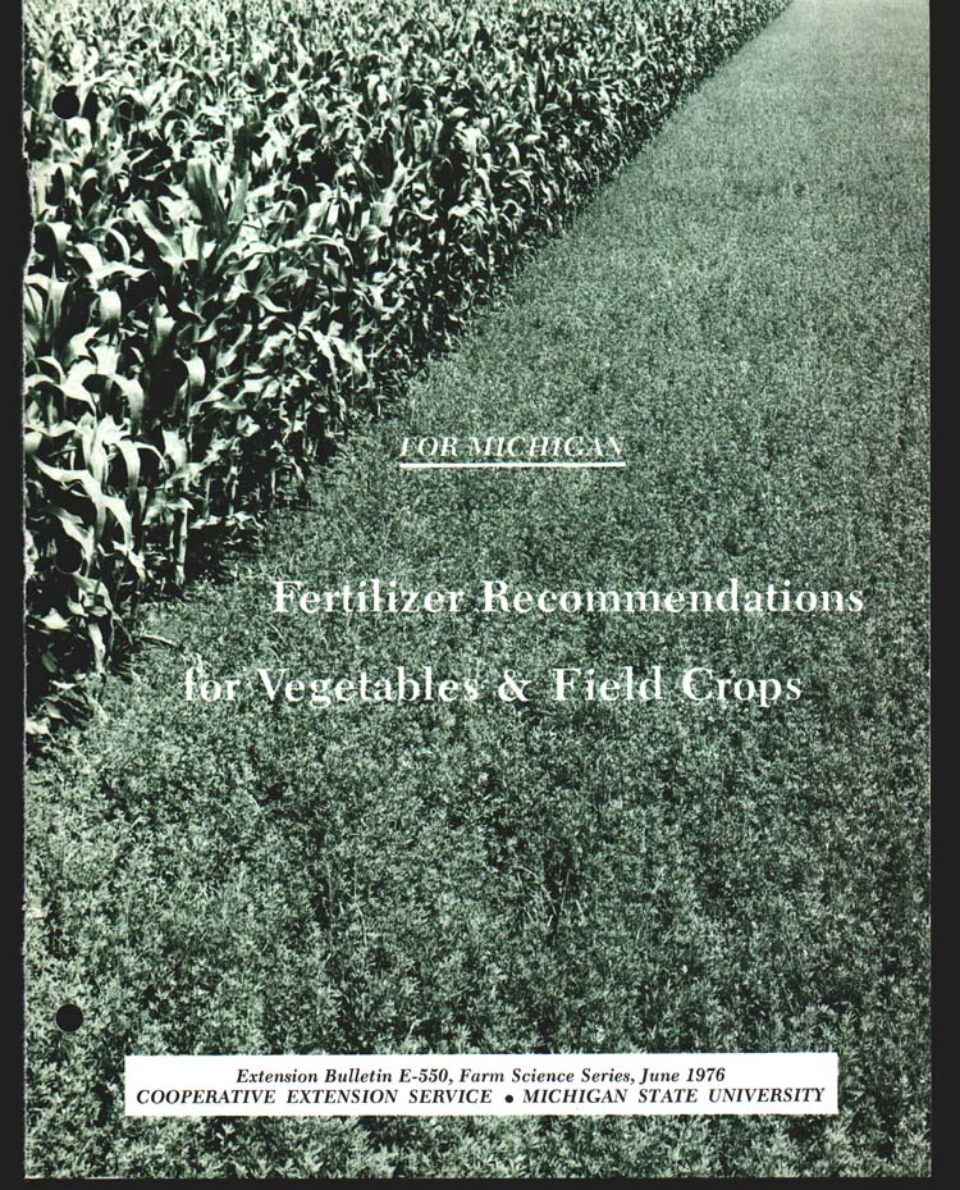

FOR MICHIGAN

Fertilizer Recommendations for Vegetables & Field Crops

Extension Bulletin E-550, Farm Science Series, June 1976
COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

FOR MICHIGAN

Fertilizer Recommendations for Vegetables & Field Crops

Table of Contents

D. D. Warncke, D.R. Christenson, and R. E. Lucas*
Department of Crop and Soil Sciences

Field and vegetable crops should be fertilized 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," recommended rates and method(s) of fertilizer application are discussed.

