.

Sorghum, Sudangrass – Sorghum and Sudangrass grown for summer pasture or chopped forage have nutrient requirements similar to corn. In estimating fertilizer requirements, use the column in Tables 5, and 8 to 10 for corn that fits the nearest yielding capacity of the soil. Normally this is the column for the 100-bushels-per-acre yield goal.

Sugar Beets – Fertilizer for sugar beets should be applied in bands one inch to the side and two inches below the seed. A band three inches directly below the seed is satisfactory. Part of the fertilizer, however, may conveniently be broadcast before plowing.

If the soil pH is above 6.8, manganese and boron are recommended. They may be applied as part of the band fertilizer.

The quality of sugar beets is affected very markedly by past nitrogen management and presently applied nitrogen. Table 7 in the fore part of this bulletin gives suggested nitrogen rates for maximum tonnage and maximum recoverable sugar.

Recommendations for Vegetable Crops on Mineral Soils

Most vegetable crops require relatively high levels of fertility for optimum yields of satisfactory quality. Fertilizer may be applied to vegetables in one or more of the following ways: (1) applied at time of planting to the green manure or cover crop 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) sidedressed or topdressed; (7) applied to the leaves (foliar feeding).

Credit any fertilizer applied by any of the above methods to the total amounts recommended in Tables 13-15.

Some rules that will aid in making decisions are:

(1) For maximum growth, fertilize a green manure crop with a high analysis nitrogen fertilizer. The recovery of the nitrogen applied to a green manure crop will amount to about 40% for the first vegetable crop.

(2) When using a high analysis phosphorus fertilizer, place in bands near the seed so as to decrease soil phosphorus fixation.

(3) If phosphorus 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.

(4) Use starter solutions high in phosphorus for spring planting or transplants.

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

(6) Foliage application is an efficient way to correct or prevent some micronutrient deficiencies. It is not recommended for applying phosphorus and potassium fertilizer because of excessive cost, inability to supply sufficient nutrients and possibility of plant injury.

Fertilizers should be applied according to soil tests for P and K, as shown in Tables 13-15.

Suggested Fertilizer Placement

Some typical fertilizer recommendations for vegetables showing placement and nitrogen rates are given below. For specific amounts, have your soil tested.

Asparagus (new planting, crowns) – Plow down 50 pounds of nitrogen, 100 pounds of phosphate, and 80 pounds of potash per acre and apply 30 pounds of phosphate in the trench before setting plants. Later, sidedress with 30 pounds of nitrogen per acre during cultivation.

Asparagus (established planting) – Alternate applications of nitrogen at the rate of 40 to 60 pounds one year, with 50 pounds each of nitrogen, phosphate, and potash per acre on alternate years, applied at the end of harvesting season on soils with medium phosphorus and potassium tests. Eliminate nitrogen application if manure is applied.

Lima Beans, Snap Beans – Apply fertilizer two inches to the side and two inches below the seed. Do not apply directly in contact with the seed. Use 25 pounds of nitrogen, 100 pounds of phosphate, and 50 pounds of potash per acre for clay loams; 25 pounds of nitrogen and 60 pounds each of phosphate and potash per acre for sandy loams. Plow down extra fertilizer if needed. Sidedress beans with urea or ammonium nitrate to supply about 30 to 40 pounds of nitrogen per acre from the time 2 to 3 true leaves have appeared up to flowering, if foliage is light

Table 13. Phosphate – phosphorus recommendations for vegetables on mineral soils.

Available soil phosphorus -- pounds of P Per Acre				Pounds Per Acre Recommended P_2O_5	P
			0-19	300	132
		0-19	20-39	250	110
	0-19	20-39	40-69	200	88
0-19	20-39	40-69	70-99	150	66
20-39	40-69	70-99	100-149	100	44
40-99	70-149	100-199	150-199	50	22
100+	150+	200+	200+	0	0
Asparagus old beds Blueberries Lima Beans (30) Peas (40)* Snap Beans (60) Turnips	Carrots (200-400) Cucumbers (150) Endive Lettuce (250) Parsnips Pumpkins Radish (40) Rutabagas (200) Spinach (100) Sweet corn (100) Sweet potatoes Squash	Asparagus crowns, new beds Broccoli (120) Brussel sprouts Cabbage (200-600) Cauliflower (160) Cucumbers (200) over 40,000 plants Egg plant (150) Muskmelons (150) Peppers (40) Rhubarb (200) Table beets (300) Water melons	Celery (400) Flower beds Home garden Onions (400) Tomatoes (500) Market garden		

*Figure in parentheses after crop is the estimated yield potential in cwts. (100 lbs.) per acre.

Table 14. Potash – potassium recommendations for vegetable crops on loams, clay loams and clays.

Available soil potassium --pounds of K per acre				Pounds Per Acre Recommended K_2O	K
			Less than 60	300	249
		Less than 60	60-99	250	205
	Less than 60	60-99	100-149	200	166
Less than 60	60-99	100-149	150-199	150	125
60-99	100-149	150-199	200-249	100	83
100-149	150-199	200-299	250-349	50	42
150-199	200-249	-	-	25	21
200+	250+	300+	350+	0	0
Asparagus* (35) old beds Blueberries Lima Beans (30) Peas (40) Pumpkins Radish (40) Snap Beans (60) Squash Turnips	Asparagus crowns, new beds Carrots (200-400) Cucumbers (150) Endive Lettuce (250) Sweet corn (100)	Cabbage (200-600) Cucumbers (200) over 40,000 plants Egg plant (150) Flower beds Muskmelons (150) Onions (400) Parsnips Peppers (40) Rhubarb (200) Rutabagas (200) Spinach (100) Sweet potatoes Table beets (300) Watermelons	Broccoli (120) Brussel sprouts Cauliflower (160) Celery (400) Home garden Market garden Tomatoes (500)		

*Figure in parentheses after crop is the estimated yield potential in cwts. (100 lbs.) per acre.

Table 15. Potash – potassium recommendations for vegetable crops on sandy loams and loamy sands.

Available soil potassium -- pounds of K per acre				Pounds Per Acre Recommended K_2O	K
		Less than 60	Less than 100	300	249
	Less than 60	60-99	100-149	250	208
Less than 60	60-99	100-149	150-199	200	166
60-99	100-149	150-199	200-249	150	125
100-149	150-199	200-249	250-299	100	83
150-199	200-249	250-349	300-399	50	42
200-249	250-299	-	-	25	21
250+	300+	350+	400+	0	0
Asparagus (35)* old beds Blueberries Lima Beans (30) Peas (40) Pumpkins Radish (40) Snap Beans (60) Squash Turnips	Asparagus crowns, new beds Carrots (200-400) Cucumbers (150) Endive Lettuce (30) Lima Beans (30) Snap Beans (60) Sweet Corn (100)	Cabbage (200-600) Cucumbers (200) over 40,000 plants Egg plant (150) Flower beds Muskmelons (150) Onions (400) Parsnips Peppers (40) Rhubarb (200) Rutabagas (200) Spinach (100) Sweet potatoes Table beets (300) Watermelons	Broccoli (120) Brussel sprouts Cauliflower Celery (400) Home garden Tomatoes (500) Market garden		

*Figure in parentheses after crop is the estimated yield potential in cwts. (100 lbs.) per acre.

green. Manganese is often needed if pH of soil is above 6.5.

