EXTENSION BULLETIN E-550
(Replaces Extension Bulletin E-159)
November 1966.

FERTILIZER Recommendations for MICHIGAN VEGETABLES AND FIELD CROPS

COOPERATIVE EXTENSION SERVICE
MICHIGAN STATE UNIVERSITY

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. N. P. Ralston, Director, Cooperative Extension Service, Michigan State University, E. Lansing, Mich.

1P—11:66-20M-DPO

Table of Contents

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 3 or 4 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 Table 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 7. See the footnote on how to use the table.

Potassium recommendations based upon soil test and yield goal are reported in Table 7, page 8, for loams-clay loams, and clays, and Table 8, page 9, for sandy loams, loamy sands, and sands. For the sands the amounts in Table 8 are to be increased 20%.

Fertilizer placements suggested for the various crops are given on page 10.

Vegetable Crops Grown on Mineral Soils

Fertilizer placement and typical rates for soils of low fertility are reported on pages 11 to 15. To modify phosphorus and potassium rates based upon soil test, see Tables 10, 11, 12, pages 12 to 14.

Crops Grown on Organic Soils

Fertilizer placement and typical rates for soils of low fertility are reported on pages 21 and 22. To modify phosphorus and potassium rates based upon soil test, see Tables 14, 15, pages 17 and 18.

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 10, 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 Recommendations for Michigan Vegetables and Field Crops

Prepared by staff members of the
Departments of Soil Science 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 16.

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, a "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 x 2.3 = percent P_2O_5; percent K x 1.2 = percent K_2O.

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

In this publication, recommendations are expressed as the oxides and as the elements.

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. Ratios and minimum grades commonly available are shown in Table 1.

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

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

Table 1. — Suggested ratios and minimum grades for fertilizers. (Percentages by weight of N-P_2O_5-K_2O.)

Ratio	Grade	Ratio	Grade
0:1:1	0-20-20	1:1:1	10-10-10
0:1:2	0-15-30	1:2:1	10-20-10
0:1:3	0-10-30	1:2:2	8-16-16
0:2:1	0-30-15	1:2:6	5-10-30
2:0:1	24-0-12	1:3:1	8-24-8
2:1:1	12-6-6	1:4:0	8-32-0
2:1:2	20-10-20	1:4:2	6-24-12
2:2:1	12-12-6	1:4:4	5-20-20

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.

Soil Acidity and pH

Soil acidity is expressed in terms of "pH," or of lime requirement. 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 micronutrients, about which more will be said later.

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.

In general, the amount of lime needed to neutralize the acidity of a soil is dependent on the pH, texture, and organic matter content of the *plow layer*. The tons of agricultural lime needed at a given pH for soils of different textures are shown in Table 2. The texture of the plow layer may vary considerably from the overall texture of the soil profile on which the soil management groups are based.

The lime requirements of acid soils submitted as samples to the state laboratory are determined by measuring the total soluble and exchangeable hydrogen and aluminum. 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.

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

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 active 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.

Basis for Fertilizer 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 fertilizer needs of a 20-ton-per-acre sugar beet crop are greater than those of a 15-ton crop. The amount needed for a 120-bushel corn crop is more than

Table 2. — Tons of limestone required to raise the pH of the plow layer of different soils to pH 6.5.

Texture of plow layer	Depth of plowing inches	pH range				Additional amounts for alfalfa to pH 6.8—7.0
		4.5—4.9	5.0—5.4	5.5—5.9	6.0—6.4	
		Tons of lime recommended*				
Clay	7	6	5	4	2	+1½
	9	8	6½	5½	3	+2
	12	10	8	7	4	+3
Clay loams and loams	7	5	4	3	2	+1
	9	6½	5½	4	2½	+1½
	12	8½	7	5	3½	+2
Sandy loams	7	4	3	2½	1½	+1
	9	5½	4	3½	2	+1½
	12	7	5½	4½	2½	+2
Loamy sands	7	3	2½	2	1	+½
	9	4	3½	2½	1½	+1
	12	5½	4½	3½	2	+1
Sands	7	2½	2	1½	½	+¼
	9	3½	2½	2	½	+½
	12	4½	3½	2½	1	+½

**Lime recommendations based on a material with 25 percent passing through a 100-mesh sieve and a neutralizing value of 90 percent.*

double that required for a 60-bushel crop. The recommendations in this bulletin are aimed at reasonable 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.

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.

Fertilizer recommendations shown in Tables 5-8 are based upon a maintenance fertility program for a particular yield goal. The recommendations call for amounts that will result in fertility build up when soils test very 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 three or four years to check the fertility reserves in the plow layer. With high value crops, soil tests may be needed every year.

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 Agricultural Experiment Station, Michigan State University, East Lansing, Michigan. These are basic interpretive soil groupings. They are based on properties of the soil profile to a depth of 3 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 3 and 4 for southern and northern Michigan, respectively, help determine the yield goals to use with the fertilizer recommendations in Tables 5-8. 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 3 and 4 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 limey at the surface; and "h" indicates subsoils which are hard and cemented.

