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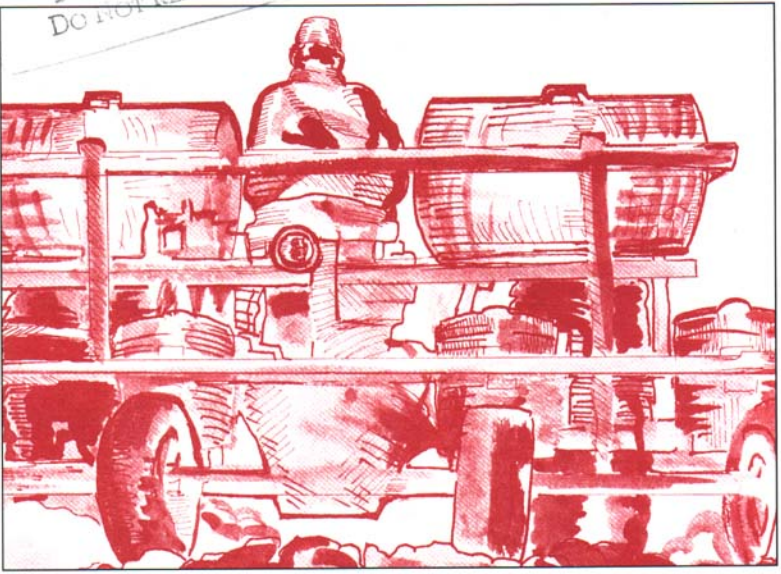
Fertilizer Recommendations for Field Crops in Michigan



This bulletin and bulletin E-550B are replacements for E-550, "Fertilizer Recommendations for Vegetable and Field Crops in Michigan."

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Fertilizer Recommendations for Field Crops in Michigan[1]

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The Michigan State University soil testing program and service is part of a continuing soil fertility educational effort of the Department of Crop and Soil Sciences and the Cooperative Extension Service. Soil samples can be submitted through county Cooperative Extension Service offices or directly to the MSU Soil Testing Laboratory.

This bulletin provides general guidelines for fertilizer placement and management and provides fertilizer recommendations based on analysis of the soil. The general organization provides information about soil sampling, soil testing, and soil acidity and liming followed by fertilizer recommendations for field crops grown on mineral and organic soils. Extension Bulletin E-550B, "Fertilizer Recommendations for Vegetable Crops in Michigan" gives recommendations for vegetable crops.

The goal of the soil testing and fertilizer recommendation program is to provide adequate but not excessive nutrients for crop production. Recommendations are formulated with agronomic, economic and environmental considerations.

Fertilizer recommendations given in this bulletin are based on a soil test, soil management group and/or texture of surface soil, yield goal and previous crop. Applying recommended fertilizer rates with proper timing and placement will minimize the chance that fertilizer nutrients will contaminate surface or groundwater. Fertilizers applied nearest to the period of greatest plant uptake are used most efficiently. On sloping soils, incorporate or place fertilizers beneath the soil surface to reduce runoff loss.

Nutrient Management and Water Quality

Agriculture is coming under closer scrutiny as a contributor to non-point source pollution. When more nutrients are added to the soil-plant system than the crop and soil biology can use, the risk of losing nutrients to groundwater and surface waters increases. Factors such as climate, soil type, slope of the land and soil fertility levels can influence the fate of nutrients applied to the soil.

Adding excess nutrients to soils can cause phosphorus to accumulate in the upper soil profile and increase the risk of contaminating surface waters where runoff and erosion occur. It can also lead to nitrate being leached down through the soil and into groundwater. Adding extra nutrients can create imbalances in soils which may cause poor plant growth and animal nutrition disorders for livestock eating the crops. Avoid adding surplus nutrients by soil testing at regular intervals, giving nitrogen credits for previous legume crops, giving credit for nutrients from manure and organic material additions, establishing realistic yield goals and following the fertilizer recommendations discussed in this bulletin.

As phosphorus concentrations in soils increase, the risk of losing phosphorus bound to soil particles under erosive conditions also increases. Therefore, practice adequate soil and water conservation practices which control runoff and erosion. For example, conservation tillage can reduce runoff, soil erosion and associated phosphorus loadings to surface waters.

Losses of nitrates to groundwater is a major concern because water with an excess of 10 parts per million nitrate-nitrogen poses a health hazard. Since about half of all Michigan residents obtain drinking water from groundwater, maintaining good quality groundwater is

[1]Additional information is available through the Bulletin Office at Michigan State University or your county Extension office. Additional bulletins are listed in the references section at the end of the bulletin.

important. Therefore, never exceed the agronomic fertilizer nitrogen recommendation.

Crop producers should adopt nutrient management practices that not only provide the necessary quantities of nutrients to achieve optimum crop yields, but minimize excessive additions of nutrients that may increase the risk of polluting surface and groundwater. Adding quantities of nutrients that supply the needs of crops and avoid excess amounts achieves two desirable goals. First, taking credit for nutrients supplied from all sources used in crop production generates economic benefits to the producer through decreased input costs. Second, protecting surface and groundwater quality from potential non-point source contamination, due to agricultural activities, can best be accomplished when nutrients are applied at recommended agronomic rates. See Extension Bulletin WQ-25 and Research Publication NCR-310 listed in the references section for more information.

Soil Sampling

A soil test must be made from a representative soil sample to obtain reliable soil results and fertilizer recommendations. For most field crops, sample and test soils at least once every three years. For high-value field crops grown under intensive management, sample and test soil annually.

Mineral Soils. Soil samples may be taken at any time during the year when soil temperature and moisture conditions permit. Before sampling a field, check for differences in soil characteristics. A soil survey map helps. Consider the productivity, topography, texture, drainage, color of topsoil and past management of the area to be sampled. If these features are uniform throughout the field, each composite sample of the topsoil should represent no more than 20 acres. Avoid sampling close to gravel roads, dead furrows, previous locations of brush, lime and manure piles, burned muck or any unusual areas. Areas of the field which differ from the general characteristics should be sampled and fertilized separately if sufficiently large to manage. For example, a sandy ridge could be sampled separately and fertilized with additional potash if required. Avoid sampling small areas which are not typical of the larger field. Fertilize these areas the same as the rest of the field.

Each composite sample should consist of at least 20 subsamples taken at random over the field. Mix the subsamples breaking the cores or chunks. Place a pint of the soil in the sample container for mailing to the laboratory. Soil sample boxes are available from your county Cooperative Extension Service office.

Organic Soils. For newly reclaimed organic soils or soils that have not been heavily fertilized, time of sampling is not important. On organic soils that have been fertilized for more than two or three years, the time of sampling is important. Considerable amounts of potassium may leach over winter. The potash recommendations are given for organic soils collected in the fall and assume the potassium test level decreases 25 percent because of leaching. For samples collected between March and June, decrease these recommendations for potash by 25 percent.

Soil Testing Procedures

The following is a brief discussion of the procedures used in the Michigan State University Soil Testing Laboratory.

Soil pH of mineral soils is measured using a 1:1 soil-to-water suspension; on organic soils, a 1:2 soil-to-water suspension is used. Lime requirement for mineral soils is determined using the SMP Buffer method. On organic soils, lime requirement is based on soil pH.

Available phosphorus is measured using the Bray-Kurtz P1 (weak acid) extractant while exchangeable potassium, calcium and magnesium are extracted using 1.0 N neutral ammonium acetate. Recommendations for phosphorus, potassium and magnesium are based on soil test values from these extractants.

The Bray-Kurtz P1 test does not extract all of the available phosphorus on soils which contain free calcium carbonate. These soils can be identified as having pH values above 7.2 and a Bray-Kurtz P1 test of less than 20 lb/acre. Soils in this case are extracted with sodium bicarbonate (referred to as Olsen P). This test was designed for soils with free calcium carbonate.

Available manganese and zinc are extracted with 0.1 N HCl and copper with 1.0 N HCl using a 1:10 soil-to-extractant ratio.

Mineral soil samples submitted to the MSU Soil Testing Laboratory are extracted using weighed samples. The amounts of nutrients are expressed as parts per 2 million or pounds per acre, which assumes that one acre of a loamy soil 6 2/3 inches deep weighs 2 million pounds.

Organic soil samples are measured by volume because such materials usually have much lower densities than mineral soils. Results for organic soils are expressed on a volume acre furrow slice basis (volume of an acre 6 2/3 inches deep).

Available phosphorus, calcium and magnesium are expressed as pounds of element (P, K, Ca, Mg) extracted. Available zinc, manganese and copper are expressed as parts per million (ppm). Some laboratories express all elements as parts per million. To convert parts per million to pounds for mineral soils, multiply by 2 (i.e., 2 X ppm = lb/acre). The exact conversion varies with bulk density of the soil, but organic soils have a wider variation than mineral soils. For example, for an organic soil with a bulk density of 0.34 g/cm³, 1 ppm = 0.5 lb/acre. For soils with a bulk density of 0.68, 1 ppm = 1 lb/acre.

Some laboratories express phosphorus and potassium in terms of P_2O_5 and K_2O. The factors to convert between P and P_2O_5 or K and K_2O are:

pounds P X 2.3 = pounds P_2O_5;
pounds P_2O_5 X 0.44 = pounds P

pounds K X 1.2 = pounds K_2O;
pounds K_2O X 0.83 = pounds K

The fertilizer recommendations are given in pounds of phosphate (P_2O_5) and potash (K_2O) per acre because fertilizers are expressed and sold in these terms.

Basis for Recommendations

Numerous field studies conducted throughout the state provide the basis for these fertilizer recommendations. Soil test values of the plow layer have been correlated with crop responses to fertilizer nutrients. Where data for a specific crop and/or soil are unavailable, nutrient recommendations are based on field data from similar soil and crop systems, nutrient removal of the crop and experiences in other states on similar crops.