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 can be no better than the soil sample.

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 or vegetable crops, soils should be tested annually.

Soil samples may be taken at any time during the year when temperature 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. A soils map will be helpful.

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 box for mailing to the laboratory. Soil sample boxes are available from Cooperative Extension Offices.

Extension Bulletin E-598, "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 to know 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, 6⅔ inches deep. Organic soil samples are measured by volume. This is necessary because such materials usually have much lower densities than mineral soils.

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

pounds P x 2.3 = pounds P_2O_5
pounds K x 1.2 = pounds K_20

Basis for Recommendations

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

**The authors gratefully acknowledge the assistance of L. W. Jacobs, L. S. Robertson, M. L. Vitosh, Crop & Soil Sciences Dept., and J. E. Motes, Horticulture Dept., in the preparation of this bulletin.*

Yield potentials in Tables 20 and 21 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 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 water.

Recommendations shown in Tables 5 to 7 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 gradually deplete the soil reserves to a point where some fertilizer will be needed. The soil should be retested 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

With soil testing services available to help develop good soil fertility programs, widespread nutrient deficiencies in field crops and vegetables should not occur. Observation of plant growth and color throughout the growing season can help locate problem areas in fields and allows improvement of the overall crop production program. Most deficiencies result in yellowing of leaves with the pattern varying according to nutrient deficiency and plant species. (See Extension Bulletin E-486 "Secondary-and Micro-nutrients for Vegetables and Field Crops.") Insect damage and plant diseases can also show similar color changes.

Green plant tissue tests can be used to verify a nutrient deficiency. If diagnosed early there may be time to make a corrective fertilizer application. If not, the information can help select the correct fertilizer for the next crop.

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 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 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 recommended limestone based upon the "Lime Index" value for mineral soils. For organic soils see Table 15.

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.

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 Per Acre (9" Plow Depth)*[1]		
	to pH 6.0	to pH 6.5	to pH 6.8
7.0	—	—	0.5
6.9	—	0.5	1.0
6.8	1.1	1.5	1.8
6.7	1.9	2.4	2.6
6.6	2.7	3.3	3.6
6.5	3.5	4.3	4.7
6.4	4.3	5.3	5.7
6.3	5.1	6.2	6.7
6.2	5.8	7.2	7.8
6.1	6.6	8.1	8.9
6.0	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. The maximum lime recommendation for one season is 5 tons. Retest soil in 2 years 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 E-471.

RECOMMENDATIONS FOR FIELD CROPS ON MINERAL SOILS

Major Nutrients

NITROGEN (N)—Nitrogen needs are dependent 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

TABLE 4. Nitrogen recommendations for sugar beets.

Previous Management	*PREVIOUS NITROGEN RATE–POUNDS PER 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

TABLE 2. Nitrogen fertilizer guides for corn.

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	50	100
Good legume	10	40	90	140
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 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 Mgmt.*	*250-349*	*350-449*	*450-550*
	Pounds of nitrogen per acre							
Legume and 10 tons of manure/acre	10	10	0	0	0	30	60	90
Good legume	10	10	10	0	0	70	100	130
Manure 10 tons/acre	10	30	10	0	50	90	120	150
No legume or manure	40	60	40	60	100	130	160	190

[1] *If wheat is apt to lodge, follow amounts suggested for oats. Tecumseh will respond to an additional 30 pounds of nitrogen.*
[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 late season varieties.*

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 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, Tenessee 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 mono-ammonium 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.

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 per 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.