For soils where the texture of the upper layer differs from the lower layer, a fraction is used instead of a whole number. For example, 4/1 is for loamy sand 18 to 42 inches thick over clay; 5/2 is for sand 42 to 66 inches thick over loams and clays; 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) with silty clay or clay at 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.

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.

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

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 two methods of extraction. One is using 1.0 $\underline{N}$ neutral ammonium acetate. The other employs 0.13 $\underline{N}$ hydrochloric acid. The Central Testing Laboratory uses the ammonium acetate method. Most of the county laboratories in Michigan use the hydrochloric acid extraction method.

All mineral soil samples submitted to the Central 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 mineral soil, 6 2/3 inches deep. Organic soils or synthetic soil mixes are measured by volume. This is necessary because such soils usually have much lower densities than mineral soils.

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 OVER 140 FROST-FREE DAYS annually. (Southern Michigan).

Soil management group*	corn Bu./A	winter wheat Bu./A	oats Bu./A	soybeans Bu./A	field beans Bu./A	alfalfa Tons/A	sugar beets Tons/A
Clays							
0c	90	35	75	25	—	3.8	—
1a	95	42	80	28	25	4.2	—
1b	110	45	85	32	30	4.5	16
1c	120	50	90	35	35	4.8	19
Loams—Clay loams							
2a	110	50	90	32	35	4.8	19
2b	120	55	100	35	40	5.0	20
2c	130	60	110	40	45	5.5	23
Sandy loams over Clay or Loam							
3/2a	105	45	90	32	35	4.5	18
3/1b or 3/2b	115	50	95	35	37	4.8	20
3/1c or 3/2c	120	55	100	38	40	5.0	22
Sandy loams							
3a	95	40	80	30	25	4.0	16
3b	105	50	90	33	30	4.5	19
3c	110	55	95	35	35	4.8	20
3/Ra	85	40	75	28	24	3.8	—
Loamy sands over Clay or Loam							
4/2a	95	40	75	30	25	4.0	15
4/2b-4/1b	100	45	80	35	28	4.2	16
4/2c-4/1c	105	50	85	35	30	4.5	18
Loamy sands							
4a	75	30	60	25	20	3.5	—
4b	80	35	65	32	25	3.8	—
4c	90	40	75	32	30	4.0	—
4/Ra or 4/Rb	55	25	50	22	16	3.0	—
Sands							
5.0a	50	25	45	—	—	3.0	—
5b	60	30	55	—	—	3.5	—
5c	70	35	60	25	—	3.8	—

**See page 3 for identification of soil management groups.*

A soil test, to be helpful, must be made upon a reliable soil sample. Too much is at stake to be careless in this task. Your County Agricultural Agent can give you information on how to collect soil samples and where they can be tested. A sampling service is available in some areas. Information in Michigan Extension Bulletin E-498, "Sampling Soils for Fertilizer and Lime Recommendations," also gives instructions on how to collect soil samples.

Many soil samples are tested in laboratories other than those supervised by the 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.

STARVATION SYMPTOMS

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

For many years these deficiency symptoms have been studied under controlled conditions. The appearance of a starved plant may indicate just what

Table 4. — 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 Bu./A	winter wheat Bu./A	oats Bu./A	alfalfa Tons/A
Clays				
0c	—	37	75	3.5
1a	75	35	70	3.5
1b	80	35	75	3.5
1c	85	40	75	3.5
Loams—Clay loams				
2a	90	45	75	4.0
2b	90	48	80	4.0
2c	95	50	80	4.5
Sandy loams over Clay or Loam				
3/2a	80	40	75	4.0
3/1b or 3/2b	85	40	80	4.0
3/1c or 3/2c	85	42	80	4.0
Sandy loams				
3a	70	35	75	3.5
3b	75	35	75	3.5
3c	80	35	80	3.5
3/Ra	70	30	70	3.0
Loamy sands over Clay or Loam				
4/2a	65	32	65	3.5
4/2b-4/1b	70	35	70	3.5
4/2c-4/1c	70	35	70	3.5
Loamy sands				
4a	60	28	60	3.0
4b	65	28	65	3.0
4c	70	30	65	3.0
4/Ra or 4/Rb	50	25	40	2.5
Sands				
5.0a	45	25	40	2.5
5b	50	25	45	2.5
5c	55	25	45	2.5

*See page 3 for identification of soil management groups.

nutrient shortage is causing its unhealthy condition. You can become familiar with these symptoms and decide for yourself when your plants are lacking plant nutrients. Green plant tissue tests will verify the symptoms of starvation. There may still be time to use fertilizer profitably on that particular crop, or the information may help you select the fertilizer for the next crop.

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 at the time of planting. Moreover soil tests for nitrogen are slow, tedious, difficult, and expensive to make.

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.