Carrots, Horseradish, Parsnips – Drill in or plow down the fertilizer before seeding. Use 50 pounds of nitrogen and 100 pounds each of phosphate and potash per acre on sandy loams. Topdress with 50 pounds of nitrogen per acre after plants are well started.

Table Beets, Rutabagas – Drill in fertilizer before seeding or apply in a band one inch to the side and two inches below the seed. Use 50 pounds of nitrogen, 150 pounds of phosphate, and 100 pounds of potash per acre for clay loams; 50 pounds of nitrogen, 120 pounds of phosphate, 120 pounds of potash and 1 pound of boron per acre for sandy soils. Topdress with 50 pounds of nitrogen.

Broccoli, Cabbage, Brussel Sprouts, Cauliflower – Plow down 40 to 60 pounds of nitrogen per acre with stubble or grain cover crops. For sandy soils, plow down or drill in after plowing, 50 pounds of nitrogen, 150 pounds of phosphate, 160 pounds of potash, and 1 to 2 pounds of boron per acre. Clay loams require about 200 pounds of phosphate and 100 pounds of potash per acre. Band, if possible, a part of the fertilizer near the plants or seeds. Use 4 ounces of sodium molybdate per acre for cauliflower. Use a high nitrogen starter solution for transplants (for amounts, see following information on starter solutions). Sidedress cauliflower with an additional 70 pounds of nitrogen per acre.

Sweet Corn – Plow down or sidedress about 120 pounds of nitrogen per acre. Apply N-P-K fertilizer high in phosphorus in a band 2 inches to the side and 2 inches below the seed. Extra potassium, if needed, can be plowed down.

Cucumbers – For pickling cucumbers, plow down 30 to 50 pounds of nitrogen per acre with stubble, grass, or grain cover crops. Drill in or broadcast and disk in balance of fertilizer. If fertilizer is placed in a band two inches to the side and two inches below the seed, do not apply more than 300 pounds per acre for 4-foot row spacings. Sidedress with 30 to 40 pounds of nitrogen per acre when the vines begin to run if the foliage becomes light or yellow green or if rainfall has been excessive. Drill in or disk in all the fertilizer where seeding rates exceed 40,000 per acre. A suggested rate is 700-1000 pounds of 10-20-20 per acre.

Apply in a band about 300 pounds of a fertilizer high in phosphorus, such as a 10-20-10, per acre. Place about 2 inches to the side of the seed. If the soil is above pH 6.7, use 2 percent manganese in the band fertilizer. If additional nitrogen and potassium are needed, disk in or plow down before seeding. Sidedress the crop about mid-season with 60 pounds of nitrogen per acre.

Muskmelons, Watermelons — At planting time, fertilize rye or ryegrass used for a green manure crop with 40 pounds each of nitrogen, phosphate, and potash per acre. For sandy soils, drill in, three or four inches deep, 50 pounds of nitrogen and 150 pounds each of phosphate and potash per acre after plowing. Use 50 pounds of nitrogen, 150 pounds of phosphate, and 100 pounds of potash per acre for clay loams. Sidedress with 60 pounds per acre of nitrogen three weeks after plants have emerged, or after transplanting.

Peas — Broadcast or drill two inches to the side of the seed 50 pounds each of nitrogen, phosphate, and potash per acre for sandy loams or 50 pounds of nitrogen, 100 pounds of phosphate, and 50 pounds of potash per acre on clay loams. If nitrogen deficiency is likely, topdress 20-30 pounds of nitrogen per acre when peas are 4-6 inches tall. To avoid leaf burn, apply only when plants are dry.

Radishes, Turnips — Drill in or disk in 50 pounds each of nitrogen, phosphate, and potash per acre. Boron may be needed at the rate of 1-2 pounds per acre.

Tomatoes — Plow down or drill in three or four inches deep 1/2 to 2/3 of the fertilizer recommended in Tables 11-13. Apply the remainder in bands three to four inches to the side and several inches below at planting time. Use starter solutions high in phosphate in transplanting. Apply additional nitrogen fertilizer, 30 to 90 pounds of nitrogen per acre when the first fruits are about the size of a half dollar. High rates often retard maturity but give high seasonal yields. Use 50-80 pounds of nitrogen per acre at planting time.

Rhubarb — In early spring apply 50 pounds of nitrogen, 100 pounds of phosphate, and 150 pounds of potash per acre. Sidedress with 50 pounds of N per acre two weeks after growth starts.

Market Gardens — Plow down about 50 pounds of nitrogen, 100 pounds of phosphate, and 100 pounds of potash per acre. In addition, broadcast and disk in a similar amount, or apply in bands 1 inch to the side and two inches below the seed at planting time. Make one or two applications of nitrogen between rows during the growing season. Nitrogen recommendations for individual crops are listed under the name of the crops. For other vegetables, use 40 to 100 pounds additional nitrogen per acre as indicated by foliage color. More nitrogen is needed for green leafy vegetables, tomatoes, peppers, sweet corn, and rhubarb than for beans, peas, cucumbers, melons, root crops, or asparagus.

Use starter solutions when transplanting cabbage, tomatoes, celery, etc. High analysis, water soluble fertilizers are available in most garden supply stores. Starter solutions may also be used to obtain growth of particularly leafy vegetable crops when soils are cold and temperatures are low. Avoid overfeeding, or salt burn may result.

Home Gardens — For home gardens, apply 10 to 15 pounds of fertilizer per 1,000 square feet before plowing or spading. After plowing, apply similar amounts into the soil several inches deep. Use 6-24-12, 5-20-20 or similar grades. Micronutrients may be needed. Their need is discussed under each vegetable.

In midsummer, fertilize with 5 pounds of ammonium nitrate or 4 pounds of urea per 1,000 square feet of area. Apply this in a band along the rows six inches to the side of the plants. To help maintain the organic matter level in gardens, rake in rye or wheat seed in early September. Topdress the grain cover crop some time during early March with 4 pounds of ammonium nitrate or 3 pounds of urea for each 1,000 square feet of land. If you use manure, cut all fertilizer rates in half.