Phosphorus and potassium recommendations provided by the MSU Soil Testing Laboratory provide for a buildup when soil tests are low, maintain desirable nutrient levels when soil tests are medium to high, and allow for a gradual decrease in nutrient levels when soil tests are very high. To determine if a recommendation will result in a buildup or maintenance of the present soil test level, use Table 1. A maintenance recommendation equals crop removal of nutrients, whereas a buildup recommendation exceeds removal.

The soil test for phosphorus is decreased 1 pound for each 5 to 18 pounds of P_2O_5 removed by the crop. Sandy soils decline more quickly than finer textured soils. A similar guide for potassium is that the soil test is decreased 1 pound for each 4 to 10 pounds of K_2O removed. Again, sandy soils decline more quickly than finer textured soils.

Fertilizer recommendations are based in part on yield goals. See the section titled "Yield Potentials of Soil Management Groups" for more information.

Many factors influence the efficiency of fertilizer use including soil structure, growing conditions, and fertilizer placement. Fertilizers are most effective on well-drained soils with favorable structure that promotes deep rooting.

Soil Acidity and Liming

Mineral Soils. Soil reaction is expressed as pH. A soil having a pH of 7.0 is neutral - neither acid or alkaline. A soil having a pH of 6.0 is mildly acid; pH 5.0 is strongly acid, while pH 8.0 is mildly alkaline.

Nutrients are most available in mineral soils having a pH between 6.0 and 7.0. For general field crops it is recommended that acid soils be limed to pH 6.0-6.5. If alfalfa is being established, lime the soil to pH 6.8.

The lime requirement of acid soil samples submitted to the MSU Soil Testing Laboratory is determined by measuring the total acidity. The total acidity is composed of both soluble and exchangeable aluminum and hydrogen. This method of determining lime requirement is more precise than estimates made from soil pH measurements alone, because it measures total acidity instead of just active acidity of the soil. The degree of acidity is reported as the "lime index." Lime requirement for mineral soils based on lime index is given in Table 2.

When the lime requirement is less than one ton per acre, applying lime is of questionable value because of the difficulty of uniform spreading and the economic value. When the lime requirement is less than 1 ton, the soil pH is usually adequate for optimum crop production.

Table 1. Nutrient removal by several Michigan field crops.[1]

Crop		Unit	N	P_2O_5	K_2O
				------ lb/unit -----	
Alfalfa	(Hay)	ton	45[2]	10	45
	(Haylage)	ton	14	3.2	12
Barley	(Grain)	bu	0.88	0.38	0.25
	(Straw)	ton	13	3.2	52
Birdsfoot Trefoil	(Hay)	ton	48	12	42
Bromegrass	(Hay)	ton	33	13	51
Canola	(Grain)	bu	1.9	0.91	0.46
	(Straw)	ton	15	5.3	25
Clover-grass	(Hay)	ton	41	13	39
Corn	(Grain)	bu	0.90	0.35	0.27
	(Grain)[3]	ton	26	12	6.5
	(Stover)	ton	22	8.2	32
	(Silage)	ton	9.4	3.6	7.8
Dry Edible Beans	(Grain)	cwt	3.6	1.2	1.6
Oats	(Grain)	bu	0.62	0.25	0.19
	(Straw)	ton	13	2.8	57
Orchardgrass	(Hay)	ton	50	17	62
Potatoes	(Tubers)	cwt	0.33	0.13	0.63
Red Clover	(Hay)	ton	40	10	40
Rye	(Grain)	bu	1.1	0.41	0.31
	(Straw)	ton	8.6	3.7	21
Sorghum-Sudangrass	(Hay)	ton	40	15	58
	(Haylage)	ton	12	4.6	18
Soybeans	(Grain)	bu	3.8	0.88	1.4
Sugar Beets	(Roots)	ton	4.0	1.3	3.3
Wheat	(Grain)	bu	1.2	0.62	0.38
	(Straw)	ton	13	3.3	23

[1]Sources:USDA Miscellaneous Publication No. 369; "Feeds and Feeding" by Morrison-22nd edition; Canola Growers Manual by the Canola Council of Canada; "Field Application of Manure," FA, Pennsylvania Dept. of Environmental Resources; "United States-Canadian Tables of Feed Composition," National Research Council (U.S.)-Subcommittee on Feed Composition, Third Edition, 1982.

[2]Legumes get most of their nitrogen from air.

[3] High moisture grain.

Table 2. Tons of limestone needed to raise the soil pH of mineral soils to pH 6.0, 6.5 or 6.8 as related to Lime Index and tons of limestone needed to raise soil pH of organic soils to 5.2 as related to soil pH. Values are for a plow depth of 9 inches.

Lime Index	Mineral Soils Raise Soil pH to: 6.0	6.5	6.8	Organic Soils Soil pH	Raise pH to 5.2
	------------ tons/acre -----------			------tons/acre-----	
70	0.0	0.0	0.0	5.2	0.0
69	0.0	0.6	0.8	5.1	0.8
68	1.2	1.6	1.8	5.0	1.5
67	1.9	2.5	2.9	4.9	2.2
66	2.7	3.5	3.9	4.8	2.9
65	3.5	4.4	4.9	4.7	3.6
64	4.3	5.3	5.9	4.6	4.3
63	5.1	6.3	6.9	4.4	5.8
62	5.8	7.2	8.0	4.2	7.2
61	6.6	8.2	9.0	4.0	8.6
60	7.4	9.1	10.0	3.8	10.0

Recommendations are based on the following equations and rounded to the nearest tenth of a ton:

Mineral Soils

To pH 6.0: $XL = 54.2 - 0.78 * LI$

To pH 6.5: $XL = 65.5 - 0.94 * LI$

To pH 6.8: $XL = 71.2 - 1.02 * LI$

Organic Soils

$XL = 37.0 - 7.1 * pH$

where:

XL = Lime recommendation in tons/acre

LI = Lime Index

pH = Soil pH

Retest these soils in two to three years to determine lime needs.

Do not apply more than 6 tons of lime per acre in any one season. Applying more may cause localized zones of high alkalinity, reducing the availability of essential nutrients. Retest soil with a lime index of 6.4 or below two years after application to determine if more lime is needed. When the lime need is greater than 4 tons per acre, apply the lime in a split application - i.e., half before plowing and half after plowing, more effectively neutralizes the acidity in the plow layer than one large application.

For potatoes, the soil is generally limed to pH 6.0. If there is no history of scab, or if it is not suspected because resistant varieties are grown, consider liming to pH 6.5. Do not exceed 2 tons of lime per acre at any one time. Apply lime following potato harvest, but not later than the fall prior to planting potatoes.

Lime practices need special attention under no-till crop production where nitrogen is applied to the surface of the soil. Surface applied nitrogen can cause the surface to become acid very quickly. This condition is not detected in a sample taken to the usual 8-10 inches. In this case take a sample from the top 2 inches in addition to the standard sample depth. An acid surface can reduce the effectiveness of triazine herbicides.

See Extension Bulletins E-471 and E-1566 for further information.

Organic Soils. Field crop production does not benefit from liming organic soils unless the soil pH is below 5.3 (1:2 soil:water suspension).

In some cases, the surface layer of soil may have a pH around 5.5, but the subsoil will have a much lower or higher pH. If the soil is plowed to a sufficient depth to bring some of the subsoil to the surface, the plow layer soil pH and lime requirement will change. Therefore, lime according to a soil test on a sample taken after plowing.

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

Lime recommendations for organic soils are based on soil pH rather than lime index. Table 2 gives the lime recommendations for organic soils below pH 5.3.

Recommendations for Field Crops on Mineral and Organic Soils

Crop response to increasing levels of soil fertility or applied fertilizer is continuous - that is, yield increases do not occur in a stepwise manner, but increase gradually with increasing levels of available nutrients. The recommendations in the tables of this bulletin reflect this type of response to applied nutrients over a range of soil test values. Equations are used to calculate the recommendations and are given as footnotes to each table.

Nitrogen (N) - Nitrogen needs depend on the crop to be grown, yield goal and previous management practices. A reliable nitrogen soil test taken before planting is not currently adopted for general use in the Great Lakes States. However, progress has been made using a pre-sidedress test for adjusting nitrogen recommendations for corn. This test is taken to a depth of 1 foot and analyzed for mineral nitrogen. Credit given for this nitrogen is subtracted from the current nitrogen recommendation based on yield goal.

Bacteria living symbiotically in alfalfa and clover root nodules use atmospheric N in their growth and development. Some of this "fixed" N is available directly to the host plant and some is excreted into the soil where it is available for plant uptake. When the bacteria die and the nodules decompose, additional nitrogen becomes available. Because of this nitrogen fixation by the bacteria, leguminous crops do not usually need or respond to applied nitrogen fertilizer.

When alfalfa or clover is the previous crop, a nitrogen credit is given based on percent stand. The N credit (lb/acre) for alfalfa is given by the equation: 40 + (0.60 times percent stand), where 5 to 6 plants per square foot is a 100 percent stand. For clover the equation is: 30 + (0.30 times percent stand).

Credit for nitrogen supplied from animal manures needs to be subtracted from the nitrogen recommendations listed in this bulletin. See the section titled "Manure and Other Organic Materials" for more information.

Several sources of nitrogen fertilizer are suitable for crop production. The materials are usually equally effective and should be purchased on the basis of cost per pound of actual nitrogen, convenience of application and supply.

Efficiency of nitrogen fertilizer use can be improved and nitrate contamination of surface and groundwaters can be minimized by using recommended nitrogen rates and timely nitrogen application. Proper scheduling of irrigation water to minimize leaching also minimizes nitrogen losses and maximizes efficiency.

