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Fertilizer Recommendations

Vegetable and Field Crops in Michigan

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Vegetable and Field Crops in Michigan

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The Michigan State University soil testing service offered for Michigan farmers is part of a continuing soil fertility program of the Crop and Soil Sciences Department and the Cooperative Extension Service. Soil samples can be submitted to the MSU Soil Testing Lab directly or through your County Cooperative Extension Service Office.

Fertilize field and vegetable crops on the basis of a soil test, soil type, yield goal and past crop management. Fertilizer recommendations given in this bulletin are based on the above factors. In each section "Field Crops," "Vegetables" and "Organic Soils" method of fertilizer application is discussed along with recommended rates. Applying recommended fertilizer rates with proper timing and incorporation will prevent fertilizers from being a source of surface or ground water pollution. Fertilizers applied near crop planting time or sidedressed nitrogen are utilized most efficiently for crop production. On sloping soils, incorporate fertilizers to prevent runoff loss.

With many types and grades of fertilizer available, the nitrogen, phosphorus and potassium requirements of crops can be met in a variety of ways (see Extension Bulletins E-896, Fertilizer Types, Uses and Characteristics; E-933, Liquid Fertilizers; and E-937, Understanding the MSU Soil Test: Results and Recommendations).

Soil Sampling

A soil test must be made from a representative soil sample. Soil test results and subsequent fertilizer recommendations will be no better than the soil sample.

For general rotation crops, test soils at least once every 3 years. Under intensive use for high-value field or vegetable crops, test soils 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 difference in soil characteristics. A soil survey map will be helpful. 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 topsoil 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, burned muck, or any unusual areas. Be sure the sub-samples are well mixed, and place a pint of the soil in the sample box for mailing to the laboratory. Soil sample boxes are available from your County Cooperative Extension Service Office.

Extension Bulletin E-498, "Sampling Soils for Fertilizer and Lime Recommendations" provides additional information on how to collect soil samples.

Soil Testing

Soil tests on samples representative of a field are necessary before you can be sure of what plant nutrients to apply to eliminate deficiencies as a limiting factor in crop production. Applying supplemental nutrients according to soil test results will help maximize crop yields, crop quality and net returns. Many other factors must also be managed properly for optimum crop production.

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.

Use only soil tests obtained by the Bray P_1 (absorbed) method as a basis for selecting the phosphorus recommendations 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 are measured by volume. This is necessary because such materials usually have much lower densities than mineral soils. Results for organic soils are expressed on a volume acre farrow slice basis.

Available nutrient content of soils is reported as pounds of actual phosphorus, P, and potassium, K,/acre by most soil testing labs. And the fertilizer recommendations are given in pounds of phosphate, P_2O_5, and potash, K_2O,/acre. The conversion factors are:

pounds $P \times 2.3 =$ *pounds* P_2O_5

pounds $K \times 1.2 =$ *pounds* K_2O

Basis for Recommendations

Numerous field studies throughout the state provide the basis for the nutrient recommendations. Soil test levels of the plow layer have been correlated with actual crop responses to fertilizer nutrients. For soil and cropping systems where direct field data is unavailable, nutrient recommendations are based on theoretical considerations combined with field data from similar soil systems.

Phosphorus and potassium recommendations provided by the Michigan State University Soil Test Lab provide for build-up of low fertility soils, maintaining desirable available nutrient levels for optimum crop production, and a gradual draw-down of available nutrient levels in very high fertility soils. With a desirable available P or K level, a maintenance recommendation equal to crop removal is given. Nutrient removal by several Michigan field crops is given in the chart below.

Nutrient Removal by Several Michigan Field Crops[1].

NUTRIENT REMOVAL				LBS/ACRE		
Crop	Yields			N	P_2O_5	K_2O
Corn	(Grain)	150	bu	135	53	40
	(Stover)	4.5	tons	100	37	145
	(Silage)	25	tons	235	90	195
Soybeans[2]	(Grain)	40	bu	150	35	55
Wheat	(Grain)	40	bu	50	25	15
	(Straw)	1.5	tons	20	5	35
Oats	(Grain)	80	bu	50	20	15
	(Straw)	2	tons	25	15	80
Rye	(Grain)	30	bu	35	10	10
	(Straw)	1.5	tons	15	8	25
Sorghum	(Grain)	60	bu	50	25	15
	(Stover)	3	tons	65	20	95
Sugar Beets	(Roots)	15	tons	60	20	50
Potatoes	(Tubers)	500	cwt	167	67	316
Field Beans[2]	(Seed)	18	cwt	75	25	25
Alfalfa[2]	(Hay)	5	tons	225	50	225
Bromegrass	(Hay)	3	tons	90	18	140

[1]*Source: USDA Miscellaneous Publication No. 369 and "Feeds and Feeding" by Morrison. 22nd Edition.*
[2]*Legumes get most of their Nitrogen from air.*

When soil test levels of P or K are less than desirable, additional fertilizer is recommended to build-up the available level in the soil. Hence, the total amount of P or K recommended includes both the build-up and maintenance recommendations. A gradual build-up to the desirable soil test level will occur in approximately five years.

When available P or K levels are well above the desirable range, very little or no fertilizer is recommended, allowing the crop to utilize the nutrients available in the soil system. This will cause a gradual decrease in available P and K levels. The actual rate of decrease depends upon soil type, the crop grown and the yield. As the soil test level approaches the desirable range, the recommendation again approaches maintenance.

Retest soils every two or three years to check the fertility reserves in the plow layer. With high value crops, testing every year is desirable. Before going to a conservation tillage system of crop production it is essential to build-up available phosphorus and potassium to optimum levels.

Yield potentials in Tables 27 and 28 represent practical yields under good management. These yields are based on years of field experience with different soil management groups. Yield potential on individual fields can vary substantially from these averages, depending upon management practices. 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 judgement 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. Accumulation of nutrients above a level where crop response is obtained leads to deleterious effects on soils and crops. It also increases the potential of environmental pollution due to possible erosion and/or leaching of nutrients into surface or ground waters.

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.

Soil Acidity and Liming

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

Table 1. Tons of limestone needed to raise soil pH of mineral soils to pH 6.0, 6.5 or 6.8 as determined by the "Lime Index" method.

Lime Index	Tons Lime/Acre *(9" Plow Depth)*[1]		
	to pH 6.0	to pH 6.5	to pH 6.8
70	—	—	0.5
69	—	0.5	1.0
68	1.1	1.5	1.8
67	1.9	2.4	2.6
66	2.7	3.3	3.6
65	3.5	4.3	4.7
64	4.3	5.3	5.7
63	5.1	6.2	6.7
62	5.8	7.2	7.8
61	6.6	8.1	8.9
60	7.4	9.1	10.0

[1]*To convert lime recommendations to depth of plowing other than 9 inches, divide above rates by 9 and multiply by the depth of plowing. Maximum lime application for one season is 6 tons. Retest soil in 2 years for additional lime needs.*

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, lime acid soils to pH 6.5. If alfalfa is to be grown, lime the soil 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 content. The degree of acidity is reported as the "Lime Index." This method of determining lime requirement 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 1 shows the amount of limestone recommended based upon the "Lime Index" value for mineral soils. For organic soils, see Table 20.

