EXTENSION BULLETIN E-550 February, 1970

FERTILIZER RECOMMENDATIONS

For Vegetables and Field Crops in Michigan

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COOPERATIVE EXTENSION SERVICE
MICHIGAN STATE UNIVERSITY

How to Use This Bulletin

Fertilizer needs are based upon the crop to be grown, past cropping, yield goal, soil type, and available plant nutrients. For efficient use of fertilizer, the recommendations consider all of these factors.

Field Crops Grown on Mineral Soils

The soil series greatly affects yield goals. The soil management group to which each soil series belongs is shown in the appendix. To help you estimate a practical yield goal, see Table 2 or 3 on pages 4 and 5. Average yield goals for each soil management group are given there for southern or northern Michigan.

Nitrogen recommendations are shown on pages 6 and 7 and in Tables 4 and 5. They are not based on a soil test.

Phosphorus recommendations are based upon soil tests and yield goals. They are shown in Table 6, page 8. See the footnote on how to use the table.

Potassium recommendations based upon soil test and yield goal are reported in Table 7, page 9, for loams-clay loams, and clays, and Table 8, page 10, for sandy loams, loamy sands, and sands.

Fertilizer placements suggested for the various crops are given on page 12.

Vegetable Crops Grown on Mineral Soils

Fertilizer placement and typical rates for soils of low fertility are reported on pages 12 to 15. To modify phosphorus and potassium rates based upon soil test, see Tables 11, 12, 13, pages 14 to 17.

Crops Grown on Organic Soils

Fertilizer placement and typical rates for soils of low fertility are reported on page 15 to 19. To modify phosphorus and potassium rates based upon soil test, see Tables 14, 15, pages 20 and 21.

Micronutrient needs for crops grown on organic soils are discussed on page 19.

All fertilizer recommendations are expressed as pounds of the actual plant food per acre. For example, they may call for 125 pounds of nitrogen (N), 50 pounds of phosphate (P_2O_5), 75 pounds of potash (K_2O), and 5 pounds of manganese (Mn) per acre. You will need to work out a program to apply such amounts. The sections in this publication on grades and ratios, page 1, and fertilizer placements, page 12, should help do this. Your fertilizer dealer or agricultural extension agent can also help you. Generally, several alternative programs are possible. Use the one that best fits your farming operation at competitive costs. Consider also the cost of the plant nutrients, the cost of application, and the timeliness of the application.

Fertilizer Guides for Michigan Vegetables and Field Crops

Prepared by staff members of the
Departments of Crop and Soil Sciences and Horticulture

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

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

The third group of essential elements is called *micronutrients* because they are needed in only very small amounts. These elements are sometimes called trace or minor elements. They include iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu), and molybdenum (Mo). The need for micronutrients is discussed on page 11.

MAJOR PLANT NUTRIENTS

The amounts of nitrogen, phosphorus, and potassium in a fertilizer are given in the analysis on the container. The first figure is the percentage of total nitrogen; the second, the percentage of available phosphate (P_2O_5); and the third, the percentage of water soluble potash (K_2O). For example "6-24-24" has a guarantee of at least 6 percent nitrogen, 24 percent phosphate, and 24 percent potash.

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

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

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

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

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

Grades and Ratios

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

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

Fertilizer recommendations in this publication are given in pounds of plant nutrients per acre. From these amounts the buyer needs to determine the materials, or if a mixed fertilizer, the grade and amount that come closest to the recommendation. For example, if a recommendation calls for 50 pounds of nitrogen, 100 pounds of phosphate, and 50 pounds

TABLE 1. Tons of Limestone Needed to Raise Soil pH to 6.5 or 6.8 as determined by the "Lime Index" method.

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

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

of potash, use a fertilizer having approximately a 1 to 2 to 1 ratio, such as 500 pounds of a 10-20-10.

Soil Acidity and pH

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 generally be limed to pH 6.5. If alfalfa is to be grown, the soil should be limed to pH 6.8.

The estimated lime requirement of acid soil samples submitted to the Michigan State University laboratory is determined by measuring the total soluble and exchangeable hydrogen and aluminum. The degree of acidity is reported as the "Lime Index". This method is more precise than estimates made from soil pH measurements alone, since it measures total acidity instead of just the active acidity of the soil. Table 1 reports the amount of recommended limestone based upon the "Lime Index" value.

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

Basis for Recommendations

Fertilizer recommendations are based on theoretical considerations, many field experiments, and soil tests of the plow layer. However, to find the right amount for any crop on a given soil, you must consider the crop yield desired and the rate which will result in the best investment of the money spent. The recommendations in this bulletin are aimed at average yields when soils are under good management. Good judgment, however, must be followed when using the recommendations, as different areas of Michigan vary considerably in length of the growing season and summer temperatures.

Recommendations shown in Tables 6-8 call for amounts that will result in fertility build up when soils test low. On the other hand, where soils test extremely high, the recommendations call for little or no fertilizer. For such situations, crop removal will eventually deplete the soil reserves to a point that more fertilizer will be needed. The soil tests should be repeated every two or three years to check the fertility reserves in the plow layer. With high value crops, soil tests may be needed every year.

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

The terms "texture" and "structure" are often confused when referring to soil. *Texture* is the coarseness or fineness of the soil particles. It depends on the percentage of sand, silt, and clay in the soil. *Structure* is the way these different sizes of particles are arranged into natural soil aggregates.

Soils are classified into series, such as Miami or Emmet, according to their color, texture, organic matter content, structure, thickness, chemical composition, and natural drainage. Their chemical and physical properties influence crop production goals and fertilizer response. Water-holding capacity is an important consideration, because lack of water often limits crop production. Under irrigation you must increase fertilizer rates to reach the higher potential production goals.

High productivity is frequently linked with a high level of soil organic matter. Fertilizers are not a substitute for organic matter, but, under favorable management, they help increase the organic matter content in the soils. Animal manures and crop residues are valuable sources of organic matter. Plan rotations to provide for soil organic matter maintenance.

Good Fertilizer Buys

Because the average cost of fertilizer has decreased greatly in recent years, the rates suggested in this publication have been increased over those suggested previously. Buyers, however, may need to modify the suggestions based upon input costs and prices received for the agricultural product. In making a decision on fertilizer purchase the buyer should consider: (1) handling and transportation costs, (2) ease of application, (3) equipment available, (4) physical condition of the fertilizer, (5) field soil conditions, and (6) storage costs as well as the cost of the material. Application costs, especially where only small amounts of plant nutrients are applied, can involve considerable labor expense.

Comparisons of fertilizer costs and fertility values, in general, are most reliable when based on cost per unit of available plant nutrients such as cents per pound of N, P_2O_5 or K_2O. Where liquids are priced by the volume, barrel, or other volume measure, the buyer must know the weight per unit volume as well as the percent of available nutrients in order to calculate the cost per unit of nutrient.