The recommendations in Table 5 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 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. 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

TABLE 5. 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	Alfalfa 5-6T topdressing	Alfalfa 7+ T topdressing	Corn[1] 150+ bu	Sugar beets[1] 24-28T	Potatoes[1] 300-500 cwt
Buckwheat	Alfalfa 3-4T seeding	Alfalfa 5+ T seeding	Corn silage[1] 20-30T	Potatoes[1] 150-299 cwt	
Clover	Barley[1] 40-69 bu	Barley 70-100 bu	Sugar beets 18-23T		
Corn[1] 60-89 bu	Birdsfoot Trefoil	Corn[1] 120-149 bu	Wheat[1] 65+ bu		
Cover crops	Corn[1] 90-119 bu	Corn silage[1] 15-19T			
Field beans[1] 15-29 bu (9-18 cwt)	Corn silage[1] 10-14T	Wheat[1] 40-65 bu			
Grass pasture (unimproved)	Field beans[1] 30-50 bu (19-30 cwt)				
Grasses Timothy, Orchard, Brome	Kidney beans[1] 30-50 bu (19-30 cwt)				
Kidney beans[1] 15-29 bu (9-18 cwt)	Oats 80-120 bu				
Millet	Soybeans 40+ bu				
Oats 50-79 bu	Sorghum Sudangrass				
Rye	Wheat[1] 25-39 bu				
Soybeans 20-40 bu					

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

[1]*Banding 25 lb P_2O_5/A will stimulate early plant growth, but will not necessarily increase yield.*

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 6 and 7 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 20 or 21) and in similar soils limed with calcitic 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, a magnesium deficient situation may be corrected by 50 to 100 pounds Mg per acre broadcast or 10 to 20 pounds Mg per acre row applied. 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 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. 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 the calcium content of water for Indiana varied between 8 to 450 ppm and averaged 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. Florida workers report that calcium deficiency in vegetables most likely occurs when the calcium content

TABLE 6. 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*	
					K₂O	*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	Barley 70-100 bu	Alfalfa 3-4T seeding	Alfalfa 5-6T seeding	Alfalfa 7+ T topdressing		
Buckwheat	Clover	Alfalfa 3-4T topdressing	Alfalfa 5-6T topdressing	Potatoes 300-500 cwt		
Corn 60-89 bu	Corn 90-119 bu	Birdsfoot Trefoil	Corn 150+ bu			
Cover crops	Corn silage 10-14T	Corn 120-149 bu	Corn silage 20-30T			
Field beans 15-29 bu (9-18 cwt)	Field beans 30-50 bu (19-30 cwt)	Corn silage 15-19T	Potatoes 150-299 cwt			
Grass pasture (unimproved)	Kidney beans 30-50 bu (19-30 cwt)	Sugar beets 18-23 T	Sugar beets 24-28T			
Grasses Timothy, Orchard, Brome	Oats 80-120 bu	Wheat 65+ bu				
Kidney beans 15-29 bu (9-18 cwt)	Soybeans 40+ bu					
Millet	Sorghum Sudangrass					
Oats 50-79 bu	Wheat 40-65 bu					
Rye						
Soybeans 20-40 bu						
Wheat 25-39 bu						

TABLE 7. Potash—potassium recommendations for field crops on loams, clay loams and clays.

Available soil potassium–pounds of K per acre					*POUNDS PER ACRE ANNUALLY RECOMMENDED*	
					K_2O	K
				0-59	0-119	300	249
			0-59	60-119	120-169	200	166
		0-59	60-119	120-169	170-209	150	125
	0-59	60-119	120-159	170-209	210-239	100	83
0-59	60-119	120-159	160-199	210-249	240-279	60	50
60-119	120-159	160-209	200-239	250-269	280-299	30	25
120-179	160-209	210+	240+	270+	300+	0	0
180+	210+						

Barley 40-69 bu Buckwheat Corn 60-89 bu Cover crops Field beans 15-29 bu (9-18 cwt) Grass pasture (unimproved) Grasses Timothy, Orchard, Brome Kidney beans 15-29 bu (9-18 cwt) Millet Oats 50-79 bu Rye Soybeans 20-40 bu Wheat 25-39 bu	Barley 70-100 bu Clover Corn 90-119 bu Corn silage 10-14T Field beans 30-50 bu (19-30 cwt) Kidney beans 30-50 bu (19-30 cwt) Oats 80-120 bu Soybeans 40+ bu Sorghum Sudangrass Wheat 40-65 bu	Alfalfa 3-4T seeding Alfalfa 3-4T topdressing Birdsfoot Trefoil Corn 120-149 bu Corn silage 15-19T Sugar beets 18-23T Wheat 65+ bu	Alfalfa 5-6T seeding Alfalfa 5-6T topdressing Corn 150+ bu Corn silage 20-30T Potatoes 150-299 cwt Sugar beets 24-28T	Alfalfa 7+ T topdressing Potatoes 300-500 cwt

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.