Vegetables in Flats and Flowers for Transplanting — There are several alternative programs. These are:

(1) Use a complete fertilizer such as 6-24-12 or 10-20-10 at the rate of 2 to 3 pounds per cubic yard (about 20 bushels) of soil or other mix.

(2) Use a fertilizer solution every day after plants have emerged or less frequently if soil other than peat-lite or other synthetic mix is used. This fertilizer should be an all soluble starter solution made from high phosphate formulations such as 10-30-10. Dissolve two ounces of the dry fertilizer in 5 gallons of water and apply with a sprinkling can or hose-on attachment, to cover 75 to 100 square feet. With this program, no fertilizer needs to be added to the soil mix used in plant growing.

(3) Prepare special soil mixes, especially if the soil is steamed or fumigated. A suggested soil mix is two parts, by volume, of sand and one part of shredded peat. Another is a one-to-one mixture of peat and vermiculite. To each cubic yard of the mixture, add 12 ounces of potassium nitrate, and 3 pounds of 20 percent superphosphate. If acid peat (below

pH 5.0) is used, add 6 pounds of finely ground dolomitic limestone. Additional nitrogen is needed after plants are well started. Good materials are ammonium nitrate or calcium nitrate. Dissolve two ounces in 5 gallons of water and apply as noted for option 2.

(4) For constant plant feeding with soluble fertilizer in water, prepare soil mixes and lime additions as in option No. 3. Dissolve 12 ounces of 15-30-15 or 20-20-20 in one gallon of water. Apply with injector proportioner set at a dilution ratio of 1:100. If the basic soil mix has ample phosphorus, dissolve 6 ounces of potassium nitrate and 6 ounces of ammonium nitrate per gallon of water. Dilute 1:100 with water. The final concentration of the nutrients is about 200 ppm for both the nitrogren and the potash.

Starter Solution – Starter solutions can be used on your home garden. In cold weather, growth of crops such as lettuce and tomatoes and others are promoted by additional fertilizer. Use this solution in addition to the recommended rates of dry fertilizer. Commercial starter fertilizers can be either all soluble dry material such as 15-30-15, or, 10-50-10 or they can be liquid formulations. Follow manufacturer's recommendations when using concentrated fertilizers. Liquid and dry fertilizers are essentially equal in effectiveness.

Recommendations for Organic Soils

Organic soils are classified as mucks and peats. The most important organic soil series in Michigan are Carlisle, Carbondale, Greenwood, Houghton, Kerston, Lupton and Rifle.

Additional information on the management of organic soils is given in *Organic Soils Their Formation, Distribution, Utilization and Management*, Michigan State University Agricultural Experiment Station Special Bulletin 425.

Lime Requirements

Within each series, acidity or alkalinity varies, except that Greenwood is always very acid. Crop production does not benefit from liming unless soil pH (1:2 soil: water suspension) is below 5.2, *except celery requires a soil pH of 5.5 or above.* Blueberries benefit from lime applications if soil pH is below 4.0. Apply 4 tons per acre if soil pH is below 4.0.

When the soil test magnesium level is less than 150 pounds per acre and lime is required, use at least 1 ton of dolomitic lime per acre.

In some cases, the surface foot of soil may have a pH around 5.0 and the second foot around 4.0. If the soil is plowed sufficiently deep to bring some of the acid soil to the surface, lime according to soil test on a sample taken after plowing.

Lime requirements for organic soils are shown in Table 16.

Some problem areas may be due to acid or alkaline layers in the rooting zone. In problem areas, check the soil pH at 6 inch intervals to a depth of 2 or 3 feet. Newly established areas should be tested for pH at 6 inch intervals to a depth of 2 or 3 feet.

Table 16. Lime requirements of organic soils.

Soil pH	Lime Requirement
	Tons/acre
4.9-5.0	3
4.6-4.8	5
4.2-4.5	8*
3.8-4.1	10*

**Plow down half and disc in other half after plowing.*

Effect of Time of Soil Sampling

In the case of newly reclaimed organic soils or soils which have not been heavily fertilized there is little change in soil test levels from one time of the year to another. Consequently, time of sampling is not important on these soils.

On organic soils which have been fertilized for 2 or 3 years, the time of sampling is important. Considerable amounts of potassium leach over winter. The potash recommendations in Table 18 are for samples collected in the fall. *For samples collected between January and June decrease recommendations for potash by 25 percent.*

Major Nutrients

Nitrogen requirements are given for each crop in the section on fertilizer management. Conditions which may suggest the need for additional nitrogen are: (1) organic layers less than 18 inches deep,

(2) soil pH less than 5.2, (3) heavy rainfall, (4) high water table and (5) low soil temperatures in the spring. If any one of these conditions exist, increase the suggested amounts by 30-50%, applying it as a top-or sidedress application.

Phosphate and potash requirements are given in Tables 17 and 18.

Micronutrients

Organic soils are often low in manganese, boron, copper, molybdenum, and zinc. High value crops, particularly, should be fertilized with micronutrients if conditions indicate possible need.

Micronutrients can be absorbed through the leaves of plants. Where spray equipment is available, cost of material used is greatly reduced. Suggested rates as sprays are discussed on pages 13 and 14.

Manganese (Mn) – Manganese deficiency is likely to occur on organic soils with a pH of 5.8, or above. Such a deficiency can be corrected by the application of manganese salts or by the addition of enough sulfur to acidify the soil. 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 20 are grouped according to the degree of response to treatment with manganese. The amount of manganese recommended according to soil test is shown in Table 11. Soil fixation can be very great, particularly when the fertilizer is broadcast. For this reason, place the manganese in bands near the seed. If manganous oxide is used as the manganese carrier, use only finely ground material with acid forming fertilizers. Manganese must be applied yearly, since there is usually no carryover in the available form. Chelated forms of manganese have not been effective when applied to organic soils.

Boron (B) – The need for fertilizing with boron on organic soils depends on the crop grown (see Table 19). Boron is generally applied broadcast or drilled in before seeding and should not be banded near the seed. Corn, barley, and beans may be injured by boron applications.

The availability of boron in the soil is affected by lime content. For this reason, the amounts suggested in Table 19 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 to use quantities greater than those suggested in Table 19 for table beets.

Table 17. Phosphate – phosphorus fertilizer recommendations for organic soils.

Available soil phosphorus -- pounds of P Per Acre				Pounds Per Acre Recommended P_2O_5	P
			0-19	300	132
		0-19	20-39	250	110
		20-39	40-69	200	88
	0-19	40-69	70-99	150	66
	20-39	70-99	100-149	100	44
0-19	40-69	100-149	150-199	50	22
20-49	70-99	-	-	25	11
50+	100+	150+	200+	0	0
Blueberries Clover Oats Pasture (grass) Rye Soybeans-35 bu	Asparagus Beans (snap) Corn-130 bu Mint-70 lb Radishes Sudangrass Sweet corn Turnips	Bluegrass sod Brussel sprouts Cabbage Carrots Cucumbers Endive Horseradish Lettuce-500 cwt Parsnips Potatoes-400 cwt Rutabagas Spinach Swiss chard Sugar beets Table beets	Broccoli Cauliflower Celery-600 cwt Home Garden Market Garden Onions (bunching) Onions dry-600 cwt Onions dry-600 cwt		

*Figure in parentheses after crop is the estimated yield potential in cwts. (100 lbs.) per acre.