Fall application of nitrogen is not recommended on either organic or mineral soils. Similarly, do not broadcast nitrogen on frozen ground with greater than 3 percent slope. When applying anhydrous ammonia, be sure to completely trap the gas in the soil.

Most nitrogen carriers leave an acidic residue in the soil. It requires approximately 2 pounds of limestone to neutralize the acidifying effect of each pound of nitrogen derived from urea, ammonium nitrate, anhydrous ammonia or nitrogen solutions, and 5.5 pounds if ammonium sulfate is used.

ORGANIC SOILS. Even though there is a considerable amount of nitrogen converted to the nitrate form from the organic matter in organic soils, much of it is lost through denitrification. The net available nitrogen released ranges from 40 to 100 pounds per acre. On sandy mucks the amount released is less so increase recommendations given in Table 16 by 30 to 40 pounds.

Phosphorus (P) - Phosphorus needs are based on soil test, crop to be grown and yield goal. Small plants need more phosphorus than most other nutrients, making it important to have this phosphorus available for growth early in the growing season. Previous research conducted on soils testing less than 30 pounds of phosphorus has shown both an early season growth response and a yield response to banded phosphorus. However, more recent research on soils testing higher in phosphorus has not shown the yield response from banded phosphorus even though there may be an early season improvement in plant growth. There is little chance that banded phosphorus will increase crop yields of most field crops when grown on mineral soils testing above 60 pounds per acre.

More than half of the soils in Michigan used for field crop production test very high in available phosphorus. Research shows that some reduction in soil test levels can occur without reducing crop yields. Research shows that drawdown of soil test P is similar to buildup, taking 5 to 18 pounds of P_2O_5 removal to decrease the soil test 1 pound. Reducing the amount of phosphate fertilizer applied does not cause a sudden reduction in the soil test value of high testing soils.

ORGANIC SOILS: - When phosphorus is recommended for crops grown on organic soils, banding 25-40 pounds of phosphate per acre is suggested, particularly for early planted crops. However, when soil test levels are high, banded phosphorus is not suggested.

In newly developed fibrous peats, banded phosphorus applications are more effective because phosphorus remains fairly mobile. After being in production for five years, available phosphorus levels begin to increase and routine phosphorus management can be followed.

Potassium (K) - The terms potassium and potash are often confused. Potassium is the element and is expressed with the chemical symbol K. Potash is K_2O and is the expression used for expressing percent contained in a fertilizer. For example, 0-0-60 is potassium chloride and contains 60% K_2O (potash).

The availability of potassium in a soil is related to the types and amounts of clay minerals present. Depending on the soil texture, 2 to 6 pounds of K_2O are required to increase the soil test by 1 pound K per acre. The present soil test used for potassium can adequately predict the availability of potassium for most Michigan soils. However, some soils fix potassium in forms that are not readily available to plants. Because routine soil testing does not determine the various types of clay minerals or the fixing ability of a soil, soils containing vermiculitic clays may require higher than recommended rates of potash (K_2O) to build up the available soil potassium. Once such soils have a medium to high potassium soil test level, they continue to supply potassium for some time, even though crop removal may be considerable.

Small seedlings have less need for potassium than for phosphorus. However, once plants start to grow rapidly, they use larger amounts of potassium. Since there is not a large demand for potassium by seedlings, broadcast application of potassium is as effective as banded potassium. Where the soil test is below 100 pounds per acre, banding 50-75 pounds of K_2O per acre to the side and below the seed may be beneficial.

Fall application of potassium on loamy sand and sand soils is not recommended because potassium can leach into the subsoil and may not be available for crop growth. However, potassium fertilizer can be broadcast in the fall on the finer textured soils.

Secondary Nutrients

Magnesium (Mg) - Magnesium deficiency is most likely to occur in acid soils with sandy surface texture and a subsoil as coarse or coarser than the surface. It also occurs in similar soils limed with calcic limestone or marl. Responsive field crops are potatoes, oats and corn.

Applying magnesium is recommended if a soil test indicates that the exchangeable magnesium level is below 75 pounds per acre; or when potassium exceeds magnesium as a percent of the total exchangeable bases (calcium plus magnesium plus potassium, expressed as milliequivalents per 100 grams of soil); or when the soil magnesium as a percent of total bases is less than 3 percent.

On acid soils where magnesium is needed, apply at least 1000 pounds of dolomitic limestone per acre. On non-acidic soils, magnesium deficiency may be corrected by broadcasting 50 to 100 pounds Mg per acre, or banding 10 to 20 pounds Mg per acre. Magnesium sulfate (Epsom salts), potassium-magnesium sulfate and finely ground magnesium oxide are all satisfactory sources of magnesium.

Magnesium can also be applied as a foliar spray. The suggested rate is 1-2 pounds of

Mg per acre. This can be supplied by using 10 to 20 pounds of magnesium sulfate (Epsom salts) applied in at least 30 gallons of water.

Magnesium deficiency may be induced by high rates of potassium fertilizer. In some states, agronomists strive for at least 10 percent magnesium saturation of the total exchangeable bases (equivalent basis). These high rates are aimed at preventing "grass tetany" disorders in livestock that feed on lush grass. If you are concerned with grass tetany, avoid excessive rates of potassium fertilizer and feed legume hay, which is generally higher in magnesium. Contact your animal feed specialist for specific recommendations concerning supplemental Mg in the ration.

Calcium (Ca) - Well-limed soils generally contain sufficient calcium for the growth of field crops. Even soils needing lime to correct acidity will contain sufficient calcium for plants. The poor growth of plants on acid soils is usually due to excess soluble manganese and/or aluminum, rather than calcium deficiency.

Studies in Ohio, Indiana, Michigan and Wisconsin show alfalfa and corn to yield equally well at a wide range of calcium to magnesium ratios. Therefore, adding calcium to improve the calcium to magnesium ratio is not necessary.

Sulfur (S) - Sulfur is an essential nutrient found in plants in about the same concentration as phosphorus. Current intensive cropping systems, use of higher analysis fertilizers with lower sulfur concentration and the cleanup of industrial smokestacks point in the direction of more widespread need for sulfur. However, field studies with several sulfur responsive crops on numerous sites do not show any benefit from sulfur applications. Even though the surface soils on some of these sites tested low, the subsurface soils supply more than adequate quantities of sulfur to meet plant needs. Sulfur deficiency would most likely occur on alfalfa grown on sandy soils.

Micronutrients

Micronutrient fertilizer recommendations are based on soil pH, soil test and crop responsiveness for each. The recommended rates are given in Tables 3-6 for highly responsive crops. A brief discussion of each is given.

Manganese (Mn) - Manganese deficiency may occur on oats, field beans, potatoes, soybeans, sudan grass, sugar beets and wheat. In extreme cases, barley may respond to applied manganese. Manganese availability decreases as soil pH increases. Liming can, therefore, induce a manganese deficiency on soils with marginally available Mn soil test values. Flooding or fumigation of soils temporarily increases Mn availability.

Suitable carriers are manganese sulfate, partially acidulated manganese oxides and finely ground manganous oxide. Manganese chelates are not recommended for organic soils and have not been shown to be more effective than manganese sulfate on mineral soils. Apply chelates to mineral soils at the rate of nutrient given in Table 3. Neither granular manganese oxide nor any of the manganic forms are acceptable manganese materials. Finely ground manganous oxide that has been regranulated may be reasonably effective, however. Manganese is usually fixed very readily in soil, so broadcast application is not recommended. Apply manganese to foliage if band application is not possible or does not completely alleviate the deficiency. Apply 1 to 2 pounds of Mn per acre and repeat the application if deficiency symptoms develop on new growth in 7 to 10 days.

MINERAL SOILS. A manganese deficiency is most likely to occur on dark-colored surface soils in lake bed or glacial outwash areas with a pH above 6.5. Table 3 provides recommendations for rates of manganese to apply in a band with starter fertilizer for responsive crops grown on mineral soils.

ORGANIC SOILS. Manganese deficiency is most likely to occur on organic soils with a pH of 5.8 or above. See the discussion above about using chelated sources of manganese for organic soils.

Table 4 provides general guidelines for rates of manganese to apply in a band with starter fertilizer for responsive crops grown on organic soils.

Boron (B) - Boron recommendations are based on crop response and not on soil tests. Annual applications are essential for boron-responsive crops because it occurs as a water-soluble anion subject to leaching. Never apply boron in the starter fertilizer for field beans, soybeans, corn or small grains since they are sensitive to boron injury. Applying higher than recommended rates may result

Table 3. Manganese fertilizer recommendations for responsive field crops grown on mineral soils.[1]

Soil Test	Soil pH 6.3	6.5	6.7	6.9	7.1	7.3	7.5 and above
ppm	lb Mn/acre[2]						
2	2	4	5	6	7	9	10
4	2	3	4	5	7	8	9
6	0	2	3	5	6	7	8
8	0	2	3	4	5	6	8
10	0	0	2	3	5	6	7
12	0	0	0	3	4	5	6
14	0	0	0	2	3	4	6
16	0	0	0	0	2	4	5
18	0	0	0	0	2	3	4
20	0	0	0	0	0	2	4
22	0	0	0	0	0	2	3
24	0	0	0	0	0	0	2
26	0	0	0	0	0	0	0

[1]Recommendations in this table are for band application of the suggested carriers.
[2]Recommendations are calculated from the following equation and rounded to the nearest pound:

$$XMn = -36 + 6.2 * pH - 0.35 * ST$$

where:
XMn = lb Mn/acre
pH = Soil pH
ST = ppm Mn soil test

in residual boron carryover which could injure sensitive crops. Recent research shows that applied boron is not needed for sugar beet production in Michigan. See Research Report 518 listed in the references for further information.