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

For example: Product A has 30% nitrogen and costs $66.00 per ton:

Calculation $\frac{\$66.00}{2{,}000 \times 0.30} = \frac{66.00}{600} = \$0.11$ or 11¢

For mixed materials having a common N-P-K ratio, the buyer needs to calculate an average value for all nutrients before comparing prices.

For example: Product B is 5-20-20 and costs $72.00 per ton. The total nutrient content is 5% + 20% + 20% or 45%.

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

Soil Management Groups

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

Experiences with soil management groups are used to indicate practical yield potentials with good management practices. The yield estimates in Tables 2 and 3 for southern and northern Michigan, respectively, help determine the yield goals to use with the fertilizer recommendations in Tables 4-8. These yields assume that adequate drainage has been supplied on soils of the "b" and "c" management groups.

The group numbers shown in the left hand column of Tables 2 and 3 indicate the relative coarseness of the mineral materials in the upper three feet of the soil profile: from 0, for the finest textured clays, to 5, for the coarsest textured sands. The small letters immediately following the numbers or capital letters indicate the natural drainage under which the soil developed; "a" is for well drained or moderately well drained; "b" is for imperfectly* drained, and "c" is for the more poorly drained conditions.

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

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

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

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

Thus, the L-4a soil management group reported for the Abscota series in the appendix includes naturally well drained or moderately well drained soils of loamy sand to sand textures throughout the profile, which were formed on lowlands subject to seasonal overflow. The 3a-a soil management group includes upland mineral soils, such as Munising, developed from sandy loam materials under well-drained conditions which are naturally very strongly acid throughout the profile. The M/1c soil management group includes shallow organic soils (mucks and peats) over silty clay or clay within 12 to 42 inches below the surface which were naturally very poorly drained. The Mc soil management group includes deep organic soils which are naturally very poorly drained. The soil management group designations for each of the soil series recognized to date in Michigan are reported in the appendix.

Soil interpretation sheets are available for each of these series.

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

Soil Testing

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

Only soil tests obtained by the Bray P_1 (adsorbed) 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 and 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

TABLE 2. Suggested average yield goals for crops grown on different soil management groups under good management with adequate drainage in areas with growing seasons of OVER 140 FROST-FREE DAYS ANNUALLY. (Southern Michigan).

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

See page 3 for identification of soil management groups and the appendix for the designation of the management groups for different soil series.

which they contain are expressed as pounds available in two million pounds of soil. This is about the weight of an acre of loamy soil, 6 2/3 inches deep. Organic soil samples or synthetic soil mixes are measured by volume. This is necessary because such materials usually have much lower densities than mineral soils.

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

TABLE 3. Suggested average yield goals for crops grown on different soil management groups under good management with adequate drainage in areas with growing seasons of LESS THAN 140 FROST-FREE DAYS ANNUALLY. (Northern Michigan).

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

**See page 3 for identification of soil management groups and the appendix for the designation of the management groups for different soil series.*

Soil Sampling

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

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

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

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

Information in *Michigan Extension Bulletin E-498*, "Sampling Soils For Fertilizer and Lime Recommendations", also gives instructions on how to collect soil samples.

Deficiency Symptoms

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

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

Nitrogen

The immediate nitrogen needs of a crop growing on a mineral soil depend more on the system of management than on the soil type or soil test made prior to planting.

Bacteria in alfalfa and clover root nodules take nitrogen from the air to build their own bodies. The plant is able to use the nitrogen released in the soil by the bacteria. Because of this "nitrogen fixation" by the bacteria, these crops do not usually need or respond to nitrogen fertilizer.

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

Tables 4 and 5 give estimates of the total nitrogen fertilizer required for corn and other crops. If the season is cool and wet and/or the field is poorly drained, it is usually necessary to apply larger quantities of nitrogen than indicated.

You may want to follow more detailed guide lines for estimating nitrogen needs than are shown in Table 4. The following corrections are suggested when requirements are rated against continuous corn growing on a soil containing 2 to 4 percent organic matter which receives about 60–100 pounds of nitrogen fertilizer per acre:

	POUNDS OF NITROGEN PER ACRE
CREDIT	
(subtract from total nitrogen recommended)	
4 to 8% soil organic matter	20
over 8% soil organic matter	40
150 to 200 pounds of nitrogen applied to previous crop	40
crop failure—each 40 pounds of nitrogen applied to soil management group 0, 1, 2, or 3	20
each 5 tons of manure applied	20
ADVERSE CONDITIONS	
(add to nitrogen rate suggested)	
0 to 2% soil organic matter	20
corn removed for silage (previous crop)	50
less than 40 pounds of nitrogen applied to previous corn crop	20

A number of nitrogen materials are offered for sale. Usually the materials are equally effective and should be purchased on a 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.

Time of nitrogen application is important for sandy

TABLE 4. Nitrogen Fertilizer Guides for Corn Growing on Soil Containing 2 to 4% Organic Matter.

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

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

soils (management groups 3, 4, and 5) especially if they are irrigated. For these sandy soils, delay application until a few weeks before the time the crop has its greatest nitrogen needs. Time of application of nitrogen on finer textured soils (management groups 1 and 2) may be either late fall, spring, or early summer. Do not apply nitrogen on the surface in the fall or winter for spring sown crops on land that is subject to water runoff.

Most nitrogen carriers leave an acidic residue in the soil. In general it requires 1.8 pounds of limestone for each pound of nitrogen derived from ammonium nitrate, urea, and anhydrous ammonia and 5.5 pounds if ammonium sulfate is used.

Phosphorus

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 (21-53-0), or a combination of the two.

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

Normal and triple superphosphates 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 5. Guide for estimating total nitrogen needed for small grain, potatoes, beets, beans, and grassland.

Manure application	Barley Oats Rye	Wheat*	Sugar beets	Pea Beans or Soybeans	Grass (pasture or hay) Low Level Management	Grass (pasture or hay) High Level Mgmt.	Potatoes-cwt/A. ** 250-349	Potatoes-cwt/A. ** 350-449	Potatoes-cwt/A. ** 450-550
	Pounds of Nitrogen Per Acre								
Legume and 10 tons of Manure/A	10	10	10	0	0	0	20	60	80
Good legume	10	10	10	10	0	0	60	100	120
Manure 10 T/A	10	30	50	10	0	50	90	130	160
No legume or manure	40	60	90	40	60	100-200	130	170	200

**If wheat is apt to lodge, follow amounts suggested for oats.*

***Russet Burbanks will generally require an additional 30 to 40 pounds of nitrogen to obtain the same yield goal as other late season varieties.*

TABLE 6. Phosphate—phosphorus recommendations for field crops on mineral soils.