Copper (Cu) – Acid, peaty soils are usually low in copper. Liming will not decrease the need. The carriers used for fertilizers are usually either the sulfate or oxide forms. 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 cooper 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 20 show the degree of response to copper fertilization, and data in Table 11 show copper recommendations.

Zinc (Zn) – Zinc deficiency is more likely to occur on nearly neutral or alkaline organic soils. Onions, beans, and corn are affected under Michigan conditions. Apply 3 to 4 pounds of zinc annually for 3 or 4 years, then reduce rate to 1 pound per acre.

Molybdenum (Mo) – Molybdenum deficiency has been noted on lettuce, spinach, cauliflower, cabbage, and onions. The organic soils that need molybdenum are below pH 5.5. Soils with high iron content also show a need for molybdenum.

The suggested treatment for molybdenum is a foliar spray application of 2 ounces of sodium molybdate per acre or a seed treatment at a rate of ½ ounce of sodium molybdate per acre. For seed treatment dissolve the ½ ounce of sodium molybdate in 3 tablespoons of water. Mix with seed required for one acre.

Table 19. Boron recommendations for organic soils – elemental basis.

Crop Response	Pounds per acre pH 5.0-6.4	pH 6.5-8.0
High	2	3
Medium	1/2	1
Low	0	1/2

Table 18. Potash – potassium fertilizer recommendations for organic soils.

Available soil potassium -- pounds of K Per Acre					Pounds Per Acre Recommended K_2O	K
				Less than 150	600	498
				150-249	500	416
			Less than 125	250-349	400	332
			125-199	350-424	350	290
		Less than 125	200-274	425-499	300	249
	Less than 100	125-199	275-349	500-574	250	208
	100-174	200-274	350-424	757-649	200	166
Less than 100	175-249	275-349	425-500	650-724	150	125
100-199	250-324	350-424	500-574	725-799	100	83
200-299	325-399	425-499	575-649	800-899	50	42
300+	400+	500+	650+	900+	0	0
Blueberries Oats Rye Pasture (grass)	Beans (Snap) Clover Corn 130 bu Bluegrass sod Soybeans 35 bu Sudangrass Sweet corn Turnips	Asparagus Cabbage Carrots Cucumbers Endive Lettuce 500 cwt Mint 70 lb Parsnips Radishes	Broccoli Brussel Sprouts Cauliflower Home Garden Market Garden Onions (Bunching) Dry Onions 600 cwt Potatoes 400 cwt Rutabagas Spinach Sugar beets Swiss Chard Table beets	Celery 600 cwt		

If no soil test is made and soils are low in fertility, use the amounts of potash suggested for 150 pounds of available potassium per acre. Test soil annually if little or no potash is recommended, because potash reserve can change greatly.

Broccoli, Cabbage, Cauliflower – Drill 50 pounds of nitrogen and all of the phosphate and potash into the soil 4 inches deep prior to planting. Sidedress additional nitrogen as needed; usually 30-60 pounds of nitrogen is sufficient. If the soil pH is 5.8 or above, boron and manganese should be applied. Below pH 5.8, only boron is needed. Molybdenum seed treatment or foliage spray is recommended.

Carrots, Parsnips – Disc in or plow down fertilizer containing boron and copper. Discing in is the preferred method of application.

An alternate program is to plowdown a fertilizer high in potassium (for example a 1-2-4 ratio) containing boron and copper. The remainder of the fertilizer can be applied in a band 3 inches below the seed. Use a fertilizer high in phosphate (for example a 1-4-2 or 2-4-1 ratio) for the remainder of the fertilizer needs. Do not exceed 250 pounds of nitrogen plus potash in the row on 14 inch rows. Lower rates should be used on wider rows. Sidedress additional nitrogen as needed. On well drained high organic soils, use a total of 50 pounds of nitrogen. On sandy mucks and marly soils, use a total of 80 to 120 pounds of nitrogen.

Celery – Disc or drill in the fertilizer after plowing. Apply 1 pound of boron and 2 pounds copper per acre. Spray foliage with manganese if the soil pH is above 6.5.

Table 20. Crop response to micronutrients (organic soils).

Crop	Micronutrient response			Others May be Needed
	Manganese	Boron	Copper	
Alfalfa	Medium	High	High	
Asparagus	Low	Low	Low	
Barley	Medium	None	Medium	Zinc
Beans	High	None	Low	Zinc
Blueberries	None	None	Medium	Iron
Broccoli	Medium	Medium	Medium	Molybdenum
Cabbage	Medium	Medium	Medium	Molybdenum
Carrots	Medium	Medium	Medium	
Cauliflower	High	High	Medium	Molybdenum
Celery	Medium	High	Medium	
Clover	Medium	Medium	Medium	Molybdenum
Cucumbers	Medium	Low	Medium	
Corn	Low	Low	Medium	Zinc
Grass	Low	None	Low	
Lettuce	High	Medium	High	Molybdenum
Oats	High	None	High	
Onions	High	None	High	Zinc, Molybdenum
Parsnips	Medium	Medium	Medium	
Peas	High	None	Low	
Peppermint	Low	None	Low	
Potatoes	High	Low	Low	
Radishes	High	Medium	Medium	
Rye	None	None	None	
Spearmint	Medium	None	Low	
Soybeans	High	None	Low	
Spinach	High	Medium	High	Molybdenum
Sudangrass	High	None	High	
Sugar beets	Medium	High	Medium	
Sweet corn	Medium	Low	Medium	
Table beets	High	High	High	
Turnips	Medium	High	Medium	
Wheat	High	None	High	

*See Table 11 for micronutrient needs based on soil test for zinc, manganese and copper.

Sidedress one to three times during the growing season at the rate of 50 pounds of actual nitrogen per acre per application. The number of applications will depend upon the season, drainage, and type of muck. The color of the plant and plant tissue tests will help determine your nitrogen needs. Avoid excessive rates of ammonia forms of nitrogen in the spring if the soil has been fumigated. Ammonia fertilizers can be used after June 15.

Certain celery varieties need magnesium applied as a spray. Use Epsom salts (magnesium sulfate) at the rate of 10 pounds per acre per week. If this rate does not correct the magnesium yellowing, increase the rate to 20 pounds. Calcium is needed to prevent blackheart disorder and is applied as calcium chloride at the rate of five to ten pounds per acre weekly.