Applying less than 1 ton lime per acre is of questionable economic value. When the lime requirement is less than 1 ton/acre, soil pH is usually adequate for optimum crop production. Retest these soils in two years to determine lime need.

Apply a maximum of 6 tons lime/acre in any one season. Applying more may cause localized zones of high alkalinity, reducing availability of essential nutrients. Retest soil with a "Lime Index" of 6.4 or below two years after application to determine additional lime need.

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. Do not exceed 2 tons lime/acre at any one time and apply it in the fall for the potato crop next year.

Further information on liming is discussed in MSU Extension Bulletin E-471.

RECOMMENDATIONS FOR

Field Crops on Mineral Soils

Major Nutrients

NITROGEN (N) — Nitrogen needs depend on crop to be grown, yield goal, and previous management practices. Nitrogen fertilizer recommendations based on these factors are given in Tables 2, 3 and 4. If the season is cool and wet and/or the field is poorly drained, additional quantities of nitrogen may be necessary.

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. 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.

A number of nitrogen materials are offered for sale (see Extension Bulletin E-896). Usually, the materials are equally effective and should be purchased on the

Table 2. Nitrogen fertilizer guides for corn.

Previous crop or manure application	Yield Goal/Acre					
	60-89 Bu 10-14 Tons	*90-119 Bu 15-19 Tons*	*120-149 Bu 20-24 Tons*	*150-179 Bu 25-30 Tons*	*180-209 Bu*	*210-240 Bu*
	Pounds of nitrogen/acre					
Legume and 10 tons manure/acre	0	0	50	100	150	200
Good legume	10	40	90	140	190	240
Manure 10 tons/acre	30	60	110	160	210	260
No legumes, no manure	70	100	150	200	250	300

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

Table 3. Guide for estimating total nitrogen needed for small grains, potatoes, beans and grassland.

Manure Application	*Barley Oats Rye*	*Wheat*[1]	*Field Beans or Soybeans*[2]	*Grass (Pasture or hay)*		*Potatoes-cwt/acre*[3]		
				Low level management	High level management	250-349	350-449	450-550
	Pounds of nitrogen/acre							
Legume and 10 tons of manure/acre	10	10	0	0	0	50	80	110
Good legume	10	30	10	0	0	90	120	150
Manure 10 tons/acre	10	50	10	0	50	110	140	170
No legume or manure	40	80	40	60	100	150	180	210

[1]Recommendations are for short-and stiff-strawed varieties. For varieties susceptible to lodging, use no more than 60 pounds N/acre on sandy soils and 40 pounds N/acre on fine textured soils.

[2]South of Lansing no nitrogen is recommended for soybeans.

[3]Russet Burbanks will generally require an additional 30 to 40 pounds of nitrogen to obtain the same yield goal as other full season varieties.

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. Ammonium forms are recommended for fall application on the fine textured soils to minimize leaching loss. Fall nitrogen applications are not suggested for sandy loams, loamy sands and sand soils.

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 are composed of a series of orthophosphate molecules connected by the process of dehydration. They are a satisfactory source of phosphorus and have many desirable properties. (For additional information see Extension Bulletin E-896). 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.

Table 4. Nitrogen recommendations for sugar beets.

Previous Management	Previous Nitrogen Rate pounds/acre		
	< 50	50 to 100	> 100
	Pounds of nitrogen per acre		
Legume and Manure (10 T/A)	10	10	10
Good Legume	10	10	10
Manure (10 T/A)	30	10	10
No Legume or Manure	60	40	20

Phosphorus fertilizers show their greatest benefits for fast growth of small seedlings, particularly when soil temperatures are low. For barley, corn, wheat, field beans, kidney beans and sugar beets which are seeded when soil temperatures are low, a minimum of 25 pounds P_2O_5/acre is desirable in the starter fertilizer, even when the phosphorus soil test is high. Fertilizers high in phosphorus are generally recommended in starter solutions or in bands near the seed. Once a crop has developed a good root system, the plant is better able to utilize soil phosphorus.

Studies have shown 5 to 11 pounds P_2O_5/acre are required to increase the soil test 1.0 pound P/acre in sandy loam and loamy sand soils. To increase the P soil test 1.0 pound/acre in loams and clay loams requires 12 to 16 pounds P_2O_5/acre. These values can be used to determine the amount of phosphate fertilizer required to build-up the P soil test to a desired level. Phosphorus recommendations given in this bulletin provide for build-up of low phosphorus soils over a five-year period. More rapid or immediate build-up can be accomplished by using the values given above. Tables 5 to 10 provide phosphorus recommendations based on soil test results for various field crops.

POTASSIUM (K) — Potassium chloride (muriate of potash), which contains 60 percent K_2O, is the most common and cheapest source of potassium. It is highly effective for nearly all field crops. Potassium sulfate, potassium-magnesium-sulfate and potassium nitrate are other effective carriers which are used for specialty crops such as potatoes, blueberries, greenhouse tomatoes and in potting soil mixes. These 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 of potassium is particularly heavy when the 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. Depending upon soil texture, 2 to 6 pounds K_2O/acre are required to increase the soil test 1.0 pound K/acre. 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. Make a corrective application of an additional 1,000 pounds K_2O. Once such soils have a good test, they will continue to supply potash for some time even though crop removal may be considerable. Research has shown that more soil K is released to an available form on clay loam soils than on loamy sands. Therefore, less potassium fertilizer is needed on soils high in clay for maximum yields. Recommended potash (K_2O) rates are given in Tables 5 to 10.

Table 5. Annual phosphorus (P_2O_5) and potassium (K_2O) recommendations for alfalfa grown on mineral soil.

Yield, ton/acre	*3-4*	*5-6*	*7-8*
Test Level	**Phosphorus recommendations, lb P_2O_5/acre**		
0 - 19 lb P/acre	75	100	125
20 - 39	50	75	100
40 - 59	25	50	75
60 - 79	0	25	50
80 - 99	0	0	25
100+	0	0	0
Potassium recommendations, lb K_2O/acre on sandy loams and loamy soils			
0 - 49 lb K/acre	300	350	400
50 - 99	250	300	350
100 - 149	200	250	300
150 - 199	150	200	250
200 - 249	100	150	200
250 - 299	50	100	150
300 - 349	0	50	100
350 - 399	0	0	50
400+	0	0	0
Potassium recommendations, lb K_2O/acre on loams, clay loams and clay			
0 - 49 lb K/acre	300	400	500
50 - 99	200	300	400
100 - 149	150	200	300
150 - 199	100	150	200
200 - 249	50	100	150
250 - 299	0	50	100
300 - 349	0	0	50
350+	0	0	0

Table 6. Annual phosphorus (P_2O_5) and potassium (K_2O) recommendations for small grains.