Available soil phosphorus* -- pounds of P Per Acre						Pounds Per Acre Annually Recommended P_2O_5	Pounds Per Acre Annually Recommended P
					0-19	250	110
				0-19	20-39	200	88
			0-19	20-39	40-69	150	66
		0-19	20-39	40-69	70-99	100	44
	0-19	20-39	40-69	70-99	100-149	75	33
0-29	20-39	40-69	70-99	100+	150+	50	22
30+	40+	70+	100+	-	-	25	11
Alfalfa 3-4T topdressing Buckwheat Clover Corn 60-89 Bu Cover crops Field Beans 15-29 Bu Oats 50-79 Bu Grass pasture Rye Soybeans 30-49 Bu	Alfalfa 5-6T topdressing Alfalfa 3-4T seeding Barley 40-69 Bu Corn 90-119 Bu Corn silage 10-14 T Field beans 30-50 Bu Oats 80-120 Bu Soybeans 50+ Sudangrass	Alfalfa 5-6T seeding Barley 70-100 Bu Corn 120-149 Bu Corn silage 15-19 T Wheat 30-49 Bu	Corn 150+ Bu Corn silage 20-30T Sugar beets 18-23T Wheat 50-70 Bu	Sugar beets 24-28T	Potatoes** 250-350 cwt		

To use this table, look for the crop to be grown showing the nearest yield potential. Then find the position of the soil test range in the overlying column of figures. To determine the phosphate (P_2O_5) needed, follow dotted 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 per acre
Recommendation—50 pounds of P_2O_5 per acre

**If no test is made and the soil is probably low in phosphorus, use the recommendations shown for a test of 25 pounds per acre.*

***For a yield goal of 400 cwt., increase recommendations 20%.*

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

Potassium

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 potting soil mixes. They are used to help maintain low chloride levels and prevent soluble salt accumulation.

Small seedlings have less need for potassium than for phosphorus. On the other hand, once plants start to grow rapidly, they utilize large amounts of potassium. Crop removal is particularly heavy when the 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. For this reason, broadcast application is often recommended. A corrective treatment of 200 to 300 pounds of potash per acre is suggested for soils testing less than 100 pounds of potassium per acre.

The potassium-supplying ability of a soil is related

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
				Less than 60	250	208
			Less than 60	60-109	200	166
		Less than 60	60-99	110-159	150	125
	Less than 60	60-99	100-139	160-209	100	83
Less than 60	60-99	100-139	140-179	210-249	75	62
60-99	100-149	140-179	180-219	250-299	50	42
100-179	150-199	180-219	220-239	-	25	21
180+	200+	220+	240+	300+	0	0
Barley 40-69 Bu Buckwheat Corn 60-89 Bu Cover crops Field beans 15-29 Bu Oats 50-79 Bu Grass pasture Rye Soybeans 30-49 Bu	Barley 70-100 Bu Clover Corn 90-119 Bu Corn silage 10-14T Field beans 30-50 Bu Oats 80-120 Bu Soybeans 50+ Bu Sudangrass Wheat	Alfalfa 3-4T Corn 120-149 Bu Corn silage 15-19T Sugar beets 18-23T Wheat 50-70 Bu	Corn 150+ Bu Corn silage 20-30T Sugar beets 24-28T	Alfalfa 5-6T Potatoes** 250-350 cwt		

**If no soil test is made the soil is probably low in potassium, use the recommendations shown for a soil test of 130 pounds of K per acre.*

***For a yield goal of 400 cwt., increase recommendations 20%.*

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 fixation ability of a soil. If applications of 300-500 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 applied. Once such soils have a good soil test, they will continue to supply potash for some time even though crop removal may be considerable.

The recommendations in Tables 7-8 show the potassium rates based on soil tests, crop grown, and yield goal.

Farm Manures

Manures are valuable primarily because of their plant nutrient content. They also serve as a source of organic matter for improving soil physical conditions. Table 9 gives some average plant nutrient figures for several kinds of common farm animal manures. During the first year, about 50% of the nitrogen and phosphorus and all of the potassium are available. These amounts can be subtracted from the fertilizer recommendation.

Magnesium

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 2 or 3) and in similar soils limed with calcic limestone or marl. Responsive crops are cauliflower, muskmelons, potatoes, peas, oats, and corn. Magnesium deficiency is a common disorder in greenhouse tomatoes.

Dolomitic limestone should be applied to acid sandy soils which have less than 75 pounds of exchangeable magnesium per acre. At least 1,000 pounds of dolomitic limestone should be used. This will add about 100 pounds of magnesium per acre.

TABLE 8. Potash—potassium recommendations for field crops on sandy loams and loamy sands.

Available soil potassium** -- pounds of K Per Acre					Pounds Per Acre Annually Recommended	
					K_2O	K
				Less than 60	300	249
			Less than 60	60-99	250	208
		Less than 60	60-89	100-149	200	166
	Less than 60	60-89	90-119	150-199	150	125
Less than 60	60-89	90-119	120-159	200-249	100	83
60-89	90-129	120-159	160-189	250-299	75	62
90-149	130-169	160-199	190-219	300-399	50	42
150-199	170-219	200-239	220-259	-	25	21
200+	220+	240+	260+	400+	0	0
Barley 40-69 Bu Buckwheat Corn 60-89 Bu Cover crops Field beans 15-29 Bu Oats 50-79 Bu Grass pasture Rye Soybeans 30-49 Bu	Barley 70-100 Bu Clover Corn 90-119 Bu Corn silage 10-14 T Field beans 30-50 Bu Oats 80-120 Bu Soybeans 50+ Bu Sudangrass Wheat 30-49 Bu	Alfalfa 3-4 T Corn 120-149 Bu Corn silage 15-19 T Sugar beets 18-23 T Wheat 50-70 Bu	Corn 150+ Bu Corn silage 20-30 T Sugar beets 24-29 T	Alfalfa 5-6 T Potatoes*** 250-350 cwt		

**For soils classified as sands (Table 2 or 3), increase recommendations 20%.*

***If no soil test is made and the soil is probably low in potassium, use the recommendations for a soil test of 80 pounds of K per acre.*

****For a yield goal of 400 cwt., increase recommendations 20%.*

On sandy soils which are not acid and have less than 75 pounds of exchangeable magnesium per acre, soluble magnesium fertilizers may be needed. The suggested annual rate is 20 to 40 pounds of magnesium (Mg) per acre in the row fertilizer. Magnesium sulfate, sulfate of potash-magnesium, or magnesium oxide are all satisfactory carriers of magnesium.

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

Magnesium deficiency in crops may be induced by high rates of potassium and sodium materials. When soil tests indicate that the ratio of the pounds of exchangeable potassium to exchangeable magnesium is greater than 3 to 1, crops should be watched for possible magnesium deficiency.

In Michigan, crop response to magnesium fertilizer has not been observed if the soil magnesium exceeds 3 percent of the total bases. In some states, agronomists strive to have at least 10 percent magnesium of the total exchangeable bases (equivalent basis). These high levels are aimed to help prevent "grass tetany" disorders in livestock which feed on lush grass.

Anyone concerned with "grass tetany" should avoid excess rates of potassium fertilizer. He should also feed some legume hay, which is generally high in magnesium. He also should consider feeding magnesite or other magnesium carriers which can be mixed with supplemental grain rations. For amounts, contact your animal feed specialist.