Corn (field or sweet) – Plant population goals should be about 20,000 plants per acre. Band a complete fertilizer 2 inches to the side and below the seed. Do not exceed 250 pounds of nitrogen plus potash in the band. Plow down additional potash requirements prior to planting. Sidedress supplemental nitrogen (50-80 pounds) if the plants are not dark green in color in late June. Manganese, zinc and copper may be needed.

Head Lettuce, Spinach – Apply a high phosphate fertilizer (1-4-2, 2-4-1- ratio) in a band 1 inch to the side and 2-3 inches below the seed. Do not exceed 250 pounds of nitrogen plus potash in the row at planting time. Plow down additional potash requirements prior to planting. Sidedress with 50 pounds of nitrogen at blocking time.

Apply ½ pound of boron and 2 pounds of copper in the row at planting time. If the soil pH is 5.8-6.4 use 5 pounds of manganese and if it is above 6.4, apply 10 pounds per acre in the row at planting. Molybdenum seed treatment may be needed on acid fibrous peats.

Onions – Apply a high phosphate fertilizer (1-4-2, 2-4-1 ratio) in a band 2-3 inches below the seed. Do not exceed 250 pounds of nitrogen plus potash in the band on 14 inch rows. Plow down additional potash requirements prior to planting. Side or topdress with 80 pounds of nitrogen in June.

Apply 2-4 pounds of copper and 3 pounds of zinc in the band at planting time. If the soil pH is 5.8-6.4 apply 5 pounds of manganese and if it is above 6.4 apply 10 pounds of manganese per acre in the row at planting time.

Peppermint, Spearmint – Drill in or broadcast the phosphate and potash in the spring before the crop emerges. Topdress in June with 70 pounds of nitrogen. Use a pelleted form and apply when the foliage is dry. **Use of a drag or finger-tooth harrow at this stage of growth may increase the incidence of wilt.**

If soil pH is above 6.5, apply 5 pounds of manganese with the spring applied fertilizer.

Potatoes – Apply a high phosphorus analysis fertilizer 2 inches to the side and 2 inches below the seed piece. Do not exceed 250 pounds of nitrogen plus potash in the band on 28 inch rows. Plow down additional potash requirements prior to planting. Nitrogen is required at 50-60 pounds per acre. Extra nitrogen may be needed if June is cold, if the field is poorly drained or if the soil has a pH less than 5.0. Apply 30-50 pounds in late June or early July for late potatoes.

Apply 10 pounds of manganese in the row if the soil pH is above 6.0. Manganese may be sprayed on the foliage at the rate of 1 pound per acre four times during the growing season.

Table Beets, Swiss Chard, Radish, Turnips, Rutabagas – Drill in or disk in fertilizer. Use 1 pound of boron per acre in the fertilizer for radishes, 2 pounds boron for turnips, rutabagas and swiss chard, and 4 pounds for table beets. If soil pH is above 6.0, use 5 to 10 pounds of manganese per acre in the fertilizer for all crops. In-row application of manganese sulfate is especially needed for the production of radishes. For phosphate-potash rates, see Tables 17 and 18.

Beans, Soybeans – See Tables 17-18 for rates of phosphate and potash. Disk in or plow down the fertilizer. If the pH is above 6.0, plow down the potash and place in a band near the seed a fertilizer high in phosphorus which contains manganese. Additional manganese may be needed for soybeans and can be applied as a spray on affected plots with 2 pounds of manganese (actual) in 15 gallons or more of water per acre. Use 1 to 3 pounds of zinc per acre in row fertilizer for field beans if pH is above 6.5.

Sod – Turfgrasses used in sod production are somewhat less responsive to phosphate and potash than most vegetable crops. These nutrients should be applied at rates based on soil tests suggested in Tables 22 and 23, and worked into the soil before establishment.

After fall seedings have emerged, 25-40 pounds nitrogen per acre can be topdressed. Suggested annual nitrogen rates for established sod are 90-150 pounds nitrogen per acre for Merion Kentucky bluegrass, 80-120 pounds for other Kentucky bluegrasses, and 40-80 pounds for red fescues. Intermediate rates should be used for mixtures and blends of these grasses. Nitrogen should be applied at 4 to 6 week intervals during the growing season. DO NOT apply more than 40 pounds nitrogen per acre at any one time.

A minimum of two applications of nitrogen per year are suggested with more applications when higher rates are used. Summer nitrogen applications should be used primarily to maintain color and growth desired or to "green-up" the sod before harvest.

Sod and Turfgrasses on Mineral Soils

Sod production on mineral soils requires more nitrogen than on organic soils. Recommended rates are 200-300 pounds nitrogen per acre per year for Merion Kentucky bluegrass, 120-200 pounds for other Kentucky bluegrasses, and 80-160 pounds for red fescues. For mixtures or blends of these grasses, intermediate rates are best.

Nitrogen should be applied at 4 to 6 week intervals during the growing season with a maximum of 60 pounds of nitrogen per acre in one application.

Phosphate and potash should be applied according to soil tests based on Tables 22 and 23 and worked into the soil before establishment.

Turfgrasses are most responsive to nitrogen, although adequate levels of other nutrients are also needed. The suggested ranges for annual nitrogen requirements for several turfgrass species in Michigan are shown in Table 21.

Liberal irrigation, especially on sandy soils, may require increasing these levels somewhat for optimum quality turf. Such conditions may increase leaching, however. Careful, well-planned irrigation and fertilization schedules will reduce the potential for leaching. If use of the turf area permits, a lower nitrogen-requiring grass (such as creeping red fescue) should be planted on sandy sites, especially along lakes and streams.

The nitrogen rates suggested in Table 21 may be decreased by 20 to 40 percent if clippings are returned to the turf. The lone exception to this is for fairways where clipping return is already assumed. Personal judgment is important in evaluating the nitrogen needed to maintain the desired quality and vigor of the turf.

Nitrogen fertilizers should be applied a minimum of 2 times per year, spring (April-May) and late summer (late August-early September). Grasses usually respond best when about two-thirds of the nitrogen is applied in the spring and one-third in late summer. No more than 1 to 1.5 pounds of nitrogen per 1000 square feet should be applied at one time, especially during warm weather. For grasses which require 5 or more pounds nitrogen per 1000 square feet annually, a minimum of 4 applications is suggested.

Phosphorus and potassium applications should be based upon soil tests. Soil samples should be taken from the 0-2 inch soil depth with the thatch discarded. Tables 22 and 23 are guides for determining the desired rates of phosphorus and potassium, respectively. Generally, no more than 1.5 pounds of any element should be applied per 1000 sq. feet at one time. If recommendations call for more than this amount, consider two or more applications.