Use 1 to 2 pounds of boron per acre for alfalfa grown on sandy loam, loamy sand and sand soils.

Zinc (Zn) - Extractable (0.1 N HCl) Zn values used in conjunction with soil pH, provides a very good indicator for availability of zinc to plants. Zinc availability decreases as pH increases. Therefore, more Zn is recommended at higher pH levels for a given zinc soil test level. Finely ground zinc oxide that has been regranulated may be reasonably effective, but granular forms of zinc oxide are not effective. Band applications are suggested, but a broadcast application of 10 pounds or more of Zn per acre is effective. Annual applications of zinc will build up available zinc levels and gradually eliminate the need for supplemental zinc. Foliar sprays of 0.5 pounds of zinc as zinc sulfate per acre will correct zinc deficiencies of growing crops.

MINERAL SOILS. Zinc may be needed for field beans and corn grown on alkaline mineral soils of the lake-bed region of eastern Michigan depending on the soil test level of the soil. Deficiency is especially noted on crops growing on spoil-banks, over tile lines where calcareous subsoil is mixed in, or where high rates of phosphorus are applied. Recommended rates based on soil tests are given in Table 5. These rates are for inorganic salts of zinc. Use one-fifth of this rate for chelates.

ORGANIC SOILS. Zinc deficiency is more likely to occur on nearly neutral or alkaline organic soils. Field beans and corn are most often affected under Michigan conditions. Recommended rates based on

Table 4. Manganese fertilizer recommendations for responsive crops grown on organic soils.[1]

Soil Test	Soil pH 5.8	6.0	6.2	6.4	6.6	6.8	7.0 and above
ppm	lb Mn/acre[2]						
2	2	4	5	7	9	10	12
4	0	3	5	6	8	10	11
6	0	2	4	6	7	9	11
8	0	2	3	5	7	9	10
10	0	0	3	5	6	8	10
12	0	0	2	4	6	7	9
14	0	0	2	3	5	7	8
16	0	0	0	3	4	6	8
18	0	0	0	2	4	5	7
20	0	0	0	0	3	5	6
22	0	0	0	0	2	4	6
24	0	0	0	0	2	4	5
26	0	0	0	0	0	3	5
28	0	0	0	0	0	2	4
30	0	0	0	0	0	2	3
32	0	0	0	0	0	0	3
34	0	0	0	0	0	0	2
36	0	0	0	0	0	0	2

[1] Recommendations in this table are for band application of the suggested carriers.
[2] Recommendations are calculated from the following equation and rounded to the nearest pound:

$$XMn = -46 + 8.38 * pH - 0.31 * ST$$

where:

XMn = lb Mn/acre
pH = soil pH
ST = ppm Mn soil test

soil tests are given in Table 5.

Copper (Cu) - Field crops grown on mineral soils are not known to respond to applied copper.

However, acid peaty soils are usually low in copper and field crops will respond to applications of the nutrient. The carriers used are usually the sulfate or oxide forms. Copper applied to organic soil is not easily leached and contributes to buildup of available soil copper. For this reason, no further copper fertilization is needed if a total of 20 pounds per acre has been applied for low or medium responsive crops and 40 pounds per acre for high responsive crops, or if the copper soil test level exceeds 20 ppm.

Oats, wheat, sorghum and sudan grass are highly responsive to applied copper. The medium responsive field crops are clover, sugar beets and corn. Pastures, rye, field beans, soybeans and potatoes are rated as "low responsive."

Table 6 gives the recommendations based on responsive ratings for field crops grown on organic soils.

Manures and Other Organic Materials

Appling organic materials to Michigan soils for crop production is an accepted agricultural practice. In addition to animal manures, other organic materials including sewage sludge, septage, food processing wastes, and fermentation wastes are applied to soils in Michigan.

Table 5. Zinc recommendations for responsive field crops grown on mineral and organic soils.

Soil Test	Soil pH 6.6	6.8	7.0	7.2	7.4	7.6 and above
ppm	lb Zn/acre[2]					
1	1	2	3	4	5	6
2	0	1	2	3	4	5
3	0	1	2	3	4	5
4	0	0	1	2	3	4
5	0	0	1	2	3	4
6	0	0	1	2	3	4
7	0	0	0	1	2	3
8	0	0	0	1	2	3
9	0	0	0	0	1	2
10	0	0	0	0	1	2
11	0	0	0	0	1	2
12	0	0	0	0	0	1
13	0	0	0	0	0	1

[1]Recommendations in this table are for band application of an inorganic zinc carrier. When chelates are used, these rates may be divided by 5.
[2]Recommendations are calculated from the following equation and rounded to the nearest pound:

$$XZn = -32 + 5.0 * pH - 0.4 * ST$$

where: XZn = lb Zn/acre
pH = Soil pH
ST = ppm Zn soil test

It is highly desirable to recycle nutrients and organic matter contained in these materials. However, some potential hazards may be encountered when organic materials are applied to the soil-plant system for crop production if good management practices are not followed. These can include excessive additions of nutrients, additions of trace elements and trace organic chemicals, pathogens, soil physical problems, odors and insects which spread disease. The Department of Crop and Soil Science at MSU can help you evaluate the benefits/risks of applying a specific waste by-product to crop land.

The application of most organic materials to land in Michigan is regulated by the Michigan Department of Natural Resources (MDNR). Any land application program must be approved by the MDNR. However, this agency has not required livestock producers to obtain permits for land application of manures, except where poor manure handling and management have contaminated water. For more information concerning MDNR requirements, contact the MDNR Waste Management Division, P. O. Box 30028, Lansing, MI 48909.

Animal manure can be a valuable source of nutrients for crop production. However, the nutrient varies considerably from farm to farm, depending on many factors, including animal species, feed used, amount and type of bedding, and amount of water added. Table 7 shows the wide range in nutrient composition of manures sampled from numerous farms. Due to this wide variation, average nutrient values can be very misleading. The recommended method to determine the nutrient content for manure is to sample the manure and send it to a laboratory for analysis. The results should include: percent dry matter, ammonium nitrogen (NH_4-N), total nitrogen, phosphate (P_2O_5) and potash (K_2O).

Table 6. Copper fertilizer recommendations for crops grown on organic soils.

Soil Test	Crop Response		
	Low	Medium	High
ppm	lb Cu/acre[1]		
2	3	4	6
4	3	4	5
6	2	4	5
8	2	3	4
10	2	3	4
12	2	3	3
14	1	2	3
16	1	2	2
18	1	2	2
20	1	1	2
22	1	1	1
24	0	1	1

[1] Recommendations are calculated from the following equations and rounded to the nearest pound:

High Responsive Crops $XCu = 6 - (0.22 * ST)$

Medium Responsive Crops $XCu = 6 - (0.22 * ST) * 0.75$

Low Responsive Crops $XCu = 6 - (0.22 * ST) * 0.50$

where: XCu = lb Cu/acre

ST = ppm Cu soil test

Table 7. Range in nitrogen, phosphate and potash analysis for various animal manures showing farm to farm variation.

Type of Manure	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	lb/ton			lb/1000 gallons		
Dairy	5-16	2-16	2-31	3-51	2-21	2-58
Beef	4-20	1-13	3-29	6-37	1-29	5-30
Swine	3-27	1-62	2-18	1-61	1-63	1-49
Poultry	1-111	1-96	2-55	35-75	13-91	13-39

The manure analysis should then be used in conjunction with the rate of application to calculate the amount of nutrients supplied from the manure. By giving credit for nutrients supplied from manure, the risk of water pollution will be minimized and economic benefits will also be gained.

There are a number of management practices which are suggested for producers utilizing animal manure. First, fields receiving manure should be sampled and tested every three years. Use these results along with a realistic yield goal to determine the nutrient needs for the crops to be grown. Second, analyze manure for its nutrient content. Subtract the quantity of nutrients supplied from the fertilizer recommendations to determine need for additional fertilizer nutrients. Third, do not exceed the agronomic rate of nitrogen for crops by the amount of available nitrogen in the manure applied or in the manure plus fertilizer used. Fourth, follow soil and water conservation practices to reduce the risk of nutrients entering surface water. Practices used to control runoff and erosion for a particular site should consider factors such as type of manure, surface residue or vegetative conditions, slope, soil type and proximity to surface water. Fifth, keeping records of manure analyses, soil test reports and rates of manure and fertilizer application for individual fields helps identify land areas needed for effectively utilizing the nutrients contained in animal manures. Good record keeping demonstrates good management and may be beneficial if the producer's management practices are challenged.

See Extension Bulletin WQ-12, "Livestock Manure Management for Efficient Crop Production and Water Quality Preservation" for methods of accounting for nutrients supplied from manures. Additional recommended manure management practices can be found in "Generally Accepted Agricultural Practices for Manure Management and Utilization," as adopted by the Michigan Commission of Agriculture.

Suggested Fertilizer Management and Recommendations for Field Crops

Corn and Corn Silage Sorghum and Sudangrass

Corn - Place planting-time fertilizer 2 inches to the side and 2 inches below the seed. At this placement the fertilizer application may include up to 40 pounds of nitrogen and 100 pounds of potash per acre and all the recommended phosphorus. Including phosphorus in the row fertilizer when the available soil phosphorus is high may stimulate early season growth, but seldom increases the corn yield. Plow down or broadcast and incorporate any phosphorus and potassium fertilizer that is required in excess of that banded at planting.

Irrigation of corn influences the fertilizer requirements because it increases the yield goal. These requirements are accounted for by larger yield goals. Nitrogen management will need to be adjusted and part of the nitrogen will need to be applied either sidedressed or through the irrigation system. One management system suggests to apply one-third preplant, one-third sidedressed and the remainder applied through the irrigation system.