Calcium

Calcium is an essential nutrient needed for plant growth. Fortunately, well-limed soils are rich in calcium. Even soils needing lime to correct acidity generally contain sufficient calcium for plants. The poor

TABLE 9. Average amounts of nitrogen, phosphorus, and potassium and the combined value of manures from different farm animals.

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

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

***Probably contained some feed residues.*

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

growth of plants on acid soils is usually due to excess soluble manganese, iron and/or aluminum.

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

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

Sulfur

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

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

MICRONUTRIENTS FOR MINERAL SOILS

Manganese

The 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 of this element is most likely to occur on dark-colored surface soils in lake bed or glacial outwash areas. Apply 5 to 10 pounds of manganese per acre in a band with the fertilizer near the seed. Suitable carriers are manganese sulfate and finely ground manganous oxide. Broadcast application of manganese is not recommended. Neither granular manganese oxide nor any of the manganic forms are acceptable manganese materials. Also the use of Mn EDTA (chelate) has not been effective for organic soils.

Boron

Boron at the rate of 2 to 3 pounds per acre may be needed for sugar beets, table beets, cauliflower, celery, turnips, and rutabagas. Use 1 to 2 pounds per acre for alfalfa on sandy loams and sandy soils. Lettuce, broccoli, spinach, and cabbage may need 1 pound of boron per acre. *Never apply boron for beans, cucumbers, soybeans, peas, or small grains.*

Zinc

Zinc has been found to be needed for beans and corn grown on alkaline soils of the 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 corrected the deficiency on beans and onions.

Micronutrients can be absorbed through the leaves of plants from foliar applications. Where spray equipment is available, cost of material used is greatly reduced. If compatible, the micronutrients can be added to a fungicide or insecticide spray. Suggested micronutrient sources and rates per acre as sprays are as follows:

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

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

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

Manganese — 1.0 percent.
Boron — 0.125 percent.
Copper — 0.5 percent.
Zinc — 0.5 percent inorganic or 0.125 percent organic.
Molybdenum — 0.04 percent.
Iron — 0.1 percent.
Sulfur — 1.0 percent.

FIELD CROPS
SUGGESTED FERTILIZER PLACEMENT

Alfalfa — Alfalfa Brome

For new seedings, apply a fertilizer high in phosphorus through the attachment on the grain drill. Allow 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 oats, if oats are used as a nurse crop, or with the fertilizer. Fertilizer rates greater than 100 pounds of phosphate and/or 50 pounds of potash per acre should be broadcast and plowed down or disked-in ahead of seeding.

Boron is needed annually 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 companion crop has been harvested.

TABLE 10. Micronutrient Response and Fertilizer Needs as Indicated by Soil Tests. (For Responsive Crops Growing on Known Deficient Soil Types!)

MANGANESE (0.1 N HCl EXTRACTION)

Soil Test	Mineral Soils				Organic Soils			
	Above pH 6.5		Below pH 6.5		Above pH 6.3		Below pH 6.3	
ppm Mn	Response	Mn-lbs/A	Response	Mn-lbs/A	Response	Mn-lbs/A	Response	Mn-lbs/A
Below 5	Probable	8	Probable	6	Certain	16	Certain	12
5-10	Probable	6	Possible	4	Certain	12	Probable	8
11-20	Possible	4	None	0	Probable	8	Possible	4
21-40	None	0	None	0	Possible	4	None	0
Above 40	None	0	None	0	None	0	None	0

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

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

COPPER FOR ORGANIC SOILS

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

**Rates for inorganic salts such as zinc sulfate.*

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

Barley — Oats — Wheat — Rye

The proper place to apply fertilizer for small grains is one inch to the side and one inch below the seed. Most 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. In general do not drill in direct contact with the seed more than a total of 100 pounds of plant nutirients ($N + P_2O_5 + K_2O$) for sandy soils and 140 pounds per acre for fine-textured soils. If additional amounts are needed, apply in a separate operation.

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

Manganese is recommended in the band fertilizer for wheat, oats, and barley growing on lake bed soils and dark colored flats where the 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.

Small Grain — Legume Seeding

Recommendations in Tables 6 to 8 do not show recommendation for a legume seeded in small grain. For such situations, the phosphorus recommendations for the small grain are usually sufficient for starting a legume crop. Potassium recommendations, however, are usually not adequate for the legume crop. The extra potassium for the legume can be applied at time of the small grain seeding, providing the limits on amounts in direct contact with the small grain seed are followed. An alternate program is to apply the extra potassium as a topdressing on the legume when one or two cuttings of hay have been removed.

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 pH's 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 tilling. To prevent the deficiency, apply 3 to 4 pounds of zinc per acre in the row fertilizer. If organic forms such as zinc chelates are used, apply 0.5 to 0.8 pounds of zinc per acre.

Corn — Corn Silage

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

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

Grass (Pasture or Hay)

Grass usually needs high-nitrogen fertilizer such as 2-1-1 or 4-1-2 ratio. This fertilizer may be topdressed in winter or early spring. Under intensive cropping, additional topdressings are applied during the growing season. When a new seeding is started, more liberal rates of phosphorus and potassium are applied. These materials are applied broadcast after plowing and then are disked into the top 3-4 inches of soil. Tables 5-8 report suggested fertilizer amounts based upon soil tests. A soil test can help determine the available amounts of phosphorus and potassium.

Potatoes

Apply up to 60 pounds of nitrogen, 200 pounds of phosphate, and 100 pounds of potash per acre in bands two inches to the side and level with or slightly below the seed piece. Plow down or disk in additional amounts when needed. Supplemental nitrogen can be either plowed down, sidedressed, or applied in the irrigation water. For suggested nitrogen rates, see Table 5. Manganese may be needed when mineral soils test above pH 6.5. A soil test can help determine the available amounts of manganese. On soils testing low use 4 to 8 pounds of manganese per acre in the row at planting time. Manganese may be applied as a foliar spray.

Heavy applications of potassium chloride have depressed the specific gravity of potato tubers. This effect is most noticeable when large amounts of the fertilizer are placed in bands near the row at planting time or applied as a sidedressing. Fall applications of potash for the cover crop and plow-down applications in the spring are suggested for large rates of potassium chloride. Potassium sulfate and potassium nitrate are preferred potash carriers for late treatments, but are more expensive.

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

Sugar Beets

Fertilizer for sugar beets should be applied in bands one inch to the side and 2 inches below the seed. A band three inches directly below the seed is satisfactory. Part of the fertilizer, however, may conveniently be broadcast before plowing.

If the micronutrients, manganese and/or boron, are required, they may be applied as part of the band fertilizer. Broadcast applications of manganese are ineffective. The total amount of nitrogen should not exceed 100 pounds per acre. Late nitrogen applications are apt to decrease the sugar content and increase the impurities. Recommendations in Table 5 are guides for nitrogen requirements of sugar beets, based upon past treatment.