Lime should be applied if pH drops below 5.7 in

Table 21. Annual nitrogen requirements for Michigan turfgrasses.

Turfgrass	Pounds Nitrogen Per 1,000 sq. ft
Merion Kentucky Bluegrass	5-7
Kentucky Bluegrasses (Delta, Park, Kenblue)	2-4
Other Kentucky Bluegrasses	3-6
Creeping Red Fescue, sunny areas	2-4
Creeping Red Fescue, shady areas	1-2*
Colonial Bentgrasses	3-6
Greens, Tees	4-8
Fairways	2-5

**With deep root feeding of trees.*

established turf. Soil pH should be checked periodically on intensively managed turfs. Acidifying nitrogen fertilizers can reduce soil pH with continued use. Liberal irrigation from a hard water source can cause a marked increase in pH. This often leads to iron deficiency on golf greens and other closely-mowed turfs. Iron can be applied as a chelate (follow manufacturer's recommendations) or as ferrous sulfate (1½ to 2 ounces per 1000 square feet every 2 weeks or as needed).

Soil Management Groups

Soil management groups have been worked out cooperatively by the Soil Conservation Service of the United States Department of Agriculture, the Cooperative Extension Service, and the Michigan Agricultural Experiment Station. These are basic interpretive soil groupings. They are based on properties of the soil profile to a depth of 3.5 to 5.5 feet.

A soil management group identification chart is given in Table 24 and the soil management group designation for each soil series is shown in Table 25.

Experiences with soil management groups are used to indicate practical yield potentials with good management practices. The yield estimates in Tables 26 and 27 for southern and northern Michigan, respectively, help determine the yield goals to use with the fertilizer recommendations in Tables 5-10. These yields assume that adequate drainage has been supplied on soils of the "b" and "c" management groups.

The group numbers shown in the left hand column of Tables 26 and 27 indicate the relative coarseness of the mineral materials in the upper three feet of the soil profile: from 0, for the finest textured clays, to 5, for the coarsest textured sands. The small letters immediately following the numbers or capital

Table 22. Phosphate applications for turf based on soil test.

Soil Test (Lbs. P/Acre)	Pounds Phosphate (P_2O_5) Recommended		
	General Turf & Sod		Golf Greens
	Per 1000 Sq Ft	Per Acre	Per 1000 Sq Ft
Less than 15 (very low)	3	130	4
16-25 (low)	2	85	3
26-40 (medium)	1	45	2
41-70 (high)	0	0	1
More than 70 (very high)	0	0	0

Table 23. Potash applications for turf based on soil test.

Soil Test (Lbs. K/Acre)	Pounds Potash (K_2O) Recommended		
	General Turf & Sod		Golf Greens*
	Per 1000 Sq Ft	Per Acre	Per 1000 Sq Ft
Less than 50 (very low)	4	170	5
51-100 (low)	3	130	4
101-174 (medium)	2	85	3
175-250 (high)	1	45	2
More than 250 (very high)	0	0	1

**Including golf greens and other high maintenance turf on sandy soils with high irrigation rates.*

Table 24. Soil management group identification chart.

Soil Management Group Numbers	Texture of Upper Three Feet of the Soil Profile	Natural Drainage* a	b	c
0	Clays (over 55%)	-	-	0c
1	Clay to silty clay	1a	1b	1c
1.5	Clay loams	1.5a	1.5b	1.5c
2.5	Loams	2.5a	2.5b	2.5c
3	Sandy loams and stratified silts and very fine sands	3a	3b	3c
3/1	Sandy loams over clay to silty clay at 15-42"	3/1a	3/1b	3/1c
3/2	Sandy loams over loams or clay loams at 18-42"	3/2a	3/2b	3/2c
4	Loamy sands	4a	4b	4c
4/1	Sands or loamy sands over clay to silty clay at 18-42"	-	4/1b	4/1c
4/2	Sands or loamy sands over loams or clay loams at 18-42"	4/2a	4/2b	4/2c
5/2	Sands or loamy sands over loams to clays at 42-66"	5/2a	5/2b	5c
5.0	Sands with moderate or deep subsoil development	5a	5b	5c
5.3	Sands with little subsoil development	5.3a	5b	5c
5.7	Coarse sands with little or no subsoil development	5.7a	5b	5c
G	Gravelly loamy sand or sandy loams	Ga	Gc	Gc
L	Alluvial or overflow area (lowlands)	3a-L	3c-L	3c-L
M	Mucks or peats	-	-	-

**a* - *well drained, light colored;* *b* - *somewhat poorly drained, moderately dark colored;* *c* - *poorly drained, dark colored.*

letters indicate the natural drainage under which the soil developed; "a" is for well drained or moderately well drained; "b" is for imperfectly* drained, and "c" is for the more poorly drained conditions.

Where another letter follows the small letter which indicates the natural drainage and is separated from it by a dash, it indicates other characteristics of the soils important to their use. For example, a small "a" after a dash represents very acid subsoils; "c" indicates soils calcareous or limy at the surface; and "h" indicates subsoils which are hard and cemented.

For soils where the texture of the upper layer differs from the lower layer, a fraction is used instead of a whole number. For example, 4/1 is for loamy sand 18 to 42 inches thick over clay; 5/2 is for sand 42 to 66 inches thick over loams or clay. Where bedrock is within 18 to 42 inches of the surface, a capital R is shown as the denominator.

Where capital letters are the first part of the symbol, they represent important soil characteristics as follows: G for gravelly or stony soils, L for low-land or alluvial soils subject to overflow, M for muck and peats, and R for rocky soils where the bedrock is less than 18 inches from the surface. M/m is for 12 to 42 inches of muck or peat over marl. The small letters following these capital letter designations indicate the natural drainage conditions under which they were formed.

Thus, the L-4a soil management group reported for the Abscota series includes naturally well drained or moderately well drained soils of loamy sand to sand textures throughout the profile, which were formed on lowlands subject to seasonal overflow. The 3a-a soil management group includes upland mineral soils, such as Munising, developed from sandy loam materials under well-drained conditions which are naturally very strongly acid throughout the profile. The M/lc soil management group includes shallow organic soils (mucks and peats) over silty clay or clay within 12 to 42 inches below the surface which were naturally very poorly drained. The Mc soil management group includes deep organic soils which are naturally very poorly drained. The soil management group designations for each of the soil series recognized to date in Michigan are reported in Table 25.

The soil series in your field can be determined from the published soil survey reports. Soil interpretation sheets are available for each of these series. You may obtain the available information from your County Agricultural Extension or Soil Conservation Service office or the Crop and Soil Sciences Department, Michigan State University.

Additional information concerning soils of Michigan is given in "*Soils of Michigan*" Extension Bulletin E-360, available at the County Extension Office.