Harvesting corn for silage removes large amounts of plant nutrients. In a Michigan study, corn yielding 140 bushels of grain removed 120 pounds of nitrogen, 52 pounds of phosphate and 27 pounds of potash per acre. The same crop harvested for silage removed 196 pounds of nitrogen, 69 pounds of phosphate and 206 pounds of potash per acre. This comparison illustrates that nutrient removal, especially of potash, is much greater when silage is harvested. Recommendations for phosphorus and potassium are adjusted for this additional removal.

Nitrogen management for corn may involve a choice of application times: preplant, planting time and/or sidedress. Applying nitrogen in the fall is not recommended. Nitrogen applied as a sidedress will generally be used most efficiently.

MINERAL SOILS - Nitrogen recommendations for corn are given in Table 8. Phosphate and potash recommendations for corn are given in Table 9.

ORGANIC SOILS - Nitrogen recommendations for corn are given in Table 16, phosphate in Table 17, and potash in Table 18.

Sorghum and Sudangrass- Sorghum and sudangrass grown for summer pasture or chopped forage have nutrient requirements similar to those of corn silage. Use the equations for corn silage and the appropriate yield goal in Tables 8 and 9 for mineral soils. On organic soils, use recommendations in Tables 16-18.

Table 8. Nitrogen fertilizer recommendations for corn grain.

Yield Goal		Previous Crop: No Alfalfa	100% Alfalfa	60% Alfalfa
bu/acre	t/acre	lb N/acre[1]		
100	16	110	10	30
120	20	140	40	60
140	23	160	60	80
160	26	190	90	110
180	29	220	120	140
200	33	250	150	170

[1]Recommendations for corn grain are calculated from the following equation and rounded to the nearest 10 pounds. Credit for nitrogen supplied from manure should be given. See section titled "Manure and Other Organic Materials."

$$XN = [-27 + (1.36 * YG)]$$

Where alfalfa is plowed down use the equation:

$$XN = [-27 + (1.36 * YG)] - (40 + 0.60 * PS)$$

Recommendations for corn silage may be calculated using the equation:

$$XN = [-25 + (8.33 * YG)]$$

When alfalfa is plowed down use the equation:

$$XN = [-25 + (8.33 * YG)] - (40 + 0.60 * PS)$$

Where: XN = lb N/acre recommended
YG = yield goal in tons/acre
PS = percent stand of alfalfa (without the decimal)

Table 9. Phosphate (P_2O_5) and potash (K_2O) recommendations for corn grown on mineral soils.

Soil Test	Grain (bu/acre) / Silage (t/acre)	Yield Goal 100 / 11	120 / 15	140 / 18	160 / 22	180 / 25	200 / 28
lb P/acre		-----------	-----------	lb P_2O_5/acre[1]	-----------	-----------	-----------
10		60	80	90	110	130	140
20		50	70	80	100	110	130
30		40	50	70	90	100	120
40		20	40	60	70	90	110
50		0	30	40	60	80	90
60		0	20	30	50	60	80
70		0	0	20	40	50	70
80		0	0	0	20	40	60
90		0	0	0	0	30	40
100		0	0	0	0	0	30
110		0	0	0	0	0	20
		Potash recommendations for sandy loams and loamy sands					
lb K/acre		-----------	-----------	lb K_2O/acre[1]	-----------	-----------	-----------
50		200	220	240	260	280	300
75		170	190	210	230	250	270
100		150	170	190	210	230	250
125		120	140	160	180	200	220
150		100	120	140	160	180	200
175		70	90	110	130	150	170
200		50	70	90	110	130	150
225		20	40	60	80	100	120
250		0	20	40	60	80	90
275		0	0	0	30	50	70
300		0	0	0	0	30	50
325		0	0	0	0	0	20

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Table 9. continued

lb K/acre	Potash recommendations for loams, clay loams and clays --------- lb K_20/acre[1] ---------					
50	210	240	260	290	320	340
75	180	210	230	260	290	310
100	150	180	200	230	250	280
125	120	140	170	200	220	250
150	90	110	140	170	190	220
175	60	80	110	130	160	190
200	30	50	80	100	130	150
225	0	20	50	70	100	120
250	0	0	0	40	70	90
275	0	0	0	0	40	60
300	0	0	0	0	0	30

[1] Recommendations are calculated from the following equations and rounded to the nearest 10 pounds:

$$XP = -10 + 0.83 * YG - 1.25 * ST$$
$$XKs = 141 + 1.04 * YG - 1.00 * ST$$
$$XKc = 145 + 1.30 * YG - 1.25 * ST$$

Corresponding equations for silage are:

$$XP = 16 + 5.00 * YG - 1.25 * ST$$
$$XKs = 174 + 6.19 * YG - 1.00 * ST$$
$$XKc = 185 + 7.87 * YG - 1.25 * ST$$

Where:

XP = lb P_20_5/acre
XKs = lb K_20/acre for sandy loams and loamy sands
XKc = lb K_20/acre for loams, clay loams and clays
YG = Yield goal, bu/acre or tons/acre for silage
ST = Soil test, lb/acre

Small Grains

Barley, Canola, Oats, Wheat Rye, Millet, Buckwheat - Most grain drills apply fertilizer directly in contact with the seed. This placement can injure the seed when large amounts are applied, especially when the soil is dry. Do not drill more than 100 pounds of plant nutrients (N + P_2O_5 + K_2O) in direct contact with the seed for sandy soils and 140 pounds per acre for fine textured soils. If more fertilizer is needed, broadcast before planting. Follow fertilizer recommendations for total amounts of nutrients needed.

On winter wheat, apply no more than 25 pounds of nitrogen per acre in the fall. This amount may be included in the planting time fertilizer. In the spring prior to green-up, topdress additional nitrogen, usually 80 to 100 pounds N per acre for high-yielding wheat varieties and sites.

For rye grown for grain, apply 40 lb nitrogen/acre prior to spring green up. No nitrogen is recommended for rye when grown as a cover crop. Broadcast and incorporate nitrogen before planting or top dress after emergence for millet and buckwheat.

Applying manure prior to wheat often leads to increased incidence of root rot and lodging. Therefore, it is best not to apply manure prior to wheat. Wheat does best following field beans, soybeans or silage corn.

Manganese may be needed for wheat, oats and barley when grown on lake bed soils and dark-colored soils where the pH is above 6.5. Test these soils for manganese and apply the amounts shown in Table 4.

For spring-seeded small grains, apply the nitrogen before and/or at seeding.

MINERAL SOILS - Refer to Table 10 for recommended nitrogen rates and Table 11 for recommended phosphate and potash recommendations.

ORGANIC SOILS - Tables 16-18 give recommendations for oats and rye grown on these soils.

Soybeans and Field Beans

Both types of beans are very sensitive to fertilizer applied in contact with the seed. Apply row fertilizer 2 inches to the side and 2 inches below the seed. For dry beans, up to 40 lb of nitrogen, all of the phosphorus,

Table 10. Nitrogen recommendations for small grains, canola, rye, millet and buckwheat grown on mineral soils[1].

Yield Goal	Barley	Canola	Oats	Wheat
bu/acre	lb nitrogen/acre[2]			
40	20	80	20	40
60	40	100	20	70
80	50	110	30	90
100	-	-	40	120
120	-	-	50	-

[1] Nitrogen recommendation for rye (grain), 40 lb/acre; rye (cover), 0 lb/acre; millet, 100 lb/acre; buckwheat, 40 lb/acre.

[2] Recommendations are calculated from the following equations and rounded to the nearest 10 pounds. Credit for nitrogen supplied from manure and legumes should be given. See sections titled "Manure and Other Organic Materials" and "Nitrogen."

$$XN = A + B * YG$$

Where: XN = lb N/acre
YG = Yield goal, bu/acre

For Barley: A = -12 and B = 0.8
For Canola: A = 50 and B = 0.8
For Oats: A = 0 and B = 0.4
For Wheat: A = -13 and B = 1.33

and 60 lb potash may be included in the starter fertilizer. Before planting, broadcast and incorporate any additional fertilizer if needed. For soybeans grown on soils testing below 40 pounds per acre for phosphorus, apply all of the phosphorus and up to 60 lb of potash in the banded fertilizer. On soils testing higher in phosphorus, equal success can be obtained with broadcast fertilizer, except where manganese is required. When this nutrient is needed, the most efficient method of application is with the starter fertilizer.

Soybeans that are well inoculated with Rhizobium bacteria prior to seeding or grown in soil containing a sufficient population of Rhizobia have rarely shown any yield response to nitrogen fertilizer. When these bacteria supply adequate nitro-

Table 11. Phosphate (P_2O_5) and potash (K_2O) recommendations for barley, oats, canola, wheat, rye, millet, buckwheat, grass pasture and brassicas grown on mineral soils.