Sorghum — Sudangrass

Sorghum and Sudangrass grown for summer pasture or chopped forage have nutrient requirements similar to corn. In estimating fertilizer requirements, use the columns in Tables 4-8 for corn that fits the

TABLE 11. 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 Peas (40)* Turnips	Carrots (200-400) Cucumbers (150) Endive Lettuce (250) Lima beans (20) Parsnips Pumpkins Radish (30) Rutabagas (200) Snap beans (60) Spinach (100) Sweet corn (100) Sweet potatoes Squash	Asparagus crowns new beds Broccoli (120) Brussel sprouts Cabbage (200-600) Cauliflower (160) Cucumbers (200) over 40,000 plants Egg plants (150) Muskmelons (150) Peppers (40) Rhubarb (200) Table beets (300) Water melons	Celery (400) Flower beds Home garden Dry onions (400) Tomatoes (500) Market garden		

**Figure in perentheses after crop is the estimated yield potential in cwts. (100 lbs.) per acre. If no soil test is made and the soil is probably low in phosphorus, use the recommendations shown for a test of 20 to 39 pounds of P per acre.*

nearest yielding capacity of the soil. Normally this is the column for the 100-bushels-per-acre yield goal.

VEGETABLE CROPS

Most vegetable crops require relatively high levels of fertility for optimum yields of satisfactory quality. Fertilizer may be applied to vegetables in one or more of the following ways: (1) applied at time of planting to the green manure or cover crop preceding the vegetable crop; (2) plowed down; (3) drilled in after plowing; (4) placed in bands near the seed; (5) used in starter solutions; (6) sidedressed or topdressed; (7) applied to the leaves (foliar feeding).

Credit any fertilizer applied by any of the above methods to the total amounts recommended in Tables 11 to 13.

Some rules that will aid in making decisions are:

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

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

(3) If phosphorus is to be sideplaced, drill in or plow down a fertilizer high in nitrogen and potassium. This reduces possible injury to small plants or germinating seeds and helps decompose 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 & potassium fertilizer because of excessive cost, inability to supply sufficient nutrients and possibility of plant injury.

Fertilizers should be applied according to soil tests for P and K, pH and soil type, as shown in Tables 11-13. Some typical recommendations for growing vegetables on mineral soils at low to medium fertility, in terms of N, P_2O_5, and K_2O are:

SOILS OF LOW FERTILITY

Asparagus (New Planting — Crowns)

Plow down 50 pounds of nitrogen, 100 pounds of phosphate, and 80 pounds 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. Repeat the plow-down and nitrogen application for several years.

Asparagus (Established Planting)

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

Lima Beans, Snap Beans

Apply fertilizer two inches to the side and two inches below the seed. Do not apply directly in contact with the seed. Use 25 pounds of nitrogen, 100 pounds of phosphate, and 50 pounds of potash per acre for clay loams, and 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 2-3 true 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 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, and 50 pounds of nitrogen, 120 pounds of phosphate, 120 pounds of potash and 1 pound of boron per acre for sandy soils. Topdress with 50 pounds of nitrogen.

Broccoli, Cabbage, Brussel Sprouts, Cauliflower

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

Sweet Corn

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

Cucumbers

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

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

Muskmelons, Watermelons

At planting time, fertilize rye or ryegrass used for a green manure crop with 40 pounds each of nitrogen, phosphate, and potash per acre. For sandy soils,

TABLE 12. Potash—potassium recommendations for vegetable crops on loams, clay loams and clays. (Table 2 or 3).

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

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

drill in, three or four inches deep, 50 pounds of nitrogen and 150 pounds each of phosphate and potash per acre after plowing. Use 50 pounds of nitrogen, 150 pounds of phosphate, and 100 pounds of potash per acre for clay loams. Sidedress with 60 pounds per acre of nitrogen three weeks after plants have emerged, or after transplanting.

Peas

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

Radishes, Turnips

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

Tomatoes

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

Rhubarb

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

Market Gardens

Plow down about 50 pounds of nitrogen, 100

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

**Figure in parentheses after crop is the estimated yield potential in cwts. (100 lbs.) per acre. If no soil test is made and the soil is probably low in phosphorus, use the recommendations shown for a test of 60 to 99 pounds of K per acre.*

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

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

Home Gardens

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

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

Vegetables in Flats and Flowers for Transplanting

There are several alternative programs. These are:

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

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

(3) Prepare special soil mixes, especially if the soil is steamed or fumigated. A suggested soil mix is two parts, by volume, of sand and one part of shredded peat. Another is a one-to-one mixture of peat and vermiculite. To each cubic yard of the mixture, add 12 ounces of potassium nitrate, and 3 pounds of 20 percent superphosphate. If acid peat (below pH 5.0) is used, add 6 pounds of finely ground dolomitic limestone. Additional nitrogen is needed after plants are well started. Good materials are ammonium nitrate or calcium nitrate. Dissolve two ounces in 5 gallons of water and apply as noted for option 2.

(4) For constant plant feeding with soluble fer-

SOME CONVERSION FACTORS

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

1 acre is equal to 43,560 square feet.

1 gallon of concentrated liquid fertilizer weighs about 11 pounds.

1 pint of water weighs about 1 pound.

1 pint of dry fertilizer weighs about 1 pound.

1 pint is equal to 2 cups.

1 pint is equal to 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 turned to a depth of 6 2/3 inches weighs about 500,000 pounds.

0.1 ounce or 2.8 grams of fertilizer per bushel equals about 100 pounds per acre.

1 pound of fertilizer per cubic yard is equal to 800 pounds per acre.

20 bushels of soil mix equals about 1 cubic yard.

1 ounce or 28 grams per gallon is equivalent to 3 pounds per 48 gallons.

1 ounce of fertilizer per 100 gal. makes a salt solution of 75 ppm.

SOME EQUIVALENT RATES:

Pounds per acre desired	Amount needed		
	One square foot	Cubic yard	1,000 sq. feet 33' x 30'
100	—	2 ounces	2.3 pounds
500	1 teaspoon	10 ounces	11.5 pounds
1,000	2 teaspoons	1.3 pounds	23 pounds

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

Starter Solution

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

RECOMMENDATIONS FOR ORGANIC SOILS

In several county soil surveys, organic soils are classified either as mucks or peats. Carlisle, Houghton, Kerston, Lupton, and Carbondale mucks and Rifle and Greenwood peats represent the more important types.

Within each of these types, the acidity or alkalinity varies somewhat, except that Greenwood peat is always very acid. Organic soils usually do not benefit from liming unless the pH is below 5.2. An exception is land for celery which should test pH 5.5 or above. Application of lime on muck when it is not needed is likely to lower crop yields. Greenwood peat must be limed for the production of all crops except blueberries. Even blueberries may benefit from limestone if the soil pH is below 4.0.

Sometimes the pH of the surface foot of soil is around 5.0, but the second foot of soil may have a pH around 4.0. In this case, apply lime after deep plowing. When organic soils require lime and the soil tests below 150 pounds of magnesium per acre, use some dolomitic limestone.