**Somewhat poorly drained is a synonym for "imperfectly drained.*

Table 25. Management group designation for different soil series. See tables 26 and 27 for suggested yield goals.

Soil Series	Soil Mgm't. Group*
Abscota	L-4a
Adolph	2.5c
Adrian	M/4c
Ahmeek	3a-a
Alcona	3a
Algansee	L-4c
Alger	3a
Allendale	4/1b
Allouez	Ga
Alpena	Ga
Amasa	3a-a
Angelica	2.5c
Antrim	4a
Arenac	5/2b
Arkport	3a
Auburndale	2.5b
AuGres	5b
AuTrain	5a-h
Avoca	4/2b
Bach	2.5c-c
Baraga	Ga
Barker	1.5a
Barry	3c
Belding	3/2b
Bellefontaine=Fox	
Bentley	4a
Bergland	0c
Berrien	5/2a
Berville	3/2c
Bibon	5/2a
Blount	1.5b
Blue Lake	4a
Bohemian	2.5a
Bono	1c
Bowers	1.5b
Boyer	4a
Brady	4b
Brant=Menominee	
Breckenridge	3/2c
Brems	5b
Brevort	4/2c
Bridgman**	5.3a
Brimley	2.5b
Bronson	4a
Brookston	2.5c
Bruce	2.5c
Brule	L-2c
Burleigh	4/2c
Burt	3/Rbc
Cadmus	3/2a
Capac	2.5b
Carbondale	Mc
Carlisle	Mc
Casco	4a
Cathro	M/3c
Celina	2.5a
Ceresco	L-2c
Champion	3a-a
Channing	5b-h
Charity	1c-c
Charlevoix	3b
Chatham	3a
Chelsea	5a
Cheneaux	4b

Soil Series	Soil Mgm't. Group*
Chesaning=Iosco	
Chippeny	M/Rc
Cohoctah	L-2c
Coldwater	3b
Coloma	4a
Colwood	2.5c
Conover	2.5b
Coral	3b
Corunna	3/2c
Coventry	3a
Crivitz	4a-a
Crosby	2.5b
Crosien	2.5b
Croswell	5a
Crystal Falls	3/Ra
Dafter	2/1b
Dawson**	Mc-a
Deer Park**	5.3a
Deerton	4/Ra
Deford	4c
Del Rey	1.5b
Detour	Gbc
Diana	Gbc
Dighton	2.5a
Dowagiac	3a
Dresden	3a
Dryburg	3/2a
Dryden	3a
Duel	4/Ra
East Lake	5a
Eastport**	5.3a
Echo	5a
Edmore	4c
Edwards	M/mc
Eel	L-2a
Elmdale	3a
Elo	2.5a-a
Emmert	Ga
Emmet	3a
Ensign	Rbc
Ensley	3c
Epoufette	4c
Essexville	4/2c-c
Evart	L-4c
Ewen	L-2a
Fabius	4b
Fairport	2/Ra
Fence	2.5a
Fox	3a
Froberg	1a
Fulton	1b
Gaastra	2.5b
Gagetown	2.5a-c
Gay	3c
Genesee	L-2a
Gilchrist	4a
Gilford	4c
Gladwin	4b
Glendora	L-4c
Glengary	L-2c
Gogebic	3a-a
Goodman	2.5a
Gormer	L-2c
Granby	5c

Soil Series	Soil Mgm't. Group*
Graycalm	5a
Grayling**	5.7a
Greenwood**	Mc-a
Griffin=Shoals	
Guelph	2.5a
Hartwick=Kalkaska	
Hessel	Gbc
Hettinger	1.5c
Hiawatha	5a
Hibbing	1.5a
Hillsdale	3a
Hodunk	3a
Homer=Brady	
Houghton	Mc
Hoytville	1c
Huron=Huronville	
Huronville	1.5a
Ingalls	4/2b
Ionia	3a
Iosco	4/2b
Iron River	3a-a
Isabella	2.5a
Jeddo	1.5c
Johnswood	3a
Kalamazoo	3a
Kalkaska	5a
Karlin	4a
Kawbawgam	3/Rbc
Kawkawlin	1.5b
Kendallville	3/2a
Kent	1a
Kerston	L-Mc
Keweenaw	4a-a
Kibbie	2.5b
Kinross	5c
Kiva	4a
Kokomol	2.5c
Lacota	3c
Lake Linden	1.5a
Lamson	3c
Landes	L-2a
Lapeer	3a
Latty	1c
Leelanau	4a
Lenawee	1.5c
Linwood	M-3c
Locke	3b
Londo	2.5b
London-Londo	
Longlois	2.5a
Longrie	3/Ra
Loxley	Mc-a
Lucas	1a
Lupton	Mc
Mackinac	2.5b
Macomb	3/2b
Mancelona	4a
Manistee	4/2a
Marenisco	4a-a
Markey	M/Ac
Marlette	2.5a
Matherton	3b
Maumee	5c
McBride	3a

Soil Series	Soil Mgm't. Group*
McGregor	3b-c
Mecosta	L-4a
Melita	5/2a
Menominee	4/2a
Metamora	3/2b
Metea	4/2a
Miami	2.5a
Michigamme	3/Ra
Minoa	3b
Missaukee	3b
Monico	3b-a
Montcalm	4a
Moran	2/Ra
Morley	1.5a
Morocco	5b
Moye	4b
Munising	3a-a
Munuscong	3/1c
Mussey	4c
Nahma	3/Rbc
Nappanee	1b
Negaunee	3/Ra
Nekoosa=Brems	
Nester	1.5a
Nestoria	3a
Newaygo	3a
Newton	5c
Nisula	1b
Nunica	1.5a
Oakville	5a
Ockley	2.5a
Ocqueoc	4/2a
Ogden	M/1c
Ogemaw**	5b-h
Ogontz	3/2c
Omega**	5.7a
Omena	3a
Onaway	2.5a
Onota	3/Ra
Ontonagon	0a
Orienta	5/2b
Oshtemo	4a
Otisco	4b
Ottawa	5/2a
Ottokee	4a
Owosso	3/2a
Padus	3a-a
Palms	M/3c
Palo	3b
Parkhill	2.5c
Parma	3/Ra
Paulding	0c
Pelkie	L-2c
Pence	4a-a
Pennock	L-2c
Perrin	4a
Pert	1.5b
Perth=Pert	
Peshekee	Ra
Pewamo	1.5c
Pickford	1c
Pinconning	4/1c
Pinora	1-2c
Plainfield	5a

Table 25 (Continued)