Table 5 gives 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 5. 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 to 100 pounds of nitrogen fertilizer per acre:

CREDIT (subtract from total nitrogen recommended)	POUNDS OF NITROGEN PER ACRE
4 to 8% soil organic matter	20
over 8% soil organic matter	40
140 to 180 pounds of nitrogen applied to previous crop	40
corn after good red clover sod	50
corn after 50% grass sod — 50% alfalfa	60
corn after good alfalfa	80
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	50
less than 40 pounds of nitrogen applied to previous corn crop	20

Deficiency symptoms and green-tissue tests make it possible to predict, with a considerable degree of accuracy, where supplemental nitrogen applications are likely to be profitable. It is easy to test for nitrate in the growing plant. This service is offered by county soil testing laboratories and the Central Laboratory on the M.S.U. campus.

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

Table 5. — Guide for estimating total pounds of nitrogen (N) fertilizer per acre needed by field crops as affected by previous management.*

Plow down or topdress treatment**	Corn plants per acre and expected yield 14,000 70 Bu.	16,000 100 Bu.	18,000 130 Bu.	Sugar beets 20 tons	Small grain	Late potatoes 300 cwt.	Beans soybeans 35 Bu.
Legumes and 8 tons of manure per acre	5	10	40	10	10	25	10
Legumes—no manure	10	40	80	20	10	55	10
8 tons of manure per acre	40	80	120	60	30	95	20
No legumes—no manure	70	110	150	90	50	125	40

**Include in the total the nitrogen applied at planting time.*

***Most calculations assume 4 pounds of nitrogen for each ton of manure. To determine fertilizer requirements, when other than 8 tons are used, subtract or add a corresponding amount to the values listed.*

before each cultivation. Apply nitrogen fertilizer as soon as you notice a deficiency.

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 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.

One of the best times to apply nitrogen for summer crops on both fine and coarse textured soils is at time of plowing. This places the nitrogen down in moist soil and saves another trip over the field after plowing which can cause soil compaction. Extra sidedressing of nitrogen may be needed if a heavy crop population has been started or if the season is unusually cool or wet.

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.

Table 6. — Phosphate—phosphorus recommendations for field crops — growing on mineral soils with pH 6.0 to 7.0. (Available soil phosphorus determined by Bray P_1 method.)

Available soil phosphorus* — pounds of P Per Acre						Pounds Per Acre Annually Recommended	
						P_2O_5	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 - 4T. topdressing Alfalfa - 3T. seeding Buckwheat Clover Corn 60-79 Bu. Cover crops Field beans 15-29 Bu. Oats 50-79 Bu. Pasture Rye Soybeans 30-50 Bu.	Alfalfa - 6T. topdressing Alfalfa - 4T. seeding Barley 40-69 Bu. Corn 80-119 Bu. Field beans 30-50 Bu. Oats 80-120 Bu. Sudangrass	Alfalfa - 6T. seeding Barley 70-100 Bu. Corn 120-140 Bu. Wheat 30-49 Bu.	Sugar beets 18-23 T. Wheat 50-70 Bu.	Sugar beets 24-28 T.	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%.*

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 show 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 and the possible inactivation of the magnesium enzyme.

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.

Fixation of available phosphorus occurs in acid soils because of reactions with iron and aluminum. On calcareous soils, phosphorus is fixed by calcium. To help prevent high fixation, soils should have a pH of 6.0 to 7.0. Fixation is greatest when water soluble, finely ground material is broadcast. Granulation of the fertilizer and band application help prevent this fixation. Because of fixation, a rapid soil phosphorus build-up program by broadcasting phosphorus fertilizer has not been too effective in Michigan.

Data in Table 6 show the phosphorus recommendations for field crops based upon soil tests and yield goals. These rates are suggested for soils that test above pH 6.0. Soils that are more acid require up to 30 percent more phosphorus. Soils vary greatly in phosphorus fixation. Generally, fine textured soils show greater fixation than coarse textured soils. These fixation differences can be noted when the soils are tested again.

Table 7. — Potash — potassium recommendations for field crops growing on loams-clay loams and clays. (Table 3 or 4). Available soil potassium determined by the 1 N ammonium acetate method or 0.13 N hydrochloric acid method.

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
100-139	150-199	180-219	220-239	—	25	21
140-179	—	—	—	—	15	12.5
180+	200+	220+	240+	300+	0	0
Barley 40-69 Bu. Buckwheat Corn 60-79 Bu. Cover crops Field beans 15-29 Bu. Oats 50-79 Bu. Pasture Rye Soybeans 30-50 Bu.	Alfalfa - 3T. Barley 70-100 Bu. Clover Corn 80-119 Bu. Field beans 30-50 Bu. Oats 80-120 Bu. Sudangrass Wheat 30-49 Bu.	Alfalfa - 4T. Corn 120-140 Bu. Sugar beets 18-23 T. Wheat 50-70 Bu.	Alfalfa - 6T. Sugar beets 24-28 T.	Potatoes** 250-350 cwt.		

**If no soil test is made and 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%.*

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 100 to 200 pounds of potash per acre is suggested for soils testing less than 100 pounds of potassium per acre.