The amount of ground limestone required for organic soils will depend on the pH and the depth to which the extreme acidity extends. With the pH between 4.6 and 5.0, an application of 3 to 6 tons per acre of agricultural limestone is likely to be needed for most crops; with a pH ranging from 4.2 to 4.5, 8 tons of limestone; and with pH 3.8 to 4.2, 10 tons.

Since organic soils which have never been fertilized are almost always low in phosphorus and potassium, make the pH test only on the plowed layer. Also test the pH value for the underlying soil at a depth of 18 to 24 inches. After the soil has been well fertilized for 2 or 3 years, determine the available phosphorus and potassium, along with the pH, in a sample taken at a depth of 7 inches. Since the applied fertilizer remains largely in the plowed layer, only the pH test is necessary at the 18-24 inch depth. Rechecking the soil tests every year is advisable. Send package and information to your soil testing laboratory.

MAJOR NUTRIENTS

The pounds of phosphate and potash fertilizer recommended as indicated by the soil test are shown in Tables 14 and 15. *Soils of low fertility usually test about 30 pounds of phosphorus and 150 pounds of potassium per acre. Use fertilizer recommendations for these values if you do not have a soil test made and the soil is low in fertility.*

Nitrogen requirements are related to draining, soil temperature, and depth of the organic layer. Conditions which usually require the use of nitrogen are the following: (1) organic layers less than 18 inches deep, (2) soil with a pH less than 5.2, (3) after heavy rainfall, (4) high water table, (5) low soil temperature. Spring-planted crops on most adequately drained soils require 50 to 100 pounds of nitrogen per acre. Crops planted in late spring or early summer usually require only ½ as much nitrogen.

MICRONUTRIENTS

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

Micronutrients can be absorbed through the leaves of plants. Where spray equipment is available, cost of material used is greatly reduced. Suggested rates as sprays are discussed on page 18.

Manganese

Manganese deficiency is likely to occur on organic soils with a pH of 5.8 or above. Such a deficiency can be corrected by the application of manganese salts or by the addition of enough sulfur to acidify the soil. Very acid soils that have been limed usually show a greater need for manganese fertilization than do soils naturally high in lime.

Crops listed in Table 16 are grouped according to the degree of response to treatment with manganese. The amount of manganese suggested for crops as affected by pH is shown in Table 17. 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 carry-over in the available form.

Boron

The need for fertilizing with boron on organic soils depends on the crop grown (see Table 16). 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 the lime content. For this reason, the amounts suggested in Table 18 are greater on high-lime soils. In estimating boron needs, expect some residual effect for the succeeding crop. However, this will not injure sensitive crops if recommended rates are applied. It may be necessary to use quantities greater than those suggested in Table 18 for table beets.

Copper

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

TABLE 14. 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+	50	22
20-49	70-99	150+	-	25	11
50+	100+	-	-	0	0
Clover	Asparagus	Cabbage	Broccoli		
Oats	Beans	Carrots	Cauliflower		
Rye	Corn-130 Bu	Cucumbers	Celery-600 cwt		
Soybeans-35 Bu	Mint-70 lb	Endive	Onions-600 cwt		
Pasture (grass)	Radishes	Lettuce-500 cwt			
	Sudangrass	Parsnips			
	Sweet corn	Potatoes-400 cwt			
	Turnips	Spinach			
		Sugar beets			
		Table beets			
		Bluegrass sod			

To use this table, look for the crop grown. Then find the position of the approximate soil test in the same column. To determine amount of phosphate fertilizer needed, follow line to appropriate column on the right.

EXAMPLE: Recommend 150 pounds per acre of phosphate (P_2O_5) for broccoli if soil test is 80 pounds per acre. Recommendations in this table assume you will use the proper placement of fertilizer.

spray. Crops listed in Table 16 show the degree of response to copper fertilization, and data in Table 19 show copper recommendations.

Zinc

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

Molybdenum

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

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

ORGANIC SOILS OF LOW FERTILITY

Broccoli, cabbage, and cauliflower

Drill in 4 inches deep 50 pounds of nitrogen, 100 pounds of phosphate, and 250 pounds of potash per acre. These crops need a sidedressing of 30 to 100 pounds of nitrogen fertilizer depending upon drainage and weather conditions. Cauliflower needs boron and manganese in the fertilizer if the soil pH is 5.8 or above. If below pH 5.8, use boron. Molybdenum seed treatment or foliage spray is generally needed.

Carrots, parsnips

Disk in or plow down fertilizer containing boron and copper. Disk-in is preferred for soils of low fertility.

An alternate program is to plow down a fertilizer high in potassium, containing boron and copper. A fertilizer high in phosphorus can be applied at a light rate in a band 3 inches below the seed. Do not use large rates in bands near the seed as this can cause misshapen roots. For well drained, high-organic soils, use 50 pounds of nitrogen per acre. For sandy mucks and marly soils, use 80 to 120 pounds of nitrogen per acre.

TABLE 15. Potash—potassium fertilizer recommendations for organic soils.

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

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.

A typical fertilizer program for soils of low fertility is to apply 50-120 pounds of nitrogen, 150 pounds of phosphate and 250 pounds of potash containing 1 pound boron and 2 pounds of copper per acre. Manganese if needed can be applied on the foliage.

Celery

For celery, disk in or drill in the fertilizer after plowing. This usually consists of 50 pounds of nitrogen, 200 pounds of phosphate and 400 pounds of potash and 2 pounds of boron per acre. Spray foliage with manganese if the soil is above pH 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, then 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. Plow down 200 pounds of potash (K_2O) per acre. A fertilizer high in phosphorus should be applied in bands 2 inches to the side and below the seed. A typical row fertilizer is 8-32-16 applied at the rate of 200 pounds per acre. If needed, 2 percent manganese, 1 percent zinc and/or ½ percent copper is added to the row fertilizer. Growers may want to consider 1/8 percent boron in the row fertilizer if it can be placed away from the seed. Sidedress with 50 to 80 pounds of actual nitrogen if plants are not dark green in color in late June.

Head lettuce, spinach

Disk in or plow down 200 pounds of potash (K_2O) per acre. Apply in band 2 to 3 inches below the seed and 1 inch to the side, a fertilizer high in phosphorus containing ½ pound of boron and 2 pounds of copper per acre. A typical fertilizer grade is 10-20-10, 10-30-10 or 16-48-0 applied at the rate of 200 to 500 pounds per acre. In addition, if the pH is 5.8 to 6.4, use 5 pounds of manganese per acre in the row fertilizer. If the pH is above 6.4 then use 10 pounds of manganese per acre. Molybdenum seed treatment may be needed on acid fibrous peats. Sidedress the spinach or the lettuce at blocking time with 50 pounds of nitrogen per acre.

Onions

Plow down or disk in 200 pounds of potash (K_2O) per acre. Apply in bands 2 to 3 inches below the seed a fertilizer high in phosphorus containing copper. A typical fertilizer is 8-32-16, 10-20-10, 10-30-10 or 16-48-0 at the rate of 150-500 pounds per acre. Use 5 pounds of manganese in the band fertilizer if the pH is 5.8 to 6.4 and 10 pounds manganese per acre if the pH is above 6.4. Topdress onions in June with 250 pounds of pelleted ammonium nitrate or 200 pounds of urea per acre. Zinc at the rate of 3 pounds per acre is needed for several years on newly developed land. Copper, if needed, is usually applied with the row fertilizer at the rate of 1 to 5 pounds per acre.

