Fig. 40. Lime not necessary for alfalfa on this soil with pH 4.3. 0—no lime; 1—2 tons per acre; 2—6 tons per acre; 3—10 tons per acre. The exchangeable calcium was much higher in this soil than in the preceding figure. Nitrogen had to be added to unlimed alfalfa because of inability of bacteria to supply sufficient nitrogen (precipitated calcium carbonate).

As noted in Table 7 the amount of lime required per unit change of pH varied with the different soils. Even though soils 1 and 2 in their natural state have approximately the same pH, the addition of limestone at the rate of 12 tons per acre changed the pH from 3.6 to 5.6 for soil 1 and from 3.7 to 7.0 for soil 2. As the percent of organic matter in the soil increases, the amount of lime required per unit of pH change generally increases. On an average, one ton of limestone per acre will raise the soil pH about 0.2 units when mixed to a depth of 7 inches.

Liming acid soils will lower soluble iron and aluminum (45). Over-liming should be avoided because of the reduction in availability of manganese and boron. When liming an acid soil, it is generally recommended that manganese and boron be applied to insure

TABLE 7—The effect of calcium carbonate applied to five soils in the greenhouse on the yield of onion bulbs, soil reaction, and content of exchangeable manganese

Tons $CaCO_3$ per acre	Mean yield(*a*) (grams per plot)					Exchangeable manganese, p.p.m.					pH value				
	Soil					Soil					Soil				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0...........	0.33	0.19	166	212	203	25.0	3.5	3.7	8.7	15.0	3.6	3.7	4.1	4.4	4.9
2...........	145	175	201	217	180	17.5	5.0	5.0	6.2	13.7	4.1	4.2	4.8	5.0	5.2
4...........	149	172	213	202	192	15.0	3.7	3.7	3.7	1.2	4.5	5.0	5.3	5.5	6.0
6...........	164	141	196	202	190	10.0	2.5	1.2	2.5	3.7	4.8	5.0	5.8	6.1	6.2
8...........	168	108	151	187	140	5.0	1.2	0.0	1.2	1.2	5.0	6.0	6.4	6.6	6.6
10...........	151	46	103	161	172	0.0	0.0	0.0	0.0	2.5	5.3	7.0	6.9	7.0	6.9
12...........	146	37	79	143	159	0.0	0.0	0.0	0.0	0.0	5.6	7.0	7.1	7.2	7.0

(*a*) Averages of three replications.
Data from Shickluna and Davis (179).

against a temporary deficiency of these two minor elements. A decrease in the availability of applied phosphorus may also result from liming (108).

Method of application.

One-half of the lime should be applied and disked into the soil before plowing (15 inches deep) and the other half applied after plowing and disked well into the soil. In cases where an acid layer exists close to the surface and is turned up by plowing, the lime should be applied after plowing. It is important to maintain as extensive a root zone area as possible because the roots are unable to penetrate an extremely acid layer. The water table should be maintained high

TABLE 8—The effect of calcium carbonate on the manganese content in the tops and bulbs of onions(a). (See Table 7 for soil data)

Treatment (tons $CaCO_3$ per acre)	Parts per million (oven-dry basis)									
	Soil 1		Soil 2		Soil 3		Soil 4		Soil 5	
	Tops	Bulbs	Tops	Bulbs	Tops	Bulbs	Tops	Bulbs	Tops	Bulbs
0...........	...	..	..	..	125	50	175	22	875	50
2...........	1,125	100	338	38	63	31	169	22	173	28
4...........	625	88	200	22	61	25	31	12	50	19
6...........	350	53	75	13	31	3	19	7	31	..
8...........	225	38	25	9	19	6	13	7	25	16
10...........	94	28	75	13	19	6	13	4	22	13
12...........	44	25	22	3	13	6	13	6	25	13

(*a*) Dried for 48 hours at 80-85° C.
Data from Shickluna and Davis (179).