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.

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, the increased use of fertilizers low in sulfur, and the clean up of industrial smoke stacks. 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.

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 Extension Bulletin E-486, "Secondary- and Micro-nutrients for Vegetables and Field Crops." Recommended rates of manganese and zinc are given in Tables 8 and 9.

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

TABLE 8. Manganese fertilizer needs as indicated by soil tests (0.1 N HCl extractable) for responsive crops.

Soil Test	MINERAL SOILS		ORGANIC SOILS	
	pH 6.0 to 6.5	*Above pH 6.5*	*pH 5.8 to 6.4*	*Above pH 6.4*
ppm Mn	Pounds Mn per 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 9. Zinc fertilizer needs as indicated by soil tests (0.1 N HCl extractable) for responsive crops.

Soil Test	MINERAL SOILS		
	Below pH 6.7	*pH 6.7 to 7.4*	*Above pH 7.4*
ppm	Pounds Zn per 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

lake bed or glacial outwash areas and above pH 6.5. 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. 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.

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 since they are sensitive to boron.

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 spoil 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 proven effective in correcting zinc deficiencies on growing crops.

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 micronutrient can be added to a fungicide or insecticide spray. Suggested micronutrient sources and rates per acre as sprays are given in Extension Bulletin E-486.

Animal Manures

Manures are valuable primarily for their plant-nutrient content and as an excellent source of organic matter for improving soil physical conditions. Table 10 gives some average plant nutrient figures for several kinds of common animal manures. During the

TABLE 10. Average amounts of nitrogen, phosphorus and potassium and the combined value of manures from different farm animals.

Type of Manure	*N*	*P_2O_5*	*K_2O*	*Value*[1]	*N*	*P_2O_5*	*K_2O*	*Value*[1]
	Pounds per ton				Pounds per 1000 gallons			
Chicken	30	18	9	10.50	74	68	27	31.40
Beef	14	8	13	5.70	24	13	24	9.80
Dairy	11	5	11	4.30	26	10	31	10.30
Hog	10	6	9	4.10	53	22	28	17.80
Horse	14	5	14	5.20	—	—	—	
Sheep	28	9	24	9.80	—	—	—	

[1]*Calculated assuming present retail costs per pound acre are: N = 20 cents; P_2O_5 = 20 cents; and K_2O = 10 cents.*

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.

Soils receiving manure should be soil tested frequently and manure and fertilizer rates adjusted accordingly. Manures should be incorporated 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. 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 11 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 (DNR) is regulating the use of these materials on land. Any grower having the opportunity to use wastewater and/or sludges should contact the DNR. Guidance in using these materials may also be obtained from the Soil Conservation Service and the Cooperative Extension Service.

Industrial Wastes

Some industrial wastes can be suitable soil amendments for improving the fertility status or physical conditions of soils. Growers considering the use of industrial waste on their land should consult with the Department of Crop and Soil Sciences at Michigan State University 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 For Field Crops

Alfalfa, Alfalfa-Brome, Clover, Birdsfoot Trefoil– Fertilizer recommendations for alfalfa seedings given in Tables 5 to 7 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 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

TABLE 11. 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 0.23-18.6	0.02-1.8 0.05-4.1	0.1-3.3 0.23-7.6	2.0-66 4.6-152
Potassium as K_2O	4.0-27 4.8-32	0.9-6.1 1.1-7.3	0.05-0.9 0.06-1.1	1.0-18 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*

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.

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—When legumes are seeded with small grains, 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—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 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 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 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 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 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 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 harvested for silage would remove 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 needed during the growing season. When a new seeding is being established, more liberal rates of phosphorus and potassium are applied. These materials are applied broadcast after plowing and disked into the top 3 to 4 inches of soil. Tables 5-7 report suggested fertilizer amounts based upon soil tests.