Wheat, bu/acre		*25-39*	*40-64*	*65-90*
Barley, bu/acre		*40-69*	*70-100*	
Oats, bu/acre	*50-79*	*80-109*	*110-140*	
Test Level	**Phosphorus recommendations, lb P_2O_5/acre**			
0 - 19 lb P/acre	50*	75	100	125
20 - 39	25	50	75	100
40 - 59	0	25	50	75
60 - 79	0	0	25	50
80 - 119	0	0	0	25
120+	0	0	0	0
Potassium recommendations, lb K_2O/acre on sandy loams and loamy sands				
0 - 49 lb K/acre	100*	100	150	200
50 - 99	75	75	100	150
100 - 149	50	50	75	100
150 - 199	25	25	50	75
200 - 249	0	25	25	50
250 - 299	0	0	0	25
300+	0	0	0	0
Potassium recommendations, lb K_2O/acre, on loams, clay loams and clays				
0 - 49 lb K/acre	150*	150	200	250
50 - 99	100	100	150	200
100 - 149	50	50	100	150
150 - 199	25	25	50	100
200 - 249	0	0	25	50
250 - 299	0	0	0	25
300+	0	0	0	0

**Recommendations in this column apply to rye, buckwheat, millet, grass pasture.*

Table 7. Annual phosphorus (P_2O_5) and potassium (K_2O) recommendations for dry beans and soybeans on mineral soils.

Field Beans, cwt/acre:	*10-19*	*20-30*
Kidney Beans, cwt/acre:	*10-19*	*20-30*
Soybeans, bu/acre:	*20-40*	*40-60*
Test Level	**Phosphorus recommendations, lb P_2O_5/acre**	
0 - 19 lb P/acre	50	75
20 - 39	25	50
40 - 59	0	25
60+	0	0
Potassium recommendations, lb K_2O/acre, on sandy loams and loamy sands		
0 - 49 lb K/acre	100	150
50 - 99	75	100
100 - 149	50	75
150 - 199	25	50
200 - 249	0	25
250+	0	0
Potassium recommendations, lb K_2O/acre, on loams, clay loams and clays		
0 - 49 lb K/acre	100	150
50 - 99	50	100
100 - 149	25	50
150 - 199	0	25
200+	0	0

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 27 & 28) 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/acre, or (2) if potassium exceeds magnesium as a percent of the total bases (calcium plus magnesium plus potassium, expressed as milliequivalents/100 grams of soil), 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, apply at least 1,000 pounds of dolomitic limestone. On soils which are not acid, a magnesium deficient situation may be corrected by 50 to 100 pounds Mg/acre broadcast or 10 to 20 pounds Mg/acre row applied. Magnesium sulfate (epsom salts), potash-magnesium-sulfate or finely ground magnesium oxide are all satisfactory sources of magnesium.

Magnesium can be applied as a foliar spray. Suggested rates/acre are 10 to 20 pounds of magnesium sulfate (epsom salts) in at least 30 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. If you are concerned with "grass tetany," avoid excessive rates of potassium fertilizer, and feed legume hay, which is generally high in magnesium. You might also consider magnesium carriers which can be mixed with grain or salt rations. Contact your animal feed specialist for amounts and sources. See Extension Bulletin E-994 for more on magnesium.

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.

The calcium content of soil water varies between 8 to 450 ppm and averages near 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 supply sufficient calcium to 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. The disorders are more related to environmental factors which influence calcium uptake than to low soil calcium content. Calcium deficiency symptoms are many times preceded by a period of moisture stress. 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. Maintaining very high potassium soil test levels can contribute to calcium-related disorders.

Studies in Wisconsin and Indiana have shown alfalfa and corn to yield equally well at a wide range of calcium to magnesium ratios. Therefore, adding calcium to improve the calcium to magnesium ratio is not necessary. See Extension Bulletin E-996 for more on calcium.

SULFUR (S) — Sulfur is an essential nutrient found in plants in about the same amount as phosphorus. You might suspect that sulfur deficiency could be widespread because of more intensive cropping, the increas-

Table 8. Annual phosphorus (P_2O_5) and potassium (K_2O) recommendations for corn grown on mineral soils.

Yield *Grain, bu/acre:* *Silage, tons/acre:*	*90-119* *10-14*	*120-149* *15-19*	*150-179* *20-24*	*180-209* *25-30*	*210-240*
Test Level	**Phosphorus recommendations, lb P_2O_5/acre**				
0 - 19 lb P/acre	75	100	125	150	175
20 - 39	50	75	100	125	150
40 - 59	25	50	75	100	125
60 - 79	25	25	50	75	100
80 - 99	25	25	25	50	75
100 - 119	25	25	25	25	50
120 - 139	0	0	0	25	25
140+	0	0	0	0	0
	Potassium recommendations, lb K_2O/acre, on sandy loams and loamy sands				
0 - 99 lb K/acre	150	200	250	300	300
100 - 149	100	150	200	250	275
150 - 199	75	100	150	200	225
200 - 249	50	50	100	150	175
250 - 299	0	25	50	100	125
300 - 349	0	0	0	50	75
350+	0	0	0	0	0
	Potassium recommendations, lb K_2O/acre, on loams, clay loams and clays				
0 - 99 lb K/acre	150	200	300	400	400
100 - 149	100	150	200	300	350
150 - 199	50	100	150	200	250
200 - 249	0	50	100	150	200
250 - 274	0	0	50	100	150
275 - 299	0	0	0	50	100
300 - 324	0	0	0	0	50
325+	0	0	0	0	0

ed use of fertilizers low in sulfur, and the cleanup of industrial smokestacks. Field trials, however, have not shown any need for sulfur as a plant nutrient. Soil mineral sources 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. Additional information on sulfur is available in Extension Bulletin E-997.

Micronutrients for Mineral Soils

Micronutrient fertilizer recommendations are based on soil pH, soil test and crop response for each. A brief discussion of each is given. Detailed information is presented in bulletin E-486, "Secondary-and Micronutrients for Vegetables and Field Crops."

MANGANESE (Mn) — Mineral soils of Michigan may be deficient in manganese for the production of oats, beans, peas, potatoes, soybeans, sudangrass, sugar beets, spinach, and wheat. 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 and above pH 6.5. Manganese availability decreases with increases in pH. Liming can, therefore, induce a Mn deficiency on soils with marginal available Mn levels. Determining precisely the Mn availability in soil is difficult because its availability changes with oxidation state.

Table 11 provides general guidelines for rates of Mn to apply in a band with starter fertilizer for responsive crops. Suitable carriers are manganese sulfate, chelated materials and finely ground manganous oxide. Manganese chelates are no more effective than manganese sulfate. Neither granular manganese oxide nor any of the manganic forms are acceptable manganese materials. Since Mn is fixed very readily in soil, broadcast application is not recommended. Manganese can

Table 9. Annual phosphorus (P_2O_5) and potassium (K_2O) recommendations for potatoes grown on mineral soils.

Yield, cwt/acre	*200-349*	*350-449*	*450-550*
Test Level	**Phosphorus recommendations, lb P_2O_5/acre**		
0 - 39 lb P/acre	150	200	250
40 - 79	125	150	200
80 - 119	100	125	175
120 - 169	75	100	150
170 - 219	50	75	125
220 - 269	25	50	100
270 - 319	0	25	75
320 - 399	0	0	50
400+	0	0	25
Potassium recommendations, lb K_2O/acre on sandy loams and loamy sands			
0 - 49 lb K/acre	300	350	350
50 - 99	250	300	350
100 - 149	200	250	300
150 - 199	150	200	250
200 - 249	100	150	200
250 - 299	50	100	150
300 - 349	0	50	100
350 - 399	0	0	50
400+	0	0	0
Potassium recommendations, lb K_2O/acre on loams, clay loams and clays			
0 - 49 lb K/acre	300	400	400
50 - 99	200	300	400
100 - 149	150	200	300
150 - 199	100	150	200
200 - 249	50	100	150
250 - 299	0	50	100
300 - 349	0	0	50
350+	0	0	0

Table 10. Annual phosphorus (P_2O_5) and potassium (K_2O) recommendations for sugarbeets grown in mineral soils.