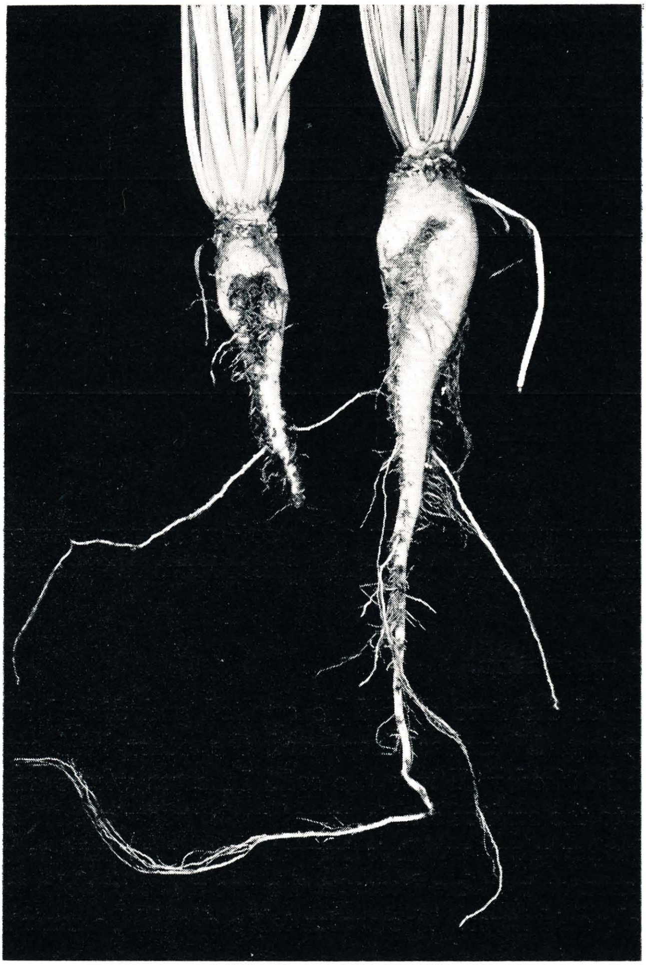

Fig. 41. Effect of acid subsoil (pH 3.9) on development of sugar beet roots. Plant on left shows effect when lime is mixed to a depth of 6 inches. Plant on right was grown where lime was mixed to 12 inches deep.

enough so plant roots can obtain a good moisture supply. Additional lime should be applied as needed to maintain a suitable pH in the root zone area.

Sulfur.

Sulfur is used to supply crop needs, to reduce the pH, and increase the availability of phosphorus, manganese and boron in nearly neutral or alkaline soils. Rates of 200 to 1000 pounds per acre are recommended depending upon the degree of alkalinity, the soil reaction throughout the profile and the presence of marl. Five hundred pounds of sulfur per acre will reduce the pH of the top 6 inches of organic soil approximately 0.3 unit in the absence of free marl or limestone. Response to sulfur may be expected from many crops when the soil pH is above 5.8. For soils containing marl, sulfur applications are usually not economical. Such crops as sugar beets, mint, carrots and cabbage should be grown. Sulfur will reduce soil pH so that blueberries can be grown (Figs. 42 and 43). However, sulfur application is not economical for large areas if the pH is above 5.8.

Fig. 42. Sulfur lowers pH of soil so that blueberry plants grow satisfactorily. One ton of sulfur is required to reduce the soil reaction of an acre 6 inches one pH unit.

Fig. 43. Blueberry plants failed to survive with a soil pH of 6.0. A favorable range in soil reaction for this crop is pH 4.0–5.0.

Frost Control

Susceptibility to frost injury is an important factor in determining the adaptability of any crop to organic soil. Frost damage to crops is more likely to occur on organic soils than on mineral soils. A difference of 10°F. between air temperatures over organic soils and surrounding mineral soils frequently occurs. Three factors are important causes of frost occurrence: 1) rapid loss of heat from the soil surface by radiation, 2) poor conduction, and 3) the settling of cold air in lowlying areas.

Under climatic conditions existing in the vicinity of East Lansing, Michigan, frosts may occur any month of the year. A temperature of 18°F. at the surface of the soil was recorded at the Michigan State University Muck Experimental Farm on June 10, 1949. Frost damage is most likely on cool, clear nights with low humidity when conditions are most favorable for heat loss by radiation.

Methods of control.

Frost hazards may be reduced by 1) irrigation, 2) mechanical stirring of the air, 3) smudges and heaters, 4) presence of a body of water, 5) improvement of air drainage, 6) heavy fertilization with potash, 7) sanding or claying, 8) close spacing of crops, 9) selection of frost-hardy crops, and 10) cultural methods.

1. Irrigation. A dry surface acts as an insulator, reduces the rate of heat conductance and thus increases the frost hazard. Water applied either by overhead methods or sub-irrigation increases the rate of heat conductance and the total mass weight. When water freezes, the heat released amounts to over 33 million B.T.U.[5] per acre inch of water. Sprinkling foliage with water further reduces frost damage because of this factor. Unfortunately 2 or 3 successive nights of freezing temperatures often occur. Application of excess quantities of water by rotating sprinklers to prevent frost can waterlog the soil, which can severely damage crops. Mechanical damage to plants can occur from use of sprinklers because of heavy ice accumulation on the foliage. Possibly a fog-type system that materially reduces the volume of water applied would be more satisfactory than the present type of equipment.

Flooding with water is used as a frost control method in cranberry production. In this case, an effective water control system is necessary.

2. Mechanical stirring of air. Under conditions of high radiation and low wind velocity, the air temperature 20 feet above the

[5] A B.T.U. is the amount of heat required to raise 1 pound of water 1 degree F. One pound of water at 32 degrees F. changed to solid ice requires a removal of 144 B.t.u.