	Crop	Yield goal, bu/acre				
	Barley	40[1]	60	80	-	-
	Oats	60	90	120	-	-
Soil	Canola	-	-	40	60	80
Test	Wheat	-	-	50	70	90
lb P/acre		----- lb P_2O_5/acre[2] -----				
10		50	70	100	120	140
20		40	60	80	100	130
30		20	50	70	90	110
40		0	30	60	80	100
50		0	20	50	70	90
60		0	0	30	50	80
70		0	0	20	40	60
80		0	0	0	30	50
90		0	0	0	20	40
100		0	0	0	0	30
		Potash recommendations for sandy loams and loamy sands				
lb K/acre		----- lb K_2O/acre[2] -----				
50		70	100	120	140	160
75		60	80	110	130	150
100		50	70	100	120	140
125		40	60	80	100	130
150		20	50	70	90	110
175		0	30	60	80	100
200		0	20	50	70	90
225		0	0	30	50	80
250		0	0	20	40	60
275		0	0	0	30	50
300		0	0	0	20	40
325		0	0	0	0	30

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Table 11. continued

lb K/acre	Potash recommendations for loams, clay loams and clays ------ lb K_20/acre[2] ------				
50	110	140	180	210	250
75	90	120	160	190	230
100	70	100	140	170	210
125	50	90	120	160	190
150	30	70	100	140	170
175	0	50	90	120	150
200	0	30	70	100	130
225	0	0	50	80	120
250	0	0	30	60	100
275	0	0	0	40	80
300	0	0	0	20	60
325	0	0	0	0	40
350	0	0	0	0	20

[1]Recommendations in this column apply to rye, buckwheat, millet, grass pasture and brassica species grown for forage.
[2]Recommendations are calculated from the following equations and rounded to the nearest 10 pounds:

$$XP = A + B * YG - C * ST$$
$$XKs = A + B * YG - C * ST$$
$$XKc = A + B * YG - C * ST$$

where:
XP = lb P_20_5/acre
XKs = lb K_20/acre sandy loams and loamy sands
XKc = lb K_20/acre loams, clay loams and clays
YG = Yield goal, bu/acre
ST = Soil test, lb/acre

and the coefficients are:

	XP			XKs			XKc		
	A	B	C	A	B	C	A	B	C
Barley	16	1.15	1.25	52	1.15	0.50	74	1.75	0.75
Canola	65	1.09	1.25	102	1.09	0.50	145	1.73	0.75
Oats	8	1.83	1.25	46	0.83	0.50	67	1.25	0.75
Wheat	53	1.09	1.25	90	1.09	0.50	135	1.63	0.75

gen for the soybean crop, nitrogen fertilization is not recommended. Be sure to inoculate the soybean seed if a well nodulated soybean crop has not been grown in that field in the past three years.

Soybeans and field beans often need manganese when grown on organic soils and dark-colored sandy soils with a pH higher than 5.8 or lake bed soils and depressional areas having gray subsoil and a surface pH above 6.5. Follow the recommended rate based on soil tests in Tables 3 and 4. Foliar applications are also effective and often preferred, especially when growing soybeans on organic soils.

Field beans grown on soils with a pH of 7.2 or higher are highly responsive to zinc fertilizer. Zinc deficiency is particularly noticeable on land previously planted to sugar beets, or where calcareous subsoils are exposed by land leveling or after tiling. Recommendations based on soil test are given in Table 5.

Mineral Soils - Nitrogen fertilizer is not recommended for soybeans. Apply 40 lb N/acre for field beans grown in 28- or 30-inch rows and 60 lb N/acre for beans grown in rows less than 23 inches wide and for colored beans grown with irrigation. Phosphate and potash recommendations are given in Table 12.

Organic Soils - Tables 16-18 give recommendations.

Potatoes

Follow recommendations based on a soil test. Then apply up to 60 pounds of nitrogen, all of the phosphate and 100 pounds of potash per acre in bands 2 inches to the side and level with or slightly below the seed pieces. Additional potash (and phosphate if needed) can be broadcast and incorporated before planting. Supplemental nitrogen can be sidedressed, applied in the irrigation water or in the spray program. Applying nitrogen after plant emergence is generally more efficient than nitrogen applied preplant. After harvest, establish cover crops to take up any residual nitrogen and to protect the soil against wind erosion.

Manganese may be needed when mineral soils test above pH 6.5 and above pH 5.8 on organic soils. Use a soil test to determine the need for manganese. See Tables 3 and 4 for manganese recommendations based on soil test.

Fall applications of potash are not recommended on loamy sand, sand and organic soils because of potential loss by leaching. Spring plow-down applications are suggested when high rates of potassium are required.

Nitrogen fertilizer recommendations are based on expected yield goal and are then adjusted for varietal differences and nitrogen fixed by previous legume crop. Russet Burbank is the only variety where the nitrogen rate should be adjusted. Increase the recommendation by 40 pounds per acre for this variety.

Mineral Soils - Refer to Table 13 for nitrogen, phosphate and potash recommendations for potatoes grown on mineral soils.

Organic Soils - See Tables 16-18. Nitrogen recommendations for field crops grown on organic soils.

Sugar Beets

Fertilizer for sugar beets may be applied in a band 2 inches to the side and 2 inches below the seed. On soils testing above 60 pounds of phosphorus, there is little chance of a yield increase from banded fertilizer except where manganese is needed.

If the soil pH is above 6.5, manganese may be needed for sugar beet production and the soil should be tested for manganese. See Table 4 for manganese recommendations based on a soil test. The most efficient method of applying manganese is with the starter fertilizer banded to the side and below the seed.

The quality of sugar beets is affected very markedly by applied nitrogen. Research studies show the sugar concentration and yield are maximized by using 4 pounds of nitrogen per acre for each ton of expected yield. This amounts to 80 to 100 pounds of N per acre for yields of 20 to 25 tons per acre.

Mineral Soils - Nitrogen, phosphate (P_2O_5) and potash (K_2O) recommendations for sugar beets are given in Table 14.

Organic Soils - Producing sugar beets on organic soils is not generally practiced because poor quality sugar beets are generally produced. Fertilizer recommendations are included in Tables 16-18 for those cases where production is necessary.

Forage Crops

General Fertilization of Forages. At planting, allow the legume seed to fall on top of the soil above the fertilizer band and cover no more than 1/2 inch deep with press wheels or a cultipacker. To seed bromegrass,

Table 12. Phosphate (P_2O_5) and potash (K_2O) recommendations for soybeans and dry edible beans grown on minerals soils.

Soil Test		Yield Goal				
	Dry Beans (cwt/acre)	15	20	25	30	35
	Soybeans (bu/acre)	30	40	50	60	70
lb/acre		lb P_2O_5/acre[1]				
10		50	60	80	90	100
20		40	50	60	80	90
30		30	40	50	60	80
40		0	30	40	50	60
50		0	0	30	40	50
60		0	0	0	30	40
70		0	0	0	0	30
		Potash recommendations for sandy loams and loamy sands				
lb K/acre		lb K_2O/acre[1]				
50		90	100	110	130	140
75		80	90	100	110	130
100		60	80	90	100	110
125		50	60	80	90	100
150		40	50	60	80	90
175		30	40	50	60	80
200		0	30	40	50	60
225		0	0	30	40	50
250		0	0	0	30	40
275		0	0	0	0	30
		Potash recommendations for loams, clay loams and clays				
lb K/acre		lb K_2O/acre[1]				
50		90	110	130	150	170
75		70	90	110	130	150
100		60	70	90	110	130
125		40	60	80	90	110
150		20	40	60	80	90
175		0	20	40	60	80
200		0	0	20	40	60
225		0	0	0	20	40
250		0	0	0	0	20

[1]Recommendations are calculated from the following equations and rounded to the nearest 10 pounds:

For Soybeans:

$XP = 25 + 1.25 * YG - 1.25 * ST$

$XKs = 75 + 1.25 * YG - 0.50 * ST$

$XKc = 74 + 1.89 * YG - 0.75 * ST$

For Dry Beans:

$XP = 25 + 2.50 * YG - 1.25 * ST$

$XKs = 75 + 2.50 * YG - 0.50 * ST$

$XKc = 74 + 3.77 * YG - 0.75 * ST$

where: XP = lb P_2O_5/acre
XKs = lb K_2O/acre sandy loams and loamy sands
XKc = lb K_2O/acre loams, clay loams and clays
YG = Yield, bu/acre for soybeans; cwt/acre for dry beans
ST = Soil test, lb/acre

Table 13. Nitrogen, phosphate (P_2O_5) and potash (K_2O) recommendations for potatoes grown on mineral soils.

Soil Test	Yield Goal, cwt/acre				
	300	350	400	450	500
	lb N/acre[1]				
-	150	170	180	200	210
lb P/acre	lb P_2O_5/acre[1]				
50	100	100	110	110	110
100	90	90	90	100	100
150	70	80	80	80	80
200	60	60	70	70	70
250	50	50	50	60	60
300	30	40	40	40	40
350	20	20	30	30	30
400	20	20	20	20	20
450	20	20	20	20	20
500	0	20	20	20	20
550	0	0	0	20	20
600	0	0	0	0	20
	Potash recommendations for loamy sands and sandy loams				
lb K/acre	lb K_2O/acre[1]				
50	280	300	330	350	380
75	250	280	300	330	350
100	230	250	280	300	330
125	200	230	250	280	300
150	180	200	230	250	280
175	150	180	200	230	250
200	130	150	180	200	230
225	100	130	150	180	200
250	80	100	130	150	180
275	50	80	100	130	150
300	30	50	80	100	130
325	20	30	50	80	100
350	0	0	30	50	80
375	0	0	0	30	50
400	0	0	0	0	30

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Table 13. continued

lb K/acre	Potash recommendations for loams, clay loams and clays				
	lb K_20/acre[1]				
50	280	310	350	380	410
75	250	280	310	350	380
100	220	250	280	320	350
125	190	220	250	280	310
150	160	190	220	250	280
175	130	160	190	220	250
200	100	130	160	190	220
225	60	100	130	160	190
250	30	60	100	130	160
275	0	30	60	100	130
300	0	0	30	60	100
325	0	0	0	30	60
350	0	0	0	0	30

[1]Recommendations are calculated from the following equations and rounded to the nearest 10 pounds. Credit for nitrogen supplied from manure and legumes should be given. See sections titled "Manures and Other Organic Materials" and "Nitrogen."

XN = 60 + 0.30 * YG. For Russett Burbank add 40 lb nitrogen/acre.