Yield, ton/acre	*18-23*	*24-28*
Test Level	**Phosphorus recommendations, lb P_2O_5/acre**	
0 - 19 lb P/acre	150	200
20 - 39	125	150
40 - 59	100	125
60 - 79	75	100
80 - 99	50	75
100 - 119	25	50
120 - 160	0	25
160+	0	0
Potassium recommendation, lb K_2O/acre on sandy loams and loamy sands		
0 - 49 lb K/acre	200	250
50 - 99	150	200
100 - 149	125	150
150 - 199	100	125
200 - 249	75	100
250 - 299	50	75
300 - 349	0	50
350+	0	0
Potassium recommendations, lb K_2O/acre on loams, clay loams and clays		
0 - 49 lb K/acre	200	300
50 - 99	150	200
100 - 149	100	150
150 - 199	75	100
200 - 249	50	75
250 - 299	0	50
300+	0	0

be applied foliar if band application is not possible. Two to three applications of 1 to 2 pounds Mn/acre will be necessary at key times. For more information on Mn see Extension Bulletin E-1031.

BORON (B) — Boron recommendations are based on crop response. Two to three pounds of boron/acre may be needed for sugar beets, table beets, cauliflower, celery, turnips and rutabagas. Use 1 to 2 pounds/acre for alfalfa on sandy loams and sandy soils. Lettuce, broccoli, spinach and cabbage may need 1 pound of boron/acre. Plant available boron occurs as an water-soluble anion subject to leaching. Hence, annual applications are essential for boron responsive crops. Never apply boron for beans, cucumbers, soybeans, peas or small grains since they are sensitive to boron injury. See Extension Bulletin E-1037 for more on boron.

ZINC (Zn) — Zinc is needed for beans and corn grown on alkaline soils of lake bed areas of eastern Michigan. Deficiency is especially noted on crops growing on spoil banks, over tile lines where calcareous subsoil is mixed in or where soils test high in phosphorus.

Extractable (0.1NHCl) Zn, coupled with soil pH, provides a very good indicator for availability of Zn to plants. Zinc availability decreases as pH increases. Therefore, more Zn is recommended at higher pH levels for a given Zn soil test level. Recommended rates in Table 12 are for inorganic salts of Zn. Organic salts (chelates) can be used at one-fifth the rates given in Table 12. Granular forms of zinc oxide have not been effective. Band applications are suggested, but broadcast applications are acceptable. Unlike manganese, Zn remains available in the soil. Annual applications of Zn will buildup available Zn levels gradually eliminating the need for supplemental Zn. Foliar sprays of 0.5 pounds Zn/acre (as inorganic salt) have proven effective

Table 11. Manganese fertilizer needs as indicated by soil tests (0.1 N HCl extractable) for responsive crops.

	Mineral Soils		*Organic Soils*	
Soil Test	*pH 6.0 to 6.5*	*Above pH 6.5*	*pH 5.8 to 6.4*	*Above pH 6.4*
ppm Mn	**Pounds Mn/acre**			
Below 5	6	8	12	16
5-10	4	6	8	12
11-20	0	4	4	8
21-40	0	0	0	4
Above 40	0	0	0	0

Table 12. Zinc fertilizer needs as indicated by soil tests (0.1 N HCl extractable) for responsive crops.

	Mineral Soils		
Soil Test	*Below pH 6.7*	*pH 6.7 to 7.4*	*Above pH 7.4*
ppm Zn	**Pounds Zn/acre**		
Below 2	2	3	5
3-5	0	3	3
5-10	0	2	3
11-15	0	0	2
Above 15	0	0	0

in correcting Zn deficiencies of growing crops. Extension Bulletin E-1012 contains additional information on zinc.

Animal Manures

Manures are valuable primarily for their plant-nutrient content and as an excellent source of organic matter for improving soil physical condition. Table 13 gives some average plant nutrient figures for several kinds of common animal manures. During the first year, about 50 percent of the nitrogen and phosphorus, 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/acre are deducted from fertilizer recommendations given in preceding Tables. Sheep and chicken manures add an additional 10 pounds of nitrogen/ton. Chicken manures add an additional 10 pounds of phosphate and sheep manures an additional 10 pounds of potash/ton above that for cattle manure.

Test soils receiving manure frequently and adjust manure and fertilizer rates accordingly. Incorporate manures as soon as possible after application to prevent nutrient loss by volatilization or runoff. Manures may be incorporated by disking or plowing, and liquids may be knifed into the soil. Apply manures when soil moisture conditions are relatively dry to minimize soil compaction. For additional information on manure handling, see Agricultural Engineering Fact Sheets No. 45 to 51.

Municipal Sewage Wastewaters and Sludges

Another source of plant nutrients for field crops is municipal sewage wastewater effluents and sludges. Table 14 gives the N, P, and K concentrations found in these materials from over 50 Michigan municipalities. Sewage wastewaters may also serve as a source of irrigation water.

Sludges can be a very beneficial soil amendment, providing nutrients and organic matter to the soil-plant system. Sludges vary in moisture content from a slurry of less than 1 percent solids to a dried sludge cake with greater than 40 percent solids. Sewage sludges can also contain undesirable chemicals. Metals like copper, zinc, nickel, chromium and others can be a problem if present in excessive concentrations.

The Michigan Department of Natural Resources is regulating the use of these materials on land. Any grower considering the use of wastewater and/or

Table 13. Average amounts of nitrogen, phosphorus and potassium and the combined value of manures from different animals.

Type of Manure	*N*	*P_2O_5*	*K_2O*	*Value*[1]	*N*	*P_2O_5*	*K_2O*	*Value*[1]
	Pounds/ton				**Pounds/1000 gallons**			
Chicken	30	18	9	11.40	74	68	27	34.66
Beef	14	8	13	6.28	24	13	24	10.80
Dairy	11	5	11	4.72	26	10	31	11.32
Hog	10	6	9	4.52	53	22	28	19.24
Horse	14	5	14	5.68	—	—	—	
Sheep	28	9	24	10.64	—	—	—	

[1]*Calculated assuming present retail costs per pound are:* N = 20 cents; P_2O_5 = 24 cents; and K_2O = 12 cents.

Table 14. Range of N, P and K concentrations found in the sewage wastewater effluents and sludges from more than 50 Michigan municipalities.

	Wastewater Effluents		*Sludges*	
Nutrient	*Concentration (ppm)*[1]	*Pounds per A-in*[2]	*Concentration (percent)*	*Pounds per dry ton*[3]
Nitrogen	11-75	2.5-17	0.1-3.2	2.0-64
Phosphorus as P_2O_5	0.1-8.1	0.02-1.8	0.1-3.3	2.0-66
	0.23-18.6	0.05-4.1	0.23-7.6	4.6-152
Potassium as K_2O	4.0-27	0.9-6.1	0.05-0.9	1.0-18
	4.8-32	1.1-7.3	0.06-1.1	1.2-22

[1] *ppm = parts per million; 10,000 ppm = 1%*
[2] *A-in = acre-inch; one A-in of water equals about 27,000 gallons and would cover one acre to a depth of one inch*
[3] *Sludges can vary from less than 1% solids to greater than 40% solids*

sludges should contact the DNR. Guidance in using these materials may also be obtained from the Soil Conservation Service and Cooperative Extension Service.