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 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.

Table 8. — Potash — potassium recommendations for field crops growing on sandy loams and loamy sands (Table 3 or 4).* Available soil potassium determined by the 1 N ammonium acetate method or 0.13 N hydrochloric acid method.

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
90-129	130-169	160-199	190-219	300-399	50	42
130-169	170-219	200-239	220-259	—	25	21
170-199	—	—	—	—	15	12.5
200+	220+	240+	260+	400+	0	0
Barley 40-69 Bu. Buckwheat Corn 60-79 Bu. Cover crops Field beans 15-29 Bu. Oats 50-79 Bu. Pasture Rye Soybeans 30-50 Bu.	Alfalfa - 3T. Barley 70-100 Bu. Clover Corn 80-119 Bu. Field beans 30-50 Bu. Oats 80-120 Bu. Sudangrass Wheat 30-49 Bu.	Alfalfa - 4T. Corn 120-140 Bu. Sugar beets 18-23 T. Wheat 50-70 Bu.	Alfalfa - 6T Sugar beets 24-29 T.	Potatoes*** 250-350 cwt.		

** For soils classified as sands (Table 3 or 4), 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%.*

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 cents.
**Probably contained some feed residues.

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

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.

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 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.

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 seedare 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 two inches 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 8 to 10 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.

POTATOES

Apply up to 50 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. On such soils use 5 to 10 pounds of manganese per acre in the row at planting time. Manganese may be applied as a foliar spray.

Heavy applications of potassium chloride, the common potash carrier, have often depressed the specific gravity of potato tubers. This effect is most noticeable when the fertilizer is placed in bands near the row at planting time or applied as a side dressing. 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 5-8 for corn that fits the nearest yielding capacity of the soil. Normally this is the column for the 100-bushels-per-acre yield goal.

VEGETABLE CROPS — SUGGESTED FERTILIZER PLACEMENT

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 10 to 12.

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 30% 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 of 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 major plant nutrients 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 10-12. 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:

ASPARAGUS (NEW PLANTING)

Plow down 40 pounds of nitrogen, 80 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 30 to 50 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

Table 10. — Phosphate—phosphorus recommendations for vegetables growing on well-limed soils (pH 6.0 to 7.0).

Available soil phosphorus — pounds of P Per Acre				Pounds Per Acre Recommended	
				P_2O_5	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
20-39	40-69	70-99	100-149	75	33
40-69	70-99	100-149	150+	50	22
70+	100+	150+	—	25	11
Asparagus, old beds	Asparagus, crowns	Asparagus, new beds	Celery (400)		
Peas (40)	Cucumbers (150)	Broccoli (120)	Home garden		
Radish (40)	Endive	Brussel sprouts	Dry onions (400)		
Turnips	Lettuce (250)	Cabbage (200-600)	Tomatoes (500)		
	Lima beans (20)	Cauliflower (160)			
	Parsnips	Carrots (200-400)			
	Pumpkins	Egg plants (150)			
	Snap beans (60)	Muskmelons (150)			
	Spinach (100)	Onions, bunching			
	Sweet corn (100)	Peppers (40)			
	Sweet potatoes	Rhubarb (200)			
	Squash	Rutabagas (200)			
		Table beets (300)			
		Water melons			

**Figure 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 20-39 pounds of P per acre.

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 20 pounds of nitrogen, 80 pounds of phosphate, and 40 pounds of potash per acre for clay loams, and 20 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 20 to 30 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 25 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 75 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.

BROCCOLI, CABBAGE, BRUSSEL SPROUTS, CAULIFLOWER

Plow down 30 to 50 pounds of nitrogen per acre with stubble or grain cover crops. For sandy soils, plow down or drill in after plowing 40 pounds of nitrogen, 160 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 informa-

Table 11. — Potash—potassium recommendations for vegetable crops growing on loams, clay loams and clays. (Table 3 or 4).

Available soil potassium — pounds of K Per Acre				Pounds Per Acre Recommended	
				K_2O	K
			Less than 60	250	208
		Less than 60	60-99	200	166
	Less than 60	60-99	100-149	150	125
Less than 60	60-99	100-149	150-199	100	83
60-99	100-149	150-199	200-249	75	62
100-149	150-199	200-249	250-299	50	42
150-199	200-249	—	—	25	21
200+	250+	250+	300+	0	0
Asparagus* (35) 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) Spinach (100) Sweet corn (100)	Cabbage (200-600) Egg plants Muskemelons (150) Onions bunching Parsnips Peppers (40) Rhubarb (200) Sweet potatoes Table beets (300) Water melons Rutabagas (200)	Broccoli (120) Brussel sprouts Cauliflower (160) Celery (400) Dry onions (400) Home garden Tomatoes (500)		

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

If no test is made and the soil is probably low in potassium, use the recommendations shown for a test of 100 to 149 pounds of K per acre.

tion on starter solutions). Sidedress cauliflower 2 or 3 times for a total of 100 pounds of nitrogen per acre.