Potatoes—Based on soil test information up to 60 pounds of nitrogen, 200 pounds of phosphate, and 100 pounds of potash per acre may be applied 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 3. 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 8 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. In estimating fertilizer requirements, use the column in Tables 2, and 5 to 7 for corn that fits nearest the 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 may be conveniently 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 per acre for boron and 4 to 6 pounds per acre for manganese.

The quality of sugar beets is affected very markedly by past nitrogen management and presently applied nitrogen. Table 4 in the front of this bulletin 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. Fertilizer amounts recommended in Tables 12 to 14 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).

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 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 nonleguminous 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, inabil-

ity 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. For specific amounts, have your soil tested and use fertilizer amounts according to Tables 12 to 14.

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. Apply fertilizer near the end of the harvesting season. Eliminate nitrogen application if manure is applied.

Lima Beans, Snap Beans—Apply row 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 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 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 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.

TABLE 12. 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	Carrots (200-400)	Asparagus crowns, new beds	Celery (400)		
Blueberries	Cucumbers (150)	Broccoli (120)	Flower beds		
Lima Beans[1] (30)	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)				
	Rutabagas (200)	Egg plant (150)			
	Spinach (100)	Muskmelons (150)			
	Sweet corn (100)	Peppers (40)			
	Sweet potatoes	Rhubarb (200)			
	Squash	Table beets (300)			
		Water melons			

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

TABLE 13. Potash—potassium recommendations for vegetable crops on sandy loams and loamy sands.

Available soil potassium–pounds of K per acre				*POUNDS PER ACRE RECOMMENDED*	
				K2O	*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)[1]	Asparagus	Cabbage (200-600)	Broccoli (120)
old beds	crowns, new beds	Cucumbers (200)	Brussel sprouts
Blueberries	Carrots (200-400)	over 40,000 plants	Cauliflower
Lima Beans (30)	Cucumbers (150)	Egg plant (150)	Celery (400)
Peas (40)	Endive	Flower beds	Home garden
Pumpkins	Lettuce (30)	Muskmelons (150)	Tomatoes (500)
Radish (40)	Lima Beans (30)	Onions (400)	Market garden
Snap Beans (60)	Snap Beans (60)	Parsnips	
Squash	Sweet Corn (100)	Peppers (40)	
Turnips		Rhubarb (200)	
Strawberries		Rutabagas (200)	
		Spinach (100)	
		Sweet potatoes	
		Table beets (300)	
		Watermelons	

[1]*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*	
				K2O	*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[1] (35)	Asparagus	Cabbage (200-600)	Broccoli (120)
old beds	crowns, new beds	Cucumbers (200)	Brussel sprouts
Blueberries	Carrots (200-400)	over 40,000 plants	Cauliflower (160)
Lima Beans (30)	Cucumbers (150)	Egg plant (150)	Celery (400)
Peas (40)	Endive	Flower beds	Home garden
Pumpkins	Lettuce (250)	Muskmelons (150)	Market garden
Radish (40)	Sweet corn (100)	Onions (400)	Tomatoes (500)
Snap Beans (60)		Parsnips	
Squash		Peppers (40)	
Turnips		Rhubarb (200)	
Strawberries		Rutabagas (200)	
		Spinach (100)	
		Sweet potatoes	
		Table beets (300)	
		Watermelons	

[1]*Figure in parentheses after crop is the estimated yield potential in cwts. (100 lbs.) per acres.*

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. Sidedress cauliflower with 30-40 pounds of nitrogen per acre two weeks after transplanting and an additional 30-40 pounds five weeks after transplanting.

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 slicing cucumbers and hand picked pickling cucumbers, plow down 30 to 50 pounds of nitrogen per acre with stubble, grass or grain cover crops. Broadcast and disk in balance of fertilizer not banded near seed. Up to 300 pounds per acre of fertilizer can be placed in a band two inches to the side and two 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 per 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 40,000 plants per 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 two inches to the side and two inches below the seed. The remainder of the fertilizer should be broadcast and disked-in. 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 per acre additional nitrogen when the cucumber plants tip over.