If all the fertilizer is applied broadcast, then disk in an additional 50 percent more phosphorus fertilizer than is suggested in Table 14.

Peppermint, spearmint

In the late spring before the crop emerges, apply broadcast or drill in 100 pounds of phosphate and 200 pounds of potash per acre. Topdress in June with 70 pounds of actual nitrogen per acre when the foliage is dry. Use only pelleted materials. Immediately follow the nitrogen application with a drag or finger-tooth harrow so as to knock off any nitrogen pellets adhearing to plants. Spearmint needs manganese in the fertilizer if soil pH is above 6.5.

Potatoes

Plow down or disk in 250 pounds of potash (K_2O) per acre. In addition, apply in bands near the seed piece a fertilizer high in phosphorus such as 8-32-16 or 10-30-10 applied at the rate of 500 pounds per acre. Two percent manganese is needed in the row fertilizer if the soil pH is above 6.0. Manganese can also be applied on the foliage at the rate of 1 pound (actual) per acre per spray, applied about four times during the growing season.

Avoid excess nitrogen fertilizer so as to help prevent excess tops and to aid maturity of the crop in the fall. Extra nitrogen, however, may be needed if the soil is extremely acid, the season is cool and wet, or the field is poorly drained.

Table beets, swiss chard, radish, turnips, rutabagas

Drill in or disk in the fertilizer. Use 1 pound of boron per acre in the fertilizer for radishes, 2 pounds boron for turnips, rutabagas and swiss chard, and 4 pounds for table beets. If soil pH is above 6.0, use 5 to 10 pounds of manganese per acre in the fertilizer for all crops. In-row application of manganese sulfate is especially needed for the production of radishes. For phosphate-potash rates see Tables 14 and 15.

Beans, soybeans

See Tables 14-15 for rates of phosphate and potash.

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

Merion Bluegrass sod

Although Merion bluegrass has high market value, it is less responsive to phosphate-potash fertilizer than most vegetable crops. For this crop, disk in several inches deep after plowing 150-200 pounds each of phosphate and potash per acre. This normally is sufficient P-K fertilizer until the next crop is planted.

Topdress nitrogen with a spinner-type spreader at the rate of 25-50 pounds per acre. Usually about two topdressings are needed, one in the spring and one in early fall. Summer nitrogen applications are primarily used to maintain color or to "green-up" the grass previous to harvest.

TABLE 16. Crop response to micronutrients (organic soils).

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

TABLE 17. Manganese needed for organic soils—elemental basis*.

Crop Response	Pounds per acre at pH: 5.8-6.4	6.5-7.2	7.3-8.0
High	8	12	16 **
Medium	4	8	12
Low	0	4	6

**Manganese not recommended if pH is below 5.8.*

***More practical to spray supplemental manganese on foliage two or three times during growing season.*

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

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

TABLE 19. Copper recommendations for organic soils—elemental basis (Native soil pH)*.

Crop Response	Pounds per acre at pH: 5.4	5.5-6.4	6.5 or higher
High	6	4	2
Medium	4	2	0
Low	2	1/2	0

**Double rates for fields that never received copper.*

APPENDIX

The soil management group designation for the different soil series. See Tables 2 and 3 for suggested yield goals.