SWEET CORN

Plow down or sidedress 75 to 100 pounds of nitrogen per acre. Apply 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.

MUSKMELONS, WATERMELONS

At planting time, fertilize rye or ryegrass used for a green manure crop with 40 pounds each of nitrogen, phosphate, and potash per acre. For sandy soils, drill in, three or four inches deep, 40 pounds of nitrogen and 140 pounds each of phosphate and potash per acre after plowing. Use 40 pounds of nitrogen, 160 pounds of phosphate, and 80 pounds of potash per acre for clay loams. If all of the fertilizer is placed in a band several inches to the side and below the seed, use only one-half the amount suggested for drill in application. Sidedress with 50 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 40 pounds of nitrogen, 80 pounds of phosphate, and 40 pounds of potash per acre on clay loams. If nitrogen deficiency is likely, topdress 20-30 pounds of nitrogen per acre

Table 12. — Potash — potassium recommendations for vegetable crops growing on sandy loams and loamy sands (Table 3 or 4).

Available soil potassium — pounds of K Per Acre				Pounds Per Acre Recommended	
				K_2O	K
			Less than 60	300	249
		Less than 60	60-99	250	208
	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	200-249	250-299	75	62
150-199	200-249	250-299	300-399	50	42
200-249	250-299	—	—	25	21
250+	300+	300+	400+	0	0
Asparagus (35)* Peas (40) Pumpkins Radish Squash Turnips	Asparagus crowns new beds Carrots (200-400) Cucumbers (150) Endive Lettuce (250) Lima beans (30) Snap beans (60) Spinach (100) Sweet corn (100)	Cabbage (200-600) Egg plants Muskmelons (150) Onions, bunching Parsnips Peppers (40) Rhubarb (200) Sweet potatoes Table beets (300) Watermelons Rutabagas	Broccoli (120) Brussel sprouts Cauliflower Celery (400) Dry onions (400) Home garden Tomatoes (500)		

**Figure 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 potassium, use the recommendations shown for a test of 60 to 99 pounds of K 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 10-12. 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, 150 pounds of phosphate, and 150 pounds of potash per acre. Sidedress with 40 pounds of N per acre two weeks after growth starts.

MARKET GARDEN

Plow down about 40 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. If experiences show that extra nitrogen has been profitable in the past, make one or two applications between the 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.

HOME GARDEN

Apply 10 to 15 pounds of fertilizer per 1000 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.

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.

In midsummer, fertilize with 5 pounds of ammonium nitrate or 4 pounds of urea per 1000 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 1000 square feet of land. If you use manure, cut 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 rather 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 10-50-10 or 10-52-17. 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 peat. Another is a one-to-one mixture of peat and vermiculite. To each cubic yard of the mixture, add 6 ounces of potassium nitrate, 4 ounces of potassium sulfate, and 2.5 pounds of 20 percent superphosphate. If acid peat (below pH 5.0) is used, add seven pounds of finely ground limestone. The potassium sulfate is not needed in the one-to-one mixture containing vermiculite.

STARTER SOLUTION

Starter solutions can be used on your home garden. Stir one half cup of dry fertilizer such as 5-20-10 or 10-20-10 into three gallons of water. Apply one cup of the solution to 10 feet of row or around the transplants at transplanting time or as supplemental feeding. 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 fertilizer starter solution mixtures of all soluble dry material such as 15-30-15 or 10-52-17 or 10-50-10 may be preferable, although they are more expensive than the regular fertilizers commonly applied to soils. The fertilizers formulated for soil applications and incorporation generally are not completely soluble and therefore are not so uniformly distributed when applied in solution form. In any event, follow manufacturer's recommendations when using concentrated fertilizers. Liquid and dry fertilizers are essentially equal in effectiveness.

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 600,000 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.

SOME EQUIVALENT RATES:

Pounds per acre desired	Amount needed: One square foot	100 sq. feet 10' x 10'	1,000 sq. feet 33' x 30'
100	--	3.5 ounces	2.3 pounds
500	1 teaspoon	1.2 pounds	11.5 pounds
1,000	2 teaspoons	2.3 pounds	23 pounds

MICRONUTRIENTS FOR MINERAL SOILS

The mineral soils of Michigan may be deficient in manganese and/or boron for certain crops, particularly on soils above pH 6.5. Manganese may be needed for oats, beans, potatoes, Sudangrass, sugar beets, and spinach. In extreme cases, barley, corn, and wheat may respond to manganese. A deficiency of this element is most likely to occur on dark-colored surface soils with grayish subsoils found in lake bed or glacial outwash areas. Use 5 to 10 pounds of manganese per acre applied in a band with the fertilizer near the seed. Broadcast application of manganese is not recommended.