XP = 100 + 0.05 * YG - 0.27 * ST for soil testing less than 400
XP = 23 + 0.02 * YG - 0.03 * ST for soil testing 400 and above

XKs = 175 + 0.50 * YG - 1.00 * ST
XKc = 156 + 0.63 * YG - 1.25 * ST

where:
XN = lb N/acre
XP = lb P_20_5/acre
XKs = lb K_20 for sandy loams and loamy sands
XKc = lb K_2O for loams, clay loams and clays
YG = Yield goal, cwt/acre
ST = Soil test, lb/acre

either mix the seed with a small grain or with the fertilizer.

Boron is needed annually at the rate of 1 to 2 pounds per acre on established alfalfa growing on sandy loam, loamy sand and sand soils. Boron application for alfalfa grown on the finer-textured soils has not proven beneficial. Do not apply boron in combination seedings containing grass or small grains because it will injure these plants. Apply boron for the legume as a topdressing after the grass is well established or the grain crops harvested. Include 1 pound of zinc per acre in the topdress fertilizer when the soil pH is above 7.0 and the soil test is low in zinc.

Topdress forage legumes or legume/grass mixtures with potash in early spring while the plants are dormant or immediately after hay harvest. Potash may be topdressed in the fall on all soils except loamy sands and sands, where it will leach into the subsoil. Do not apply more than 400 lb K_2O in one application.

Planting-time nitrogen is not suggested for legume seeding. Be sure to inoculate the seed before planting.

Legume Seeding without Small Grain - Adjust soil pH to 6.8 for mixtures containing alfalfa or sweet clover, and to pH 6.5 for red clover and birdsfoot trefoil. Apply and incorporate the needed lime at least six months before seeding. When more than 4 tons of lime is required, apply one-half before plowing and one-half after plowing. Incorporation by disking is suggested after each application. When sod seeding alfalfa on erosive sites, broadcast the lime without incorporation.

Fertilizer recommendations for alfalfa seeding given in Table 15 are for spring or summer clear seeding. Base fertilizer rates on soil test results. Up to 100 pounds of phosphate and 50 pounds of potash may be applied in direct contact with the seed. If the fertilizer is placed 1 to 1 1/2 inches below the seed, the seeding time fertilizer may include all of the phosphorus and up to 150 pounds of potash per acre. Broadcast and incorporate fertilizer required above these amounts. This fertilizer recommendation if sufficient to establish the legume and to provide for growth until the first cutting is removed. Beyond that point, additional fertilizer is required as a top-dress application.

Legume Seeding with Small Grain - Legume seedings are difficult to establish in high yielding small grains. If legumes are seeded with small grains, use the normal nitrogen rate. The fertilizer applied for small grain should be sufficient to carry the legume through the first season. Topdress fertilizer for the legume after the first cutting of hay. Follow the liming practices suggested for clear seeding legumes.

Seeding Grass Hay or Pasture - The recommendations for phosphate and potash are the same as those for 60 bushels of oats (Table 11). When establishing grass hay or pasture, apply 30-40 pounds of nitrogen. Do not apply in direct contact with the seed more than 100 pounds of total nutrients (N $+P_2O_5 + K_2O$) on coarse textured soils or 140 pounds for fine textured soils. Broadcast and incorporate additional nutrient as recommended.

Grass Pasture - Intensively grazed pastures: (Also referred to as controlled grazing.) Annually topdress with 60 pounds of nitogen plus the phosphate and potash given in Table 11.

Extensively grazed pastures: Annually topdress 100 pounds of nitrogen plus the phosphate and potash given in Table 11. When the forage contains more than 50% legume, nitrogen fertilizer is not recommneded.

Grass Hay - Annually topdress 100 pounds of nitrogen plus the phosphate and potash indicated by a soil test as given in Table 15. As the percent legume in a field declines, the need for applied nitrogen increases. When the percent legume is less than 50 (less than 3 plants per square foot), nitrogen is recommended at 100 pounds per acre annually.

Brassicas for Forage - Brassica species for forage include rape, kale, swedes and turnips. Brassicas can be used to break up an old pasture to be planted with an improved species and/or to extend the grazing period into the late fall. They are frequently planted after small grains have been harvested. A total of 75 pounds of nitrogen is suggested to produce good yields. Follow the recommendations in Table 11 for phosphate and potash. Apply up to 30 pounds of nitrogen, 50 pounds of phosphate and 50 pounds of potash in the row at planting. Additional fertilizer should be broadcast and incorporated before planting.

Grass Water Ways and Critical Areas - Grass waterways, highly erodible soil and other critical areas need good

Table 14. Nitrogen, phosphate (P_2O_5) and potash (K_2O) recommendations for sugar beets grown on mineral soils.

Soil Test	Yield Goal, tons/acre				
	18	20	22	24	26
	lb N/acre[1]				
-	70	80	90	100	100
lb P/acre	lb P_2O_5/acre[1]				
10	140	150	160	170	180
20	120	130	140	150	160
30	110	120	130	140	150
40	100	110	120	130	140
50	90	100	110	120	130
60	70	80	90	100	110
70	60	70	80	90	100
80	50	60	70	80	90
90	40	50	60	70	80
100	20	30	40	50	60
110	0	20	30	40	50
120	0	0	20	30	40
130	0	0	0	20	30
	Potash recommendations for loamy sands and sandy loams				
lb K/acre	lb K_2O/acre[1]				
50	180	200	210	230	240
75	170	180	200	210	220
100	150	160	180	190	210
125	130	140	160	170	190
150	110	120	140	150	170
175	90	110	120	140	150
200	70	90	100	120	130
225	50	70	80	100	110
250	30	50	60	80	90
275	20	30	50	60	70
300	0	0	30	40	60
325	0	0	0	20	40
350	0	0	0	0	20

(continued on next page)

Table 14. continued

lb K/acre	Potash recommendations for loams, clay loams and clays lb K_20/acre[1]				
50	200	220	240	260	280
75	170	190	210	230	250
100	150	170	190	210	225
125	120	140	160	180	200
150	100	120	140	160	180
175	70	90	110	130	150
200	50	70	90	110	130
225	20	40	60	80	100
250	0	20	40	60	80
275	0	0	0	30	50
300	0	0	0	0	30

[1]Recommendations are calculated from the following equations and rounded to the nearest 10 pounds. Credit for nitrogen supplied from manure and legumes should be given. See sections titled "Manure and Other Organic Materials" and "Nitrogen."

$$XN = 4.0 * YG$$
$$XP = 58 + 5.00 * YG - 1.25 * ST$$
$$XKs = 87 + 7.45 * YG - 0.75 * ST$$
$$XKc = 65 + 10.0 * YG - 1.00 * ST$$

Where:

XN = lb N/acre
XP = lb P_20_5/acre
XKs = lb K_20/acre for sandy loams and loamy sands
XKc = lb K_20/acre for loams, clay loams and clays
YG = Yield goal, tons/acre
ST = Soil test, lb/acre

fertility levels to maintain a dense, uniform cover throughout the year. Follow the guidelines for seeding grass hay or pasture. Annually topdress 40 pounds of nitrogen per acre. To prevent runoff loss, drill in topdress fertilizer.

Mineral Soils - Topdress recommendations for phosphate and potash for grass pasture are given in Table 11. Phosphate and potash recommendations for alfalfa, birdsfoot trefoil, clover and grass hay are given in Table 15.

Organic Soils - Nitrogen, phosphate and potash recommendations for selected forage crops are given in Tables 16-18. Alfalfa and alfalfa-grass mixtures are not recommended for organic soils.

Table 15. Phosphate (P_2O_5) and potash (K_2O) recommendations for alfalfa, clover, birdsfoot trefoil and grass hay grown on mineral soils.

Soil Test	Alfalfa / Other	Yield Goal, tons/acre						
	Alfalfa	2	3	4	5	6	7	8
	Other	3[1]	4	5	6	7	-	-
lb P/acre		lb P_2O_5/acre[2]						
10		60	70	90	90	110	120	130
20		40	60	70	80	90	110	120
30		30	40	60	70	80	90	110
40		20	30	40	60	70	80	90
50		0	20	30	40	60	70	80
60		0	0	20	30	40	60	70
70		0	0	0	20	30	40	60
80		0	0	0	0	20	30	40
90		0	0	0	0	0	20	30
100		0	0	0	0	0	0	20
		Potash recommendations for loamy sands and sandy loams						
lb K/acre		lb K_2O/acre[2]						
50		240	260	290	310	340	360	390
75		210	240	260	290	310	340	360
100		190	210	240	260	290	310	340
125		160	190	210	240	260	290	310
150		140	160	190	210	240	260	290
175		110	140	160	190	210	240	260
200		90	110	140	160	190	210	240
225		60	90	110	140	160	190	210
250		40	60	90	110	140	160	190
275		0	40	60	90	110	140	160
300		0	0	40	60	90	110	140
325		0	0	0	40	60	90	110
350		0	0	0	0	40	60	90
375		0	0	0	0	0	40	60
400		0	0	0	0	0	0	40

(continued on next page)

Table 15. continued

lb K/acre	Potash recommendations for loams, clay loams and clays lb K_20/acre[2]						
50	190	240	290	340	390	440	490
75	150	200	250	300	350	400	450
100	110	160	210	260	310	360	410
125	80	120	170	220	270	320	370
150	40	90	140	190	240	290	340
175	0	50	100	150	200	250	300
200	0	0	60	110	160	210	260
225	0	0	30	70	120	170	220
250	0	0	0	40	90	140	190
275	0	0	0	0	50	100	150
300	0	0	0	0	0	60	110
325	0	0	0	0	0	20	70
350	0	0	0	0	0	0	40

[1] Use appropriate yield goal for grass hay. Use appropriate column from Table 11 for grass pasture.
[2] Recommendations are calculated from the equations and rounded to the nearest 10 pounds.