Muskmelon, Watermelon—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 ½ to ⅔ of the fertilizer recommended in Tables 12-14. 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 or prior to 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.

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.

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 15.

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 15. 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.*

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

TABLE 16. 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	150-199	—	25	11
50+	100+	200+	200+	0	0

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	Sudangrass	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	

TABLE 17. Potash—potassium fertilizer recommendations for organic soils.

Available soil potassium–pounds of K Per Acre					*POUNDS PER ACRE RECOMMENDED*	
					K2O	*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	425-499	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	Beans (Snap)	Asparagus	Broccoli	Celery		
Oats	Clover	Cabbage	Brussel Sprouts	600 cwt		
Rye	Corn	Carrots	Cauliflower			
Pasture (grass)	130 bu	Cucumbers	Home Garden			
	Bluegrass sod	Endive	Market Garden			
	Soybeans	Lettuce	Onions (Bunching)			
	35 bu	500 cwt	Dry Onions			
	Sudangrass	Mint	600 cwt			
	Sweet corn	70 lb	Potatoes			
	Turnips	Parsnips	400 cwt			
		Radishes	Rutabagas			
			Spinach			
			Sugar beets			
			Swiss Chard			
			Table beets			

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.

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 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 to 50 percent, applying it as a top- or sidedress-application.

Phosphate and potash requirements are given in Tables 16 and 17.

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 Extension Bulletin E-486.

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 in 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 8. 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 18). 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.

TABLE 18. Boron recommendations for organic soils—elemental basis.

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

The availability of boron in the soil is affected by pH. For this reason, the amounts suggested in Table 18 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. It may be necessary to use quantities greater than those suggested in Table 18 for table beets.

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 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 19 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. Apply 3 to 4 pounds of zinc annually for 3 or 4 years, then reduce rate to 1 pound per acre. Rates based on soil test values are given in Table 9.

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.

TABLE 19. 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 per acre	
Below 9	3	4	6
10 - 20	1.5	2	3
21+	0	0	0

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.

Suggested Fertilizer Management for Crops Grown on Organic Soils

Nitrogen rates and fertilizer placement guidelines are given for each crop. Phosphorus and potassium should be applied at rates given in Tables 16 and 17 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 30-60 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—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 1 inch 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 per 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 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 to 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 ½ 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 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 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 5.8-6.4, 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, 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 50-60 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.

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 spray on affected spots 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 and worked into the soil before establishment.

After fall seedings have emerged, 25 to 40 pounds nitrogen per acre can be topdressed. Suggested annual nitrogen rates for established sod are 90 to 150

pounds nitrogen per 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. 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.

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 20 and 21 for those areas of Michigan with over 140 frost-free days and with less than 140 frost-free days, respectively.

TABLE 20. 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	—
1a	95	16	45	80	28	4.2	—
1b	110	17	50	85	32	4.5	18
1c	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

continued

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
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 21. 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

List of Tables

Related Publications

E-362 Producing soybeans profitably in Michigan
E-471 Lime for Michigan Soils
E-486 Secondary and micronutrients for vegtables and field crops
E-498 Sampling Soils
E-802 Effect of nitrogen fertilizer on corn yield
E-853 Irrigation Management for Corn
E-854 Navy Bean Production: Methods for Improving Yields
E-896 Fertilizers: Types, uses and characteristics
E-904 No-Till Corn, No.1, Guidelines
E-905 No-Till Corn, No.2, Fertilizer and lime practices
E-906 No-Till Corn, No.3, Soils
E-907 No-Till Corn, No.4, Weed Control
E-933 Liquid Fertilizers
E-937 Understanding the MSU soil test report: results and recommendations

Some Conversion Factors

For special application situations, 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 200 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.

This information is for educational purposes only. Reference to commercial products or trade names does not imply discrimination or endorsement by the Cooperative Extension Service. Cooperative Extension Service Programs are open to all without regard to race, color, creed, or national origin. Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Gordon E. Guyer, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824. IP3R-6:76-15M-ST, Price 35c