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 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, use 3 to 4 pounds of zinc from inorganic salts or 0.5 to 0.8 pounds from organic salts per acre, applied in the band fertilizer. Suggested rate as a preventive program is 1 pound of zinc from an inorganic salt per acre. 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 percentages that may be sold are:

Manganese — 1.0, 2.0, 5.0 percent.
Boron — 1/8, 1/4, 1/2, or 1.0 percent.
Copper — 1/2, 1.0, or 2.0 percent.
Zinc — 1/8, 1/4, 1/2, 1.0 or 2.0 percent.
Molybdenum — 0.04 or 0.08 percent.

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

Table 13. — Percentage of micronutrients suggested in mixed fertilizer as related to the amount of fertilizer applied and micronutrient needed.

Fertilizer applications pounds/Acre	Pounds of micronutrient per acre desired					
	1/2	1	2	4	6	10
	percent					
100	1/2	1	2	5	5	—
200	1/4	1/2	1	2	2	5
400	1/8	1/4	1/2	1	2	2
600	*	1/4	1/2	1/2	1	2
800	*	1/8	1/4	1/2	1	1
1,000	*	1/8	1/4	1/2	1/2	1
1,200	*	1/8	1/8	1/4	1/2	1
1,500	*	*	1/8	1/4	1/2	1
2,000	*	*	1/8	1/4	1/4	1/2

**Minimum percentage permitted in fertilizer could exceed desired quantity. Farmers should use split application of fertilizer to obtain desired amount.*

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 Tables 3 or 4) 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. 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 rate is 50 to 100 pounds of magnesium (Mg) per acre. 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.

Table 14. — Phosphate—phosphorus fertilizer recommendations for organic soils based upon available soil phosphorus using Bray P_1 method.

Available soil phosphorus — pounds of P Per Acre				Pounds Per Acre Recommended	
				P_2O_5	P
			0-19	250	110
		0-19	20-39	200	88
		20-39	40-69	150	66
	0-19	40-69	70-99	100	44
	20-39	70-99	100-149	75	33
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 100 pounds per acre of phosphate (P_2O_5) for broccoli if soil test is 80 pounds per acre.

If no soil test is made and soils are low in fertility, use amounts suggested for 20 pounds of available phosphorus. Recommendations in this table assume you will use the proper placement of fertilizer.

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 4 to 1, crops should be watched for possible magnesium deficiency.

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. 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, the magnesium content of the soil is generally low, so the use of dolomitric limestone is advisable.

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 5 tons per acre of agricultural dolomitic limestone is likely to be needed for most crops; with a pH ranging from 4.3 to 4.5, from 5 to 7 tons of limestone; and with pH 3.8 to 4.2, from 7 to 12 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 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

Table 15. — Potash fertilizer recommendations for organic soils based on soil test using 1 N ammonium acetate method or 0.13 N hydrochloric acid method.

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	300	249
		Less than 125	200-274	425-499	250	208
	Less than 100	125-199	275-349	500-574	200	166
	100-174	200-274	350-424	575-649	150	125
Less than 100	175-249	275-349	425-500	650-724	100	83
100-149	250-299	350-399	500-549	725-799	75	62
150-199	300-349	400-499	550-599	800-899	50	42
200-299	350-399	450-499	—	—	25	21
300+	400+	500+	600+	900+	0	0
Oats	Beans	Asparagus	Broccoli	Celery 600 cwt.		
Rye	Clover	Cabbage	Cauliflower			
Pasture (grass)	Corn-130 Bu.	Carrots	Onions-600 cwt.			
	Mint-70 lb.	Cucumbers	Potatoes-400 cwt.			
	Bluegrass sod	Lettuce-500 cwt.	Sugar beets			
	Soybeans-35 Bu.	Parsnips	Table beets			
	Sudangrass	Radishes				
	Sweet corn	Spinach				
	Turnips	Endive				

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

Test soil annually if little or no potash is recommended, because potash reserve can change greatly.

depth of 7 inches. Since the applied fertilizer remains largely in the plowed layer, only the pH test is necessary at the 18- to 24-inch depth. Rechecking the soil tests every few years is advisable. Send package and information to your soil testing laboratory.

RECOMMENDATIONS FOR ORGANIC SOILS

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 20 pounds of phosphorus and 100 pounds of potassium per acre. Use fertilizer recommendations for these values if you do not have a soil test made and the soil is low in fertility.*

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 5.0, (3) after heavy rainfall, (4) high water table, (5) low soil temperature. Spring-planted crops on most adequately drained soils require 25 to 75 pounds of nitrogen per acre. Crops planted in late spring or early summer usually require only ½ as much nitrogen.

Several crops such as sugar beets, potatoes, and corn may require a small amount of nitrogen for early growth on well-drained muck, but they do not need nitrogen in the broadcast portion of the fertilizer.

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.

Since most rapid soil test methods for micronutrients are not sensitive enough to measure critical deficiency levels, you should base quantity used on the crop to be grown, soil pH, and, in the case of copper and zinc, past treatment.

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

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 16.

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. Use manganese salts for immediate results; use sulfur for a more lasting effect. 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 with acid forming fertilizers. Manganese must be applied yearly, since there is usually no carryover 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 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.