SOIL SERIES	Soil management group*	SOIL SERIES	Soil management group*	SOIL SERIES	Soil management group*	SOIL SERIES	Soil management group*
ABSCOTA	L-4a	COLDWATER	3b	HIBBING	1.5a	MUNISING	3a-a
ADOLPH	2.5c	COLOMA	4a	HILLSDALE	3a	MUNUSCONG	3/1c
ADRIAN	M/4c	COLWOOD	2.5c	HODUNK	3a	MUSSEY	4c
AHMEEK	3a-a	CONOVER	2.5b	HOMER	4b	NAHMA	3/Rbc
ALCONA	3a	CONSTANTINE	4a	HOUGHTON	Mc	NAPPANEE	1b
ALGANSEE	L-4c	CORAL	3b	HOYTVILLE	1c	NEGAUNEE	3/Ra
ALGER	3a	CORUNNA	3/2c	HURON	1a	NEKOOSA	5a
ALLENDALE	4/1b	COVENTRY	3a	INGALLS	4/2b	NESTER	1.5a
ALLOUEZ	Ga	CRIVITZ	4a-a	IONIA	3a	NESTORIA	3a
ALPENA	Ga	CROSBY	2.5b	IOSCO	4/2b	NEWAYGO	3a
AMASA	3a-a	CROSWELL	5a	IRON RIVER	3a-a	NEWTON	5c
ANGELICA	2.5c	CRYSTAL FALLS	3/Ra	ISABELLA	1.5a	NISULA	1b
ANTRIM	4a	DAFTER	3/1b	JEDDO	1.5c	NUNICA	1.5a
ARENAC	5/2b	DANBY	L-2c	JOHNSWOOD	3a	OAKVILLE	5a
ARKPORT	3a	DAWSON**	Mc-a	KALAMAZOO	3a	OCKLEY	2.5a
ARVON	L-4c	DEER PARK**	5.3a	KALKASKA	5a	OCQUEOC	4/2a
AUGRES	5b	DEERTON	4/Ra	KARLIN	4a	OGDEN	M/1c
AUTRAIN**	5a-h	DEFORD	4c	KAWKAWGAN	3/Rbc	OGEMAW	5b-h
AVOCA	4/2b	DEL REY	1.5b	KAWKAWLIN	1.5b	OGONTZ	3/2c
BACH	2.5c-c	DETOUR	Gbc	KENDALLVILLE	3/2a	OMEGA**	5.7a
BANNISTER	4/2c	DIANA	Gbc	KENT	1a	OMENA	3a
BARAGA	Ga	DIGHTON	1.5a	KERSTON	L-Mc	ONAMIA	4a
BARKER	1.5a	DOWAGIAC	3a	KEWEENAW	4a-a	ONAWAY	2.5a
BARRY	3c	DRESDEN	3a	KIBBIE	2.5b	ONOTA	3/Ra
BELDING	3/2b	DRYBURG	3/2a	KINROSS	5c	ONTONAGON	1a
BELLEFONTAINE	3a	DRYDEN	3a	KIVA	4a	ORIENTA	5/2b
BENTLEY	4a	DUEL	4/Ra	KOKOMO	2.5c	OSHTEMO	4a
BERGLAND	1c	EAST LAKE	5a	LACOTA	3c	OTOSCO	4b
BERRIEN	5/2a	EASTPORT**	5.3a	LAKE LINDEN	1.5a	OTTAWA	5/2a
BERVILLE	3/2c	ECHO	5a	LAMSON	3c	OTTOKEE	5a
BIBON	5/2a	EDMORE	4c	LANDES	L-2a	OWOSSO	3/2a
BLOUNT	1.5b	EDWARDS	M/mc	LAPEER	3a	PALMS	M/3c
BLUE LAKE	4a	EEL	L-2a	LATTY	1c	PALO	3b
BOHEMIAN	2.5a	ELMDALE	3a	LEELANAU	4a	PARKHILL	2.5c
BONO	1c	ELO	1.5a-a	LENAWEE	1.5c	PARMA	3/Ra
BOWERS	1.5b	EMMERT	Ga	LINWOOD	M/3c	PAULDING	0c
BOYERL	4a	EMMET	3a	LOCKE	3b	PELKIE	L-2c
BRADY	4b	ENSIGN	Rbc	LONDON	2.5b	PENCE	4a-a
BRANT	4/2a	ENSLEY	3c	LONGLOIS	2.5a	PENNOCK	L-2c
BRECKENRIDGE	3/2c	EPOUFETTE	4c	LONGRIE	3/Ra	PERRIN	4a
BREVORT	4/2c	ESSEXVILLE	4/2c-c	LORENZO	4a	PERTH	1b
BRIDGMAN**	5.3a	EVART	L-4c	LOXLEY	Mc-a	PESHEKEE	Ra
BRIMLEY	2.5b	EWEN	L-2a	LUCAS	1a	PEWAMO	1.5c
BRONSON	4a	FABIUS	4b	LUPTON	Mc	PICKFORD	1c
BROOKSTON	2c	FAIRPORT	2/Ra	MACKINAC	2.5b	PINCONNING	4/1c
BRUCE	2.5c	FOX	3a	MACOMB	3/2b	PINORA	L-2c
BRULE	L-2c	FROBERG	1a	MANCELONA	4a	PLAINFIELD	5a
BURLEIGH	4/2c	FULTON	1b	MANISTEE	4/2a	PLEINE	3c
BURT	3/Rbc	GAASTRA	2.5b	MARENISCO	4a-a	PORCUPINE	4a
CADMUS	3/2a	GAGETOWN	2.5a-c	MARKEY	M/4c	POSEN	3a
CAPAC	2.5b	GAY	3c	MARLETTE	2.5a	RANDVILLE	4a-a
CARBONDALE	Mc	GENESEE	L-2a	MATHERTON	3b	REDRIDGE	4b
CARLISLE	Mc	GILCHRIST	4a	MAUMEE	5c	RICHTER	3b
CASCO	4a	GILFORD	4c	MCBRIDE	3a	RIFLE	Mc
CATHRO	M/3c	GLADWIN	4b	MCGREGOR	3b-c	RIMER	3/1b
CELINA	2.5a	GLENDORA	L-4c	MECOSTA	L-4a	RODMAN	Ga
CERESCO	L-2c	GLENGARY	L-2c	MELITA	5/2a	ROLLIN	M/mc
CHAMPION	3a-a	GOGEBIC	3a-a	MENOMINEE	4/2a	RONALD	3c
CHANNING	5b-h	GOMER	L-2c	METAMORA	3/2b	ROSCOMMON	5c
CHARITY	1c-c	GOODMAN	2.5a	METEA	4/2a	ROSELAWN	5.3a
CHARLEVOIX	3b	GRANBY	5c	MIAMI	2.5a	ROSELMS	0b
CHASSELL	L-4c	GRAYCALM	5a	MICHIGAMME	3/Ra	ROUSSEAU	4a
CHATHAM	3a	GRAYLING	5.7a	MINOA	3b	RUBICON**	5.3a
CHELSEA	5a	GREENWOOD**	Mc-a	MISSAUKEE	3b	RUDYARD	1b
CHENEAUX	4b	GRIFFIN	L-2c	MONTCALM	4a	RUSE	Rbc
CHESANING	4/2b	GUELPH	2.5a	MORAN	3/Ra	SAGANING	4c,
CHIPPENY	M/Rc	HARTWICK	5a	MORLEY	1.5a	SANILAC	2.5b-c
CHOCOLAY	3a-a	HESSEL	Gbc	MOROCCO	5b	SARANAC	L-2c
COHOCTAH	L-2c	HETTINGER	1.5c	MOYE	4b	SATAGO	3/Rbc
		HIAWATHA	5a			SAUBLE	5.3a

APPENDIX

The soil management group designation for the different soil series. See Tables 2 and 3 for suggested yield goals.

SOIL SERIES	Soil management group*	SOIL SERIES	Soil management group*	SOIL SERIES	Soil management group*	SOIL SERIES	Soil management group*
SAUGATUCK**	5b-h	STAMBAUGH	3a-a	TOBICO	5c-c	WARNERS	M/mc
SAVERINE	3/2b	ST. CLAIR	1a	TOLEDO	1c	WARSAW	3a
SEBEWA	3c	ST. IGNACE	Ra	TONKEY	3c	WASEPI	4b
SELFRIDGE	4/2b	STEUBEN	3a-a	TRAUNIK	5b	WASHTENAW	L-2c
SELKIRK	1b	STRONGS	5a	TRAVERSE	3b	WATERSMEET	5b-a
SEWARD	3/1a	SUMMERVILLE	Ra	TRENARY	3a	WATTON	1.5a
SHELLDRAKE**	5.3a	SUMNER	4a	TROUT LAKE**1	5b-h	WANKECHA	3a
SHINROCK	1.5a	SUNDELL	3/Rbc	TULA	3b	WAUSEON	3/1c
SHOALS	L-2c	SUNFIELD	3a	TUSCOLA	2.5a	WEA	2.5a
SIGMA	4b	SUPERIOR	1a	TWINING	1.5b	WEARE	5a
SIMS	1.5c	TAHQUAMENON**	Mc-a	TYRE	4/Rbc	WESTLAND	2.5c
SISSON	2.5c	TAPPAN	2.5c-c	UBLY	3/2a	WEXFORD	5a
SKANEE	3b-a	TAWAS	M/4c	VILAS**	5.3a	WHEATLEY	5c
SLEETH	2.5b	TEASDALE	3b	VOLINIA	3a	WHITTEMORE	1.5c-c
SLOAN	L-2c	TEDROW	4b	WAINOLA	4b	WILLETTE	M/1c
SPALDING**	Mc-a	THACKREY	2.5a	WAISKA	Ga	WINEGARS	4b
SPARTA	5a	THETFORD	4b	WAKEFIELD	2.5a-a	WISNER	1.5c-c
SPINKS	4a	THOMAS	1.5c-c	WALLACE**	5a-h	WITBECK	3c
SPIRIT	2.5b	THOMASTOWN	5b	WALLKILL	L-2c	YALMER	4a-a

**Modifying symbols used after dash in soil management groups:* (see page 3)
a--Naturally very strongly acid soils.
c--Soils which are limy at or near the surface.
h--Subsoils are hardened and cemented.
***Practicability of fertilizers doubtful.*

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. George S. McIntyre, Director, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan.

1P1R-20M-2:70-WE