Industrial Wastes

Some industrial wastes can be suitable soil amendments for improving the fertility status or physical conditions of soils. If you are considering the use of industrial waste on your land, consult with the MSU Department of Crop and Soil Sciences for assistance in evaluating that waste as a soil amendment. Some industrial wastes contain substances toxic to plant growth and are unsuitable for application to agricultural land.

Suggested Fertilizer Placement

Alfalfa, Alfalfa-Brome, Clover, Birdsfoot Trefoil — Fertilizer recommendations for alfalfa seedings given in Table 6 are for spring or summer clear seeding. Based on soil test results, apply fertilizer at rates up to 100 pounds of phosphate plus 50 pounds of potash/acre through the grain drill. If you use more fertilizer, broadcast and plow down or disk 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 as a topdress application.

At planting, allow the legume seed to fall on top of the soil above the fertilizer band and cover 1/2 inch deep. To seed bromegrass, either mix the seed with a small grain or with the fertilizer.

Boron is needed annually on established alfalfa at the rate of one to two pounds/acre. Do not apply boron in combination seedings containing grass or small grain because of injury to these plants. Apply boron for the legume as a topdressing after the grass is well established or the grain crop harvested.

Topdress alfalfa with potash in early spring while the plants are dormant, immediately after a hay harvest, or in the fall.

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

Small Grain, Legume Seeding (see Table 6) - When legumes are seeded with small grains, increase the small grain fertilizer recommendation for P_2O_5 and K_2O 25 and 50 pounds/acre, respectively. The fertilizer applied for the small grain should be sufficient to carry the legume through the first harvest season. In the fall of the first harvest year, topdress with potash at the rate indicated by a soil test. In the fall of the second harvest year, apply the recommended rates of phosphate and potash.

Barley, Oats, Wheat, Rye (see Table 6) - Proper fertilizer placement 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/acre for fine-textured soils. If additional amounts are needed, apply in a separate operation.

On winter grains, do not apply nitrogen in the fall in excess of planting time fertilizer on sands, loamy sands or sandy loams. Similarly, do not apply nitrogen on frozen ground or soils with greater than 3 percent slope. Where lodging may be a problem, use little or no additional 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/acre for soils with pH 6.5 to 7.2 and 8 to 10 pounds/acre for soils having pH 7.3 to 8.5.

Field Beans, Soybeans (see Table 7) - Beans are very sensitive to fertilizer applied in contact with the seed.

Apply row fertilizer 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 lakebed 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 the row fertilizer and applied in a band. Foliar applications are also effective and 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 zinc chelates are used, apply 0.5 to 0.8 pounds of zinc/acre.

Corn, Corn Silage (see Table 8) - Phosphorus and potassium fertilizers in excess of the row fertilizer may be plowed down. Nitrogen can be sideplaced or plowed down. Place row fertilizer 2 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/acre. The row fertilizer is usually high in phosphate to stimulate rapid, even growth of corn during early spring. Before going to no-till corn production, be sure to build up high levels of fertility in the soil.

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/acre. The same crop, if harvested for silage, removed 196 pounds of nitrogen, 69 pounds of phosphate, and 206 pounds of potash/acre. A comparison of the two practices illustrates that nutrient removal, especially potash, is great when silage is harvested.

Due to high potential for leaching loss, do not plow down nitrogen in the fall on sands, loamy sands or sandy loams. Similarly, do not broadcast nitrogen on frozen ground with greater than 3 percent slope. Use care when applying anhydrous ammonia to completely trap the gas in the soil. Broadcast or spray applications of liquid nitrogen should not exceed 10 pounds/acre after emergence of the corn. Applications of greater than 10 pounds/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, which provides a convenient means for applying a pre-emergence herbicide and supplemental nitrogen.

Sunflowers - Sunflowers grown in Michigan have nutrient requirements similar to a 100 bushel/acre corn crop. Nitrogen, phosphorus and potassium fertilizer needs can be determined from the appropriate columns in Tables 2 and 8. Place row fertilizer 2 inches to the side and 2 inches below the seed. Planting time fertilizer stimulates early growth and may contain all the phosphorus and up to 100 pounds potash and 60 pounds nitrogen. Broadcast and plowdown fertilizer required beyond the row placed fertilizer. Sidedress with 50 pounds nitrogen when plants are 6 inches tall.

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 needed during the growing season. When a new seeding is being established, apply more liberal rates of phosphorus and potassium, broadcast these materials after plowing and disk into the top 3 to 4 inches of soil. Table 6 gives suggested fertilizer amounts based upon soil tests.

Grass waterways need good fertility levels to maintain a dense, uniform cover throughout the year. Hence, the guidelines for seeding and maintaining a productive grass pasture apply for waterways. To prevent runoff loss, drill in topdress fertilizer.

For establishment and maintenance of cover vegetation on "critical areas", as defined by the Soil Conservation Service, follow fertilizer and lime recommendations identical to those for productive areas.

Potatoes (see Table 9) - Based on soil test information up to 60 pounds of nitrogen, 200 pounds of phosphate, and 100 pounds of potash/acre may be applied in bands 2 inches to the side and level with or slightly below the seed pieces. Plow down or disk 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 3. Do not apply more than 50 pounds of nitrogen/acre in the fall to cover crops grown on sands, loamy sands or sandy loams. Do not apply nitrogen on these textures if the soil is left bare. Similarly, do not broadcast nitrogen 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 need for manganese. See Table 11 for 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 require more nitrogen and

potassium than Sebagos and Katahdins to produce similar yields.

Sorghum, Sudangrass - Sorghum and Sudangrass grown for summer pasture or chopped forage have nutrient requirements similar to corn silage. In estimating fertilizer requirements, use the column in Table 8 for corn silage that fits nearest the yielding capacity of the soil.

Sugar Beets (see Table 10) - Fertilizer for sugar beets should be applied in bands 1 inch to the side and 2 inches below the seed or 3 inches directly below the seed. Part of the fertilizer may 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. Recommended rates are 1½ to 3 pounds/acre for boron and 4 to 6 pounds/acre for manganese.

The quality of sugar beets is affected very markedly by past nitrogen management and presently applied nitrogen. Table 4 gives suggested nitrogen rates for 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. Recommended fertilizer rates are designed to meet the needs of the growing vegetable crops and gradually build up low soil test levels. Once desired soil test levels are attained, a maintenance fertilization program can be developed by applying the nutrients removed by the vegetable crop. Table 15 lists the amount of nitrogen, phosphorus and potassium removed by typical yields of some Michigan vegetable crops. Recommended nitrogen rates are given in Table 16. Phosphate and potash recommendations are given in Tables 17, 18 and 19. Fertilizer may be applied to vegetables in one or more of the following ways: (1) 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).

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 percent for the first vegetable crop.

(2) When using a high analysis phosphorus fertilizer, place it in bands near the seed 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

Table 15. Nutrient removal by several Michigan vegetable crops.