Soil Series	Soil Mgm't. Group*	Soil Series	Soil Mgm't. Group*	Soil Series	Soil Mgm't. Group*	Soil Series	Soil Mgm't. Group*
Pleine	3c	Sebewa	3c	Sunfield	3a	Volinia	3a
Porcupine=Mancelona		Seeleyville	Mc	Superior	1a	Wainola	4b
Posen	3a	Selfridge	4/2b	Tacoosh	M/3c	Waiska	Ga
Poygan	1.5c	Selkirk	1b	Tahquamenon**	Mc-a	Wakefield	2.5a-a
Randville	4a-a	Seward	3/1a	Tappan	2.5c-c	Wallace**	5a-h
Richter	3b	Shelldrake**	5.3a	Tawas	M/4c	Wallkill	L-2c
Rifle	Mc	Shoals	L-2c	Teasdale	3b	Warners	M/mc
Rimer	3/1b	Sigma	4b	Tedrow	5b	Warsaw	3a
Rodman	Ga	Sims	1.5c	Thackery	2.5a	Wasepi	4b
Rollin	M/mc	Sisson	2.5a	Thetford	4b	Washtenaw	L-2c
Ronald	3c	Skanee	3b-a	Thomas	1.5c-c	Watton	1.5a
Roscommon	5c	Sleeth	2.5b	Thomastown=Wainola		Waukesha=Warsaw	
Roselawn=Rubicon		Sloan	L-2c	Tobico	5c-c	Wauseon	3/1c
Roselms	0b	Spalding**	Mc-a	Toledo	1c	Wea	2.5a
Rousseau	4a	Sparta	5a	Tonkey	3c	Weare=Kalkaska	
Rubicon**	5.3a	Spinks	4a	Traunik	5b	Westland	2.5c
Rudyard	0b	Spirit	2.5b	Traverse	3b	Wexford=Kalkaska	
Ruse	Rbc	Stambaugh	3a-a	Trenary	3a	Wheatley	5c
Saganing	4c	St. Clair	1a	Trout Lake**	5b-h	Whittemore=Wisner	
Sanilac	2.5b-c	St. Ignace	Ra	Tula	3b	Willett	M/1c
Saranac	L-2c	Steuben	3a-a	Tuscola	2.5a	Winegars	4b
Satago	2/Rbc	Strongs=Kalkaska		Twining	1.5b	Wisner	1.5c-c
Sauble**	5.3a	Summerville	Ra	Tyre	4/Rbc	Witbeck	3c
Saugatuck**	5b-h	Sumner	4a	Ubly	3/2a	Yalmer	4a-a
Saverine	3/2b	Sundell	3/Rbc	Vilas**	5.3a	Ypsi	3/1b

**Modifying symbols used after dash in soil management groups:*
a--Naturally very strongly acid soils.
c--Soils which are limy at or near the surface.
h--Subsoils are hardened and cemented.
***Practicability of fertilizers doubtful.*

Table 26. Suggested average yield goals for crops grown on different soil management groups under good management with adequate drainage in areas with growing seasons of OVER 140 FROST-FREE DAYS ANNUALLY. (Southern Michigan).

Soil management group*	Corn	Corn silage	Winter wheat	Oats	Field beans soybeans	Alfalfa 3 cuts	Sugar beets
	Bu./A	Tons/A	Bu./A	Bu./A	Bu./A	Tons/A	Tons/A
Clays							
0c	90	15	35	75	25	3.8	-
1a	95	16	42	80	28	4.2	-
1b	110	17	45	85	32	4.5	18
1c	120	18	50	90	35	4.8	20
Clay loams							
1.5a	105	17	50	85	35	5.0	-
1.5b	115	18	55	90	40	5.5	19
1.5c	125	19	60	100	42	6.0	23
Loams							
2.5a	110	17	55	90	35	4.8	19
2.5b	120	18	60	100	40	5.0	20
2.5c	130	20	60	110	45	5.5	23
Sandy loams over Clay or Loam							
3/2a	105	17	50	90	35	4.5	18
3/1b or 3/2b	115	18	55	95	40	4.8	20
3/1c or 3/2c	120	18	60	100	40	5.0	22
Sandy loams							
3a	95	16	45	80	30	4.0	16
3b	105	17	50	90	33	4.5	19
3c	110	17	55	95	35	4.8	21
3/Ra	85	14	40	75	28	3.8	-
Loamy sands over Clay or Loam							
4/2a	95	16	40	75	30	4.0	15
4/2b-4/1b	100	16	45	80	35	4.2	16
4/2c-4/1c	105	17	50	85	35	4.5	18
Loamy sands							
4a	75	13	30	60	25	3.5	-
4b	80	13	35	65	32	3.8	-
4c	90	15	45	75	32	4.0	-
4/Ra or 4/Rb	55	11	25	50	22	3.0	-
Sands							
5.0a	50	10	25	45	-	3.0	-
5b	60	11	30	55	-	3.5	-
5c	80	13	40	60	25	3.8	-

*See page 27 for identification of soil management groups and Table 25 for the designation of the management groups for different soil series.

Table 27. Suggested average yield goals for crops grown on different soil management groups under good management with adequate drainage in areas with growing season of LESS THAN 140 FROST-FREE DAYS ANNUALLY. (Northern Michigan).

Soil management group	Corn silage	Corn	Winter wheat	Field beans	Oats	Alfalfa 2 cuts
	Tons/A.	Bu./A	Bu./A	Bu./A	Bu./A	Tons/A
Clays						
0c	-	-	30	-	75	3.5
1a	12	75	35	25	70	3.5
1b	13	80	35	30	75	3.5
1c	14	85	40	35	75	3.5
Clay loams						
1.5a	13	80	40	30	75	3.7
1.5b	14	85	42	35	80	3.8
1.5c	15	90	45	40	85	4.0
Loams						
2.5a	15	90	45	35	80	4.0
2.5b	15	90	48	40	85	4.0
2.5c	16	95	50	45	90	4.5
Sandy loams over Clay or Loam						
3/2a	13	80	40	35	80	4.0
3/1b or 3/2b	14	85	40	37	85	4.0
3/1c or 3/2c	15	90	42	40	85	4.0
Sandy loams						
3a	12	75	35	25	75	3.5
3b	13	80	35	30	80	3.5
3c	14	85	40	35	85	3.5
3/Ra	11	70	30	25	70	3.0
Loamy sands over Clay or Loam						
4/2a	11	70	35	25	70	3.5
4/2b-4/1b	13	80	40	28	75	3.5
4/2c-4/1c	13	80	40	30	75	3.5
Loamy sands						
4a	11	70	28	20	60	3.0
4b	11	70	30	25	65	3.0
4c	12	75	35	30	70	3.0
4/Ra or 4/Rb	10	50	25	-	40	2.5
Sands						
5.0a	9	50	25	-	40	2.5
5b	10	55	25	-	45	2.5
5c	11	70	30	-	50	3.0

*See page 27 for identification of soil management groups and Table 26 for the designation of the management groups for different soil series.