For alfalfa:

$$XP = 44 + 12.5 * YG - 1.25 * ST$$
$$XKs = 238 + 25 * YG - 1.00 * ST$$
$$XKc = 162 + 50 * YG - 1.50 * ST$$

For other forages:

$$XP = 32 + 12.5 * YG - 1.25 * ST$$
$$XKs = 213 + 25 * YG - 1.00 * ST$$
$$KKc = 112 + 50 * YG - 1.50 * ST$$

where:
- XP = lb P_20_5/acre
- XKs = lb K_20/acre for sandy loams and loamy sands
- XKc = lb K_20/acre for loams, clay loams and clays
- YG = Yield goal, tons/acre
- ST = Soil test, lb/acre

Recommendations for Crops Grown on Organic Soils

Recommendations for nitrogen, phosphate and potash for field crops grown on organic soils are given in Tables 16-18.

Table 16. Nitrogen recommendations for field crops grown on organic soils. [1]

Crop	Yield Goal	Nitrogen Rate
		lb/acre
Clover	4 tons	0
Pasture	3 tons	0
Soybeans	35 bu	0
Rye	30 bu	20
Dry Edible Beans	15 cwt	20
Oats	80 bu	20
Wheat	70 bu	30
Sugar beets	18 tons	40
Corn	130 bu	80
Sorghum	10 ton	80
Potatoes	400 cwt	100

[1] On sandy muck soils, increase recommendations 30 to 40 pounds.

Table 17. Phosphate (P_2O) recommendations for field crops grown on organic soils.

Soil Test	Clover (4 tons) Oats (80 bu) Pasture (3 ton) Dry edible beans (15 cwt) Rye (30 bu) Soybeans (35 bu)	Corn (130 bu) Sudan grass (10 tons) Wheat (70 bu) Sugar beets)10 ton)	Potatoes (400 cwt)
lb P/acre	--------	lb P_20_5/acre[1]	--------
10	90	130	250
30	60	100	230
50	40	80	200
70	0	50	180
90	0	30	150
110	0	0	130
130	0	0	100
150	0	0	80
170	0	0	50
190	0	0	30

[1]Recommendations are calculated from the following equations and rounded to the nearest 10 pounds:

$XP1 = 100 - 1.25 * ST$

$XP2 = 138 - 1.25 * ST$

$XP3 = 263 - 1.25 * ST$

where:

$XP1$ = lb P_20_5/acre for column 1

$XP2$ = lb P_20_5/acre for column 2

$XP3$ = lb P_20_5/acre for column 3

ST = Soil test in lb/acre

Table 18. **Potash (K_2O) recommendations for field crops grown on organic soils.**

	Oats (80 bu) Pasture (3 tons) Rye (30 bu)	Clover (4 ton) Corn (130 bu)s Dry Edible Beans (15 cwt) Soybeans (30 bu) Sudangrass (10 ton) Wheat (70 bu) Sugar beets (18 ton)	Potatoes (400 cwt)
Soil Test lb K/acre		------------------ lb K_20/acre[1] ------------------	
50	180	280	440
100	140	240	400
150	100	200	360
200	60	160	320
250	20	120	280
300	0	80	240
350	0	40	200
400	0	0	160
450	0	0	120
500	0	0	80
550	0	0	40

[1]Recommendations are calculated from the following equations and rounded to the nearest 10 pounds:

$$XK1 = 220 - 0.8 * ST$$
$$XK2 = 320 - 0.8 * ST$$
$$XK3 = 480 - 0.8 * ST$$

where:
XK1 = lb K_20/acre for column 1
XK2 = lb K_20/acre for column 2
XK3 = lb K_20/acre for column 3
ST = Soil test in lb/acre

Yield Potentials of Soil Management Groups

The potential of a soil to produce good crop yields depends on its properties and how they are managed. Soils with similar properties and yield potentials form soil management groups (SMG).

Yield potentials in Tables 19 and 20 located at the end of this bulletin represent practical yield goals under good management. These yields are based on field experiences with average management and climatic conditions for the various soil management groups. Yield potential on individual fields can vary substantially from these averages, depending on management. Use these as guides when there is not sufficient experience to establish a reasonable yield goal.

Past experience is a good tool to use in setting the yield goal for a given field. A good guide for determining a reasonable yield goal is to average the three highest yields from the past 5 years. Fertilizing to try to reach a yield goal that cannot be attained because of some other limiting factor or factors increases fertilizer costs and may be detrimental to the environment due to possible erosion and/or leaching of nutrients into ground or surface waters.

References

The following bulletins are available from county Michigan State University Extension offices or from the MSU Bulletin Office, 10-B Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039.

E-471	Lime for Michigan Soils
E-498	Soil Sampling for Fertilizer and Lime Recommendations
E-550B	Fertilizer Recommendations for Vegetable Crops in Michigan
E-896	N-P-K Fertilizers
E-933	Fluid Fertilizers: Liquids and Suspensions
E-1262	Soil Management Units and Land Use Planning
E-1566	Facts About Lime: Answers to Common Questions
E-1616	Soil Sampling for No-Till and Conservation Tillage Crops
E-2058	Understanding MSU Soil Test Report: Results and Recommendations
E-2188	A Production guide for Michigan Wheat
E-2220	Best Management Practices for Potatoes: Potato Fertilizer Recommendations
NCH-02	The Philosophy of Soil Testing (Corn)
NCH-12	Managing Animal Manure as a Source of Plant Nutrients
RR-518	Yield and Quality of Sugar Beets as Affected by Applied Boron
WQ-03	Managing Organic Soils to Reduce Nonpoint Pollution
WQ-06	Nitrogen Management Strategies for Corn Producers
WQ-12	Livestock Manure Management for Efficient Crop Production and Water Quality Preservation
WQ-25	Nutrient Management to Protect Water Quality

Table 19. Average yield potentials for crops grown on various soil management groups under good management with adequate drainage, but without irrigation in areas with growing season OVER 140 FROST-FREE DAYS ANNUALLY (southern Michigan).

SMG	Corn	Corn silage	Winter wheat	Oats	Dry beans	Alfalfa 3 cuts	Sugar beets
	Bu/acre	Ton/acre	Bu/acre	Bu/acre	Bu/acre	Tons/acre	Ton/acre
Clays							
0c	95	16	35	75	25	3.8	-
1a	100	17	45	80	28	4.2	-
1b	115	18	50	85	32	4.5	18
1c	125	19	55	90	35	4.8	20
Clay loams							
1.5a	110	18	55	85	35	5.0	-
1.5b	120	19	55	90	40	5.5	19
1.5c	130	20	60	100	42	6.0	23
Loams							
2.5a	120	19	60	95	35	4.8	19
2.5b	130	20	65	105	40	5.0	20
2.5c	140	22	65	115	45	5.5	23
Sandy loams over clay or loam							
3/2a	115	19	55	95	35	3.5	18
3/lb or 3/2b	125	20	60	100	40	4.8	20
3/1c or 3/2c	140	20	65	105	40	5.0	22
Sandy loams							
3a	105	18	45	85	30	4.0	16
3b	115	19	50	95	33	4.5	19
3c	120	19	55	100	35	4.8	21
3/Ra	95	16	40	80	28	3.8	-
Loamy sands over clay or loam							
4/2a	105	18	40	80	30	4.0	15
4/2b-4/lb	110	18	45	85	35	4.2	16
4/2c-4/1c	115	19	50	90	35	4.5	18
Loamy sands							
4a	80	14	30	60	25	3.5	-
4b	85	14	35	65	32	3.8	-
4c	95	16	45	75	32	4.0	-
4/Ra or 4/Rb	60	12	25	50	22	3.0	-
Sands							
5.0a	55	11	25	45	-	3.0	-
5b	65	12	30	55	-	3.5	-
5c	80	14	40	60	25	3.8	-

Table 20. **Average yield potentials for crops grown on various soil management groups under good management with adequate drainage, but without irrigation in areas with growing season UNDER 140 FROST-FREE DAYS ANNUALLY (northern Michigan).**

SMG	Corn silage	Corn	Winter wheat	Dry beans	Oats	Alfalfa 2 cuts
	Ton/acre	Bu/acre	Bu/acre	Bu/acre	Bu/acre	Tons/acre
Clays						
0c	-	-	30	-	75	3.5
1a	12	75	35	25	70	3.5
1b	13	80	35	30	75	3.5
1c	14	85	40	35	75	3.5
Clay loams						
1.5a	13	80	40	30	75	3.7
1.5b	14	85	42	35	80	3.8
1.5c	15	90	45	40	85	4.0
Loams						
2.5a	16	95	45	35	80	4.0
2.5b	16	95	48	40	85	4.0
2.5c	17	100	50	45	90	4.5
Sandy loams over clay or loam						
3/2a	14	85	40	35	80	4.0
3/1b or 3/2b	15	90	45	37	85	4.0
3/1c or 3/2c	16	95	50	45	85	4.0
Sandy loams						
3a	13	80	35	25	75	3.5
3b	14	85	35	30	80	3.5
3c	15	90	40	35	85	3.5
3/Ra	12	75	30	25	70	3.0
Loamy sands over clay or loam						
4/2a	12	75	35	25	70	3.5
4/2b	14	85	40	28	75	3.5
4/2c or 4/1c	14	85	40	30	75	3.5
Loamy sands						
4a	11	70	28	20	60	3.0
4b	11	70	40	25	65	3.0
4c	12	75	35	30	70	3.0
4/Ra or 4/Rb	10	50	25	-	40	2.5
Sands						
5.0a	9	50	25	-	40	2.5
5b	10	55	25	-	45	2.5
5c	11	70	30	-	50	3.0

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File 22.04 (Fertilizers)