Crop	*Yield*	*lbs/acre*		
		N	P_2O_5	K_2O
Asparagus	15 cwt*	10	3	7
Beans, snap	45 cwt	90	9	12
Cabbage	200 cwt	70	15	70
Carrots	300 cwt	70	20	65
Cauliflower	60 cwt	20	8	20
Celery	450 cwt	115	95	335
Cucumber	100 cwt	10	5	18
Lettuce	200 cwt	50	22	90
Onion	400 cwt	95	50	90
Peas	30 cwt	30	7	10
Tomato	400 cwt	110	35	155

* *20 cwt = 1 ton*

Table 16. Nitrogen recommendations for vegetables grown on mineral soils.

Asparagus		Squash	75	Spinach	100
old beds	50*	Watermelon	90	Table beets	100
new + crowns	75				
Peas	50	Cabbage	100	Lettuce	125
Radish	50	Carrots	100	Sweet Corn	125
Turnips	50	Chard	100	Tomato	125
Cucumber		Eggplant	100		
30-49,000	60	Horseradish	100	Broccoli	140
50,000 plants	75	Muskmelon	100	Brussel sprouts	140
Sweet potato	60	Rutabaga	100	Cauliflower	140
Snap beans	60	Parsnip	100		
Endive	75	Pepper	100	Onion	175
Pumpkin	75	Rhubarb	100	Celery	175

* *Pounds nitrogen per acre*

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.

Suggested Fertilizer Placement

Some typical fertilizer recommendations for vegetables showing placement and nitrogen rates are given below. These assume medium phosphorus and potassium soil test levels. Base specific fertilizer amounts on soil test results according to Tables 17, 18 and 19.

Asparagus (new planting, crowns) - Plow down 50 pounds of nitrogen, 100 pounds of phosphate, and 80 pounds of potash/acre and apply 30 pounds of phosphate in the trench before setting crowns. Later, sidedress with 30 pounds of nitrogen/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/acre on alternate years. Apply fertilizer near the end of the harvest season. Eliminate nitrogen application if manure is applied.

Lima Beans, Snap Beans - Apply row fertilizer 2 inches to the side and 2 inches below the seed. Do not apply directly in contact with the seed. Use 25 pounds of nitrogen and 60 pounds each of phosphate and potash/acre for sandy loams. Plow down extra fertilizer if needed. Sidedress beans with about 30 to 40 pounds of nitrogen/acre from the time 2 to 3 leaves have appeared up to flowering if foliage is light 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/acre on sandy loams. Topdress with 50 pounds of nitrogen/acre after plants are well started.

Table Beets, Rutabagas - Drill in fertilizer before seeding or apply in a band 1 inch to the side and 2 inches below the seed. Use 50 pounds of nitrogen, 150 pounds of phosphate, and 100 pounds of potash/acre for clay loams; 50 pounds of nitrogen, 120 pounds of phosphate, 120 pounds of potash and 1 pound of boron/acre for sandy soils. Topdress with 50 pounds of nitrogen.

Table 17. Phosphorus (P_2O_5) recommendations for vegetable crops grown on mineral soils.

Asparagus old beds	*Carrots (200-400)*	*Asparagus crowns, new beds*	*Celery (400)*
Blueberries	*Cucumbers (150)*	*Broccoli (120)*	*Flower beds*
Lima Beans (30)[1]	*Endive*	*Brussel Sprouts*	*Home garden*
Peas (40)	*Lettuce (250)*	*Cabbage (200-600)*	*Onions (400)*
Snap Beans (60)	*Parsnips*	*Cauliflower (160)*	*Tomatoes (500)*
Turnips	*Pumpkins*	*Cucumbers (200) over 40,000 plants*	*Market garden*
Strawberries	*Radish (40)*	*Egg plant (150)*	
	Rutabagas (200)	*Muskmelons (150)*	
	Spinach(100)	*Peppers (150)*	
	Sweet corn (100)	*Rhubarb (200)*	
	Sweet potatoes	*Table beets (300)*	
	Squash	*Watermelons*	

Test Level **lb P/acre**	**Phosphorus recommendations, lb P_2O_5/acre**			
0 - 19	150	200	250	300
20 - 39	100	150	200	250
40 - 69	75	100	150	200
70 - 99	50	75	100	150
100 - 149	0	50	50	100
150 - 199	0	0	50	50
200+	0	0	0	0

[1]*Figure in parentheses after crop is the yield potential in cwts (100 lbs)/acre.*

Table 18. Potassium (K_2O) recommendations for vegetable crops on sandy loam and loamy sands.

	Asparagus (35) old beds	*Asparagus crowns, new bed*	*Cabbage (200-600)*	*Broccoli (120)*
	Blueberries	*Carrots (200-400)*	*Cucumbers (200) over 40,000 plants*	*Brussel sprouts*
	Lima Beans (30)[1]	*Cucumbers (150)*	*Egg plant (150)*	*Cauliflower*
	Peas (40)	*Endive*	*Flower beds*	*Celery (400)*
	Pumpkins	*Lettuce (30)*	*Muskmelons (150)*	*Home garden*
	Radish (40)	*Lima Beans (30)*	*Onions (400)*	*Tomatoes (500)*
	Snap Beans (60)	*Snap Beans (60)*	*Parsnips*	*Market garden*
	Squash	*Sweet Corn (100)*	*Peppers (40)*	
	Turnips		*Rhubarb (200)*	
	Strawberries		*Rutabagas (200)*	
			Spinach (100)	
			Sweet potatoes	
			Table beets (300)	
			Watermelons	

Test Level **lb K/acre**	**Potassium recommendation, lb K_2O/acre**			
0 - 59	200	250	300	300
60 - 99	150	200	250	300
100 - 149	100	150	200	250
150 - 199	50	100	150	200
200 - 249	25	50	100	150
250 - 299	0	25	50	100
300 - 349	0	0	25	50
350 - 399	0	0	0	25
400+	0	0	0	0

[1]*Figure in parentheses after crop is the yield potential in cwts (100 lbs)/acre.*

Broccoli, Cabbage, Brussel Sprouts, Cauliflower - Plow down 40 to 60 pounds of nitrogen/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/acre. Clay loams require about 200 pounds of phosphate and 100 pounds of potash/acre. Band, if possible, a part of the fertilizer near the plants or seeds. Use 4 ounces of sodium molybdate/acre for cauliflower. Use a high phosphorus starter solution for transplants. Sidedress cauliflower with 30 to 40 pounds of nitrogen/acre two weeks after transplanting and an additional 30 to 40 pounds five weeks after transplanting.

Sweet Corn - Plow down or sidedress about 120 pounds of nitrogen/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 slicing cucumbers and hand picked pickling cucumbers, plow down 30 to 50 pounds of nitrogen/acre with stubble, grass or grain cover crops. Broadcast and disk in balance of fertilizer not banded near seed. Up to 300 pounds/acre of fertilizer can be placed in a band 2 inches to the side and 2 inches below the seed. If the soil is above pH 6.7, use 2 percent manganese in the band fertilizer. Sidedress with 30 to 40 pounds of nitrogen/acre when vines begin to run if the foliage becomes light green or yellow green, or if rainfall has been excessive.