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

Crop Response	Pounds per acre		
	pH 5.8—6.4	pH 6.5—7.2	pH 7.3—8.0
High	10	20	40**
Medium	5	10	20
Low	0	5	10

**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	3	5
Medium	1	3
Low	0	1

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

Crop response	Pounds per acre		
	pH 5.4 or less	pH 5.5—6.4	pH 6.5 or higher
High	6	4	2
Medium	4	2	0
Low	2	0	0

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

Table 16.—Crop response to micronutrients (organic soils)

Crop	Micronutrient response			Others May be Needed
	Manganese	Boron	Copper	
Alfalfa	Low	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	High	
Cauliflower	High	High	Medium	Molybdenum
Celery	Medium	High	Medium	
Clover	Medium	Medium	Medium	Molybdenum
Cucumbers	Medium	Low	Medium	
Corn	Medium	Low	Medium	Zinc
Grass	Medium	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	

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 40 pounds of nitrogen, 80 pounds of phosphate, and 240 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 foilage spray is generally needed.

Carrots, parsnips

Drill in or plow down fertilizer containing boron and copper.

An alternate program is to plow down a fertilizer high in potassium containing boron and copper. A fertilizer high in phosphorus should be applied at the rate of 100 pounds per acre. Apply in a band 1 inch to the side and 2 inches below the seed. Do not use larger rates in bands near the seed as this can cause misshapen roots.

Celery

For celery, disk in or drill in the fertilizer *after plowing*. Use 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 150 pounds of potash (K_2O) per acre. A fertilizer high in phosphorus containing copper and zinc should be applied in bands 2 inches to the side and below 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 4 pounds of copper 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.

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. 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 200 pounds of pelleted ammonium nitrate or 160 pounds of urea per acre. Zinc at the rate of 3 pounds per acre is needed for several years on newly developed land.

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 spring before the crop emerges, apply broadcast or drill in the phosphorus-potassium fertilizer. Topdress in June with 60 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 adhering 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. Two percent manganese is needed in the row fertilizer if the soil pH is above 6.0. Manganese can also be applied on the foilage 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. Nitrogen levels can be checked using a tissue test on the base of the leaf petiole. Chemicals used for the test can be purchased from your county agricultural agent.

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 and rutabagas, and 3 pounds for table beets and swiss chard. 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 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.

Sugar beets

Plow down 240 pounds of potash (K_2O) per acre. Apply in bands three inches below the seed or one inch to the side and two inches below the seed a fertilizer high in phosphorus which contains boron. Use 5 pounds of manganese in the fertilizer if the pH is 5.8 to 6.4, and 10 pounds per acre if the pH is above 6.4.

APPENDIX

The soil management group designation for the different soil series. See Tables 3 and 4 for suggested yield goals.

Soil Series	Soil management group*
Abscota	L4a
Adolph	3c
Adrian	M/4c
Ahmeek	3a-a
Alcona	3a
Algansee	L4c
Alger	3a
Allendale	4/1b
Allouez	Ga
Alpena	Ga
Amasa	3a-a
Angelica	2c
Antrim	4a
Arenac***	5/2b
Au Gres	5b
Au Train**	5a-h
Bach	2c-c
Bannister	4/2c
Baraga	Ga
Barker	2a
Bark River	2a
Barry	3c
Belding	3/2b
Bellefontaine	3a
Bentley	4a
Bergland	1c
Berrien	5/2a
Berville	3/2c
Bibon	5/2a
Blount	2b
Blue Lake	4a
Bohemian	2a
Bono	1c
Bowers	2b
Boyer	4a
Brady	4b
Brant	4/2a
Breckenridge	3/2c
Brevort	4/2c
Bridgman**	5.3a
Brimley	2b
Bronson	4a
Brookston	2c
Bruce	2c
Brule	L2c
Burleigh	4c
Burt	3/Rc
Butternut	2c
Cadmus	3/2a
Capac	2b
Carbondale	Mc
Carlisle	Mc
Casco	4a
Celina	2a
Ceresco	L2c
Champion	3a-a
Channing**	5b-h
Charity	1c-c
Chatham	3a
Cheneaux	4b
Chesaning	4/2b
Cohoctah	L2c
Coldwater	3b
Coloma	4a
Colwood	2c
Conover	2b
Constantine	4a
Coral	3b
Coventry	3a
Crosby	2b
Croswell	5.0a
Crystal Falls	Ra
Danby	L2c
Dawson**	Mc-a
Deer Park **	5.3a
Deford	4c
Detour	Gc
Diana	Gc
Dighton	2a
Dillon	5c
Dowagiac	3a
Dresden	3a
Dryden	3a
Duel	4/Ra
East Lake	5.0a
Eastport **	5.3a
Echo	5.0a
Edmore	4c
Edwards	M/mc
Eel	L2a
Elmdale	3a
Elo	2a-a
Emmert	Ga
Emmet	3a
Ensley	3c
Epoufette	4c
Essexville	4/2c-c
Ewen	L2a
Fabius	4b
Fox	3a
Freesoil	3a
Froberg	1a
Fulton	1b
Gaastra	2b
Gagetown	2a-c
Gay	3c
Genesee	L2a
Gilchrist	4a
Gilford	4c
Gladwin	4b
Glendora	L4c
Gogebic	3a-a
Granby	5c
Graycalm	5.0a
Grayling**	5.7a
Greenwood**	Mc-a
Griffin	L2c
Guelph	2a
Hagener	5.0a
Hartwick	5.0a
Hessel	Gc
Hettinger	2c
Hiawatha	5.0a
Hillsdale	3a
Hodunk	3a
Houghton	Mc
Hoytville	1c
Huron	1a
Ingalls	4b
Ionia	3a
Iosco	4/2b
Iron River	3a-a
Isabella	2a
Jeddo	2c
Johnswood	3a
Kalamazoo	3a
Kalkaska	5.0a
Karlin	4a
Kawkawlin	2b
Kendallville	3/2a
Kent	1a
Kerston	LMc
Keweenaw	4a-a
Kibbie	2b
Kinross	5c
Kiva	4a
Kokomo	2c
Lacota	3c
Landes	L2a
Lapeer	3a
Leelanau	4a
Lenawee	2c
Linwood	M/3c
Locke	3b
London	2b
Longlois	2a
Longrie	3/Ra
Lorenzo	4a
Lupton	Mc
Mackinac	2b
Macomb	3/2b
Mancelona	4a
Manistee	4/2a
Marenisco	4a-a
Markey	M/4c