For pickling cucumbers with plant populations exceeding 50,000 plants/acre, in 10 to 24 inch rows for mechanical harvest, disk in all fertilizer. A suggested rate is 500 pounds of 10-20-20 fertilizer. Additional potassium may be required. With rows wider than 24 inches, up to 300 pounds of a fertilizer high in phosphorus such as a 10-20-10 can be placed in a band 2 inches to the side and 2 inches below the seed. Broadcast and disk in the remainder of the fertilizer. If the soil is above pH 6.7, use 2 percent manganese in the fertilizer band.

When excessive rainfall occurs on sandy soil, topdress with 30 pounds nitrogen/acre when the cucumber plants tip over.

Muskmelons, Watermelons - At planting time, fertilize rye or ryegrass used for a green manure crop with 40 pounds each of nitrogen, phosphate, and potash/acre. For sandy soils, drill in, 3 or 4 inches deep, 50 pounds of nitrogen and 150 pounds each of phosphate and

Table 19. Potassium (K_2O) recommendations for vegetable crops on loams, clay loams and clays.

Asparagus old beds	*Asparagus crown, new beds*	*Cabbage (200-600)*	*Broccoli (120)*
Blueberries	*Carrots (200-400)*	*Cucumbers (200) over 40,000 plants*	*Brussel sprouts*
Lima Beans (30)[1]	*Cucumbers (150)*	*Egg plant (150)*	*Cauliflower (160)*
Peas (40)	*Endive*	*Flower beds*	*Celery (400)*
Pumpkins	*Lettuce (250)*	*Muskmelons (150)*	*Home gardens*
Radish (40)	*Sweet corn (100)*	*Onions (400)*	*Market garden*
Snap Beans (60)		*Parsnips*	*Tomatoes (500)*
Squash		*Peppers (40)*	
Turnips		*Rhubarb (200)*	
Strawberries		*Rutabagas (200)*	
		Spinach (100)	
		Sweet potatoes	
		Table beets (300)	
		Watermelons	

Test Level lb K/acre	Potassium Recommendation, lb K_2O/acre			
0 - 59	150	200	250	300
60 - 99	100	150	200	250
100 - 149	50	100	150	200
150 - 199	25	50	100	150
200 - 249	0	25	50	100
250 - 349	0	0	25	50
350+	0	0	0	0

[1]*Figure in parentheses after crop is the yield potential in cwts (100 lbs)/acre.*

potash/acre after plowing. Use 50 pounds of nitrogen, 150 pounds of phosphate, and 100 pounds of potash/acre for clay loams. Sidedress with 60 pounds/acre of nitrogen three weeks after plants have emerged, or after transplanting.

Peas - Broadcast or drill 2 inches to the side of the seed 50 pounds each of nitrogen, phosphate, and potash/acre for sandy loams or 50 pounds of nitrogen, 100 pounds of phosphate, and 50 pounds of potash/acre on clay loams. If nitrogen deficiency is likely, topdress 20 to 30 pounds of nitrogen/acre when peas are 4 to 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/acre. Boron may be needed at the rate of 1 to 2 pounds/acre.

Tomatoes - Plow down or drill in 3 or 4 inches deep 50 to 80 pounds nitrogen/acre and the phosphate and potash fertilizer recommended in Tables 17, 18 and 19. Apply the remainder in bands 3 to 4 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/acre when the first fruits are about the size of a half dollar. High rates often retard maturity but give high seasonal yields.

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

Market Gardens - Plow down about 50 pounds of nitrogen, 100 pounds of phosphate, and 100 pounds of potash/acre. In addition, broadcast and disk in a similar amount or apply in bands 1 inch to the side and 2 inches below the seed at planting time. Make 1 or 2 applications of nitrogen between rows during the growing season for individual crops at rates listed under the name of the crops. For vegetables not listed, use 40 to 100 pounds additional nitrogen/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 stimulate growth of leafy vegetable crops when soils are cold and temperatures are low. Avoid overfeeding, or salt burn may result.

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. Soils must have greater than 20 percent organic matter to be characterized as an organic soil. In the MSU Soil Test Lab, soils having a bulk density less than 0.8 gram per cubic centimeter are handled as organic soils.

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/acre and lime is required, use at least 1 ton of dolomitic lime/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 20.

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

Table 20. Lime requirements of organic soils.

Soil pH	*Lime Requirement*
	Tons/acre
4.9 to 5.0	3
4.6 to 4.8	5
4.2 to 4.5	8[1]
3.8 to 4.1	10[1]

[1] *Plow down half and disc in other half after plowing.*

Table 21. Nitrogen recommendations for field and vegetable crops grown on organic soils.

Clover	0*	Snap beans	40	Spinach	75
Pasture	0	Turnips	40	Sweet Corn	75
Rye	10	Chard	40		
Field Beans	10			Lettuce	100
Soybeans	10	Carrot	60	Sod	100
Oats	10	Endive	60		
Asparagus				Broccoli	120
old beds	40	Cabbage	75	Brussel Sprouts	120
new, crowns	60	Corn	75	Cauliflower	120
		Mint	75	Potato	120
Radish	40	Rhubarb	75		
Rutabaga	40	Sorghum	75	Onion	150
Sugarbeets	40			Celery	160
Table beets	40				

* *Pounds nitrogen per acre*

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 may leach over winter. The potash recommendations in Table 17 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 for crops grown on organic soil are given in Table 21 and each respective 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 to 50 percent, applying it as a top- or sidedress application.

Phosphate and potash requirements are given in Tables 22 and 23.

Table 22. Potassium (K_2O) recommendations for crops grown on organic soils.

Blueberries	Beans (snap)	Asparagus	Broccoli	Celery
Oats	Clover	Cabbage	Brussel Sprouts	600 cwt
Rye	Corn 130 bu	Carrots	Cauliflower	
Pasture (grass)	Bluegrass sod	Cucumbers	Home Gardens	
	Soybeans 35 bu	Endive	Market Gardening	
	Sudan grass	Lettuce	Onions (bunching)	
	Sweet corn	500 cwt	Dry Onions—600 cwt	
	Turnips	Mint	Potatoes—400 cwt	
		70 lb	Rutabagas	
		Parsnips	Spinach	
		Radishes	Sugarbeets	
			Swiss Chard	
			Table beets	

Test Level lb K/acre	Potassium recommendation, lb K_2O/acre				
0 - 124	150	250	300	400	600
125 - 199	100	200	250	350	525
200 - 274	50	150	200	300	450
275 - 349	0	100	150	250	400
350 - 424	0	50	100	200	350
425 - 499	0	0	50	150	300
500 - 574	0	0	0	100	250
575 - 649	0	0	0	50	200
650+	0	0	0	0	150

Table 23. Phosphorus (P_2O_5) recommendations for crops grown on organic soils.

Blueberries	Asparagus	Bluegrass sod	Broccoli
Clover	Beans (snap)	Brussel sprouts	Cauliflower
Oats	Corn - 130 bu	Cabbage	Celery - 600 cwt
Pasture (grass)	Mint - 70 lb	Carrots	Home Garden
Rye	Radishes	Cucumbers	Market Garden
Soybeans - 35 bu	Sudan grass	Endive	Onions (bunching)
	Sweet corn	Horseradish	Onions dry - 600 cwt
	Turnips	Lettuce - 500 cwt	
		Parsnips	
		Potatoes - 400 cwt	
		Rutabagas	
		Spinach	
		Swiss chard	
		Sugar beets	
		Table beets	

Test Level lb P/acre	Phosphorus recommendations, lb P_2O_5/acre			
0 - 19	75	150	250	300
20 - 39	50	100	200	250
40 - 69	25	50	150	200
70 - 99	0	25	100	150
100 - 149	0	0	50	100
150 - 199	0	0	25	50
200+	0	0	0	0

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. The response of crops to the various micronutrients is given in Table 24.

Micronutrients can be absorbed through the leaves of plants. Where spray equipment is available, cost of material used is greatly reduced. Suggested foliar spray rates are discussed in Extension Bulletin E-486.

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 with a naturally high pH. 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 25). Cauliflower, celery, table beets and turnips are highly responsive to boron application. Medium responsive vegetables include broccoli, cabbage, carrots, lettuce, parsnip, radish and spinach. 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 pH. For this reason, the amounts suggested in Table 25 are greater on high pH 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. For table beets, it may be necessary to use quantities greater than those suggested in Table 25.

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 used much by the crop. For this reason, no further copper fertilization is needed if a total of 20 pounds/acre has been applied to low or medium responsive crops and 40 pounds/acre for high responsive crops.

Additional copper will be needed if soil erosion is serious or the field is plowed deeply. In many instances, the copper level in the soil is ample because of repeated applications of copper fungicide dust or spray. Table 26 shows recommended copper rates.

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. Ap-

Table 24. Relative response of selected vegetable crops to micronutrients.[1]

Crop	*Response to Nutrient*			
	Mn	B	Cu	Zn
Blueberries	low	low	medium	
Broccoli	medium	medium	medium	
Cabbage	medium	medium	medium	
Carrots	medium	medium	medium	low
Cauliflower	medium	high	medium	
Celery	medium	high	medium	
Lettuce	high	medium	high	
Onions	high	low	high	high
Parsnips	medium	medium	medium	
Peppermint	medium	low	low	low
Potatoes	high	low	low	medium
Radishes	high	medium	medium	
Spearmint	medium	low	low	low
Spinach	high	medium	high	
Sweet corn	medium	low	medium	high
Table beets	high	high	high	medium
Turnips	medium	high	medium	

[1]*The crops listed will respond as indicated to applications of the respective micronutrient when that micronutrient concentration in the soil is low.*

Table 25. Boron recommendations for organic soils—elemental basis.

Crop Response	*pH 5.0 to 6.4*	*pH 6.5 to 8.0*
	Pounds/acre	
High	2	3
Medium	½	1
Low	0	½

Table 26. Copper fertilizer needs for organic soils as indicated by soil tests (1.0 N HCl extractable).

Soil Test	*Crop Response*		
	Low	Medium	High
ppm	Pounds Cu/acre		
Below 9	3	4	6
10 - 20	1.5	2	3
21 +	0	0	0

ply 3 to 4 pounds of zinc annually for 3 or 4 years, then reduce rate to 1 pound/acre. Rates based on soil test values are given in Table 12.

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/acre or a seed treatment at a rate of 1/2 ounce of sodium molybdate/acre. For seed treatment, dissolve the 1/2 ounce of sodium molybdate in 3 tablespoons of water. Mix with seed required for one acre.

Suggested Fertilizer Management

Nitrogen rates and fertilizer placement guidelines are given for each crop. Phosphorus and potassium should be applied at rates given in Tables 22 and 23 according to soil test information.

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 to 60 pounds of nitrogen is sufficient. If the soil pH is 5.8 or above, apply boron and manganese. Below pH 5.8, only boron is needed. Molybdenum seed treatment or foliage spray is recommended.

Carrots, Parsnips - Disk in or plow down fertilizer containing boron and copper. Disking in is the preferred method of application.

An alternate program is to plow down a fertilizer high in potassium containing boron and copper. Use a fertilizer high in phosphate (for example a 1-4-2 or 2-4-1 ratio) for the remainder of the fertilizer needs banded 2 or 3 inches to the side and 3 inches below the seed. Do not exceed 250 pounds of fertilizer 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 - Disk or drill in the fertilizer after plowing. Apply 1 pound of boron/acre. Spray foliage with manganese if the soil pH is above 6.5.

Sidedress one to three times during the growing season at the rate of 50 pounds of actual nitrogen/acre/application. The number of applications will depend upon the season, drainage, and type of muck. 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 magnesium sulfate (Epsom salts) at the rate of 10 pounds/acre/week. If this rate does not correct the magnesium yellowing, increase the rate to 20 pounds. Calcium is needed to prevent black-heart disorder. Apply calcium chloride at the rate of 5 to 10 pounds/acre weekly. Direct calcium sprays into the heart of the plant.

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 and zinc 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 to 3 inches below the seed. Do not exceed 250 pounds of nitrogen plus potash in the row at planting time. Plow down additional potash prior to planting. Sidedress with 50 pounds of nitrogen at blocking time.

Apply 1/2 pound of boron and 2 pounds of copper in the row at planting time. If the soil pH is 5.8 to 6.4, use 5 pounds of manganese and if it is above 6.4, apply 10 pounds/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 to 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 to 4 pounds of copper and 3 pounds of zinc in the band at planting time. If the soil pH is 5.8 to 6.4, apply 5 pounds of manganese and if it is above 6.4, apply 10 pounds of manganese/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, then follow immediately with a drag or finger-tooth harrow.

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 to 60 pounds/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 to 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/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/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/acre in the fertilizer for all crops. In-row application of manganese sulfate is especially needed for the production of radishes.

Beans, Soybeans - 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 foliar spray on affected areas with 2 pounds of manganese (actual) in 15 gallons or more water/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. Apply these nutrients based on soil tests and work into the soil before establishment.

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

A minimum of two applications of nitrogen/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.

YIELD POTENTIALS OF

Soil Management Groups

The potential of a soil to produce good crop yields is dependent upon its properties and how they are managed. Soils with similar properties and yield potentials form soil management groups. A general discussion of soil management groups and a listing of over 300 occurring in Michigan are given in Extension Bulletin E-906, "No Till Corn: 3 Soils."

Average yield potentials of the various soil management groups are given in Tables 27 and 28 for those areas of Michigan with over 140 frost-free days and with less than 140 frost-free days, respectively.

Table 27. Average yield potentials for crops grown on different soil management groups under good management with adequate drainage but without irrigation 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/acre	*Tons/acre*	*Bu/acre*	*Bu/acre*	*Bu/acre*	*Tons/acre*	*Tons/acre*
Clays							
Oc	90	15	35	75	25	3.8	—
Ia	95	16	45	80	28	4.2	—
Ib	110	17	50	85	32	4.5	18
Ic	120	18	55	90	35	4.8	20
Clay loams							
1.5a	105	17	55	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	60	90	35	4.8	19
2.5b	120	18	65	100	40	5.0	20
2.5c	130	20	65	110	45	5.5	23
Sandy loams over Clay or Loam							
3/2a	105	17	55	90	35	4.5	18
3/1b or 3/2b	115	18	60	95	40	4.8	20
3/1c or 3/2c	120	18	65	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	—

Table 28. Average yield potentials for crops grown on different soil management groups under good management with adequate drainage but without irrigation 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/acre	*Bu/acre*	*Bu/acre*	*Bu/acre*	*Bu/acre*	*Tons/acre*
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	45	37	85	4.0
3/1c or 3/2c	15	90	50	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

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