APPENDIX (Continued)

Soil Series	Soil management group*	Soil Series	Soil management group*	Soil Series	Soil management group*
Marlette	2a	Pence	4a-a	St. Ignace	Ra
Matherton	3b	Perrin	4a	Strongs	5.0a
Maumee	5c	Perth	1b	Summerville	Ra
McBride	3a	Peshekee	Ra	Sumner	4a
McGregor	3b-c	Pewamo	2c	Sunfield	3a
Melita****	5/2a	Pickford	1c	Superior	1a
Menominee	4/2a	Pinconning	4/1c	Tahquamenon**	Mc-a
Metamora	3/2b	Plainfield	5.0a	Tappan	2c-c
Metea	4/2a	Pleine	3c	Tawas	M/4c
Miami	2a	Posen	3a	Tedrow	4b
Montcalm	4a	Randville	4a-a	Thackery	2a
Moran	3/Ra	Richter	3b	Thomas	2c-c
Morley	2a	Rifle	Mc	Tobico	5c-c
Morocco	5b	Rimer	3/1b	Toledo	1c
Moye	4b	Rodman	Ga	Tolfree	2c
Munising	3a-a	Rollin	M/mc	Tonkey	3c
Munuscong	3/1c	Ronald	3c	Traunik	5b
Mussey	4c	Roscommon	5c	Traverse	3b
Nappanse	1b	Roselawn**	5.3a	Trenary	2a
Negaunee	3/Ra	Rousseau	4a	Trout Lake**	5b-h
Nekoosa	5.0a	Rubicon**	5.3a	Tula	3b
Nester	2a	Rudyard	1b	Tuscola	2a
Newaygo	3a	Ruse	3/Rc	Twining	2b
Newton	5c	Saganing	4c	Tyre	4/Rb
Nunica	2a	Sanilac	2b-c	Ubly	3/2a
Oakville	5.0a	Saranac	L2c	Vilas**	5.3a
Ockley	2a	Satago	3/Rc	Volinia	3a
Ocqueoc	4a	Sauble**	5.3a	Wainola	4b
Ogden	M/1c	Saugatuck**	5b-h	Waiska	Ga
Ogemaw**	5b-h	Saverine	3/2b	Wakefield	2a
Ogontz	3/2c	Sebewa	3c	Wallace**	5a-h
Omega**	5.7a	Selkirk	1b	Wallkill	L2c
Onaway	2a	Seward	3/2a	Warners	M/mc
Onota	3/Ra	Shelldrake**	5.3a	Warsaw	3a
Ontonagon	1a	Shoals	L2c	Wasepi	4b
Oshtemo	4a	Sigma	4b	Washtenaw	L2c
Otisco	4b	Sims	2c	Watton	2a
Ottawa	5/2a	Sisson	2a	Wauseon	3/1c
Ottokee	5.0a	Skanee	3b-a	Wea	2a
Palms	M/3c	Sleeth	2b	Weare	5.0a
Palo	3b	Sloan	L2c	Westland	2c
Parkhill	2c	Spalding**	Mc-a	Whittemore	2c-c
Parma	3/Ra	Spartan	5.0a	Willette	M/1c
Paulding	Oc	Spinks	4a	Winegars	4b
Pelkie	L2c	Stambaugh	3a-a	Wisner	2c-c
		St. Clair	1a		

*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.
***Now called AuGres, loamy substratum by the Soil Conservation Service, U.S.D.A.
****Now called Rubicon, loamy substratum, by the Soil Conservation Service, U.S.D.A.