Fig. 44. Overhead irrigation aids faster growth for young transplants and gives frost protection.

soil may be 15°F. higher than at the surface. If this situation is present, stirring the air by mechanical means helps to prevent frost by mixing air layers. Stirring the air can cause deposition of dew which may give sufficient protection to the crop to withstand temperature drops of 2 to 3°F. below freezing. Mechanical stirring of the air can be accomplished by power driven fans.

3. **Smudges and heaters.** This method has occasionally been used as a means of frost protection. Danger from fires starting in the soil seriously limits the applicability of the method. Oil-fired radiant heaters equipped with reflectors and in some cases combined with a rotor have been tried out. The degree of protection afforded by this equipment limits its use to small areas of high value crops.

4. **Presence of bodies of water.** Protection afforded by a lake, river, or pond makes it possible to grow many crops that would otherwise be severely damaged by frost if planted away from the area influenced by the water. This accounts for successful crop production in several areas located in a relatively cool temperature zone.

5. **Air drainage.** Good air drainage will help materially to reduce frost hazards. Cold air is heavier than warm air and tends to collect in low areas thus accentuating their frosty nature. Air drainage is of special significance in the selection of a location for blueberry production because of the serious reduction in yield resulting from frost injury to the branches and fruit buds.

6. **Heavy fertilization.** Heavy applications of potash reduce frost hazards to crops. This effect is more noticeable in fall than in the spring. From a practical point of view, however, it is not recommended that plants be overfertilized with potassium to prevent frost damage.

7. **Sanding or claying.** Applying sand or clay over the soil surface reduces the danger of frost. However, labor costs involved limits this practice and it is not in general use in the United States.

8. **Close spacing of crops.** A decrease in frost hazard accompanies closer spacing of crops. This effect is particularly noticeable with poor stands of potatoes and corn. However, spacings inconsistent with optimum yields for the purpose of reducing the danger of frost are not recommended.

9. **Selection of frost hardy crops.** The selection of frost tolerant crops is one of the most practical means to prevent losses from

frost. Susceptible crops, such as corn and potatoes, should be early maturing varieties. These crops should be planted early even at risk of spring frost. Crops shown in Table 9 are classified according to their tolerance to freezing temperatures.

TABLE 9—Degree of frost tolerance by crops commonly grown in Michigan

Hardy	Medium hardy	Fairly susceptible	Easily damaged
Canary grass	Barley	Asparagus	Beans
Parsnips	Cabbage	Blueberries	Cucumbers
Rutabagas	Carrots	Corn	Melons
Rye	Cauliflower	Parsley	Peppers
Salsify	Celery	Peppermint	Squash
Spinach	Clover	Potatoes	Strawberry fruit
Timothy	Horseradish	Radish	Tomatoes
Turnips	Lettuce	Soybeans	
Brome grass	Oats	Spearmint	
	Onions	Sudan grass	
	Peas		
	Sugar beets		
	Table beets		
	Wheat		

10. Cultural methods. Loose, dry soils are more subject to frost than moist soils. Practices that will reduce frost damage are: 1) roll or cultipack, especially if the soil is peaty in texture; 2) fall plow rather than spring plow; 3) use herbicides instead of cultivation to control weeds; 4) minimum tillage after adequate compaction; 5) refrain from plowing up too much peaty subsoil; and 6) covering plants such as mint and potatoes with soil during the period of frost danger with disk hillers mounted on tractors. The soil is later removed by a light drag or by workers using leaf rakes.

Wind Erosion Control

Severe losses can result from wind damage. In addition to the soil loss and resultant lowering of elevation, many crops are either totally destroyed or seriously injured during the early part of the growing season. Losses of 1 inch of soil and complete filling in of a drainage ditch as a result of one storm have been observed.

At one location the surface of a drainage ditch had a higher elevation following erosion than the field that had been farmed. Banks of soil, 50 to 70 feet wide at the base and 6 to 8 feet high, have been built up by wind action. The underlying soil in the eroded areas may be very sandy or impervious clay or marl, which seriously limits its productivity. Wind erosion is partially responsible for the "Nomad" type of farming in several of the organic soil areas.

Injury to the growing crop may result from soil removal thus exposing the seeds or roots, or from the abrasive action of the soil particles on the young plants. It is nearly impossible to completely prevent wind erosion on organic soils during severe wind storms.

Control methods.

The following practices will reduce wind erosion losses and damage to crops:

1. Establishment of windbreaks.
2. Utilization of snow fence, burlap fence or crates.
3. Maintenance of a moist surface, either by sub-irrigation, overhead irrigation or compaction.
4. Interplanting of grain between the crop rows.
5. Use of grain strips.
6. Establishment of a grass planting on the ditch bank.
7. Use of cover crops.
8. Employment of minimum tillage methods where field surfaces are left rough rather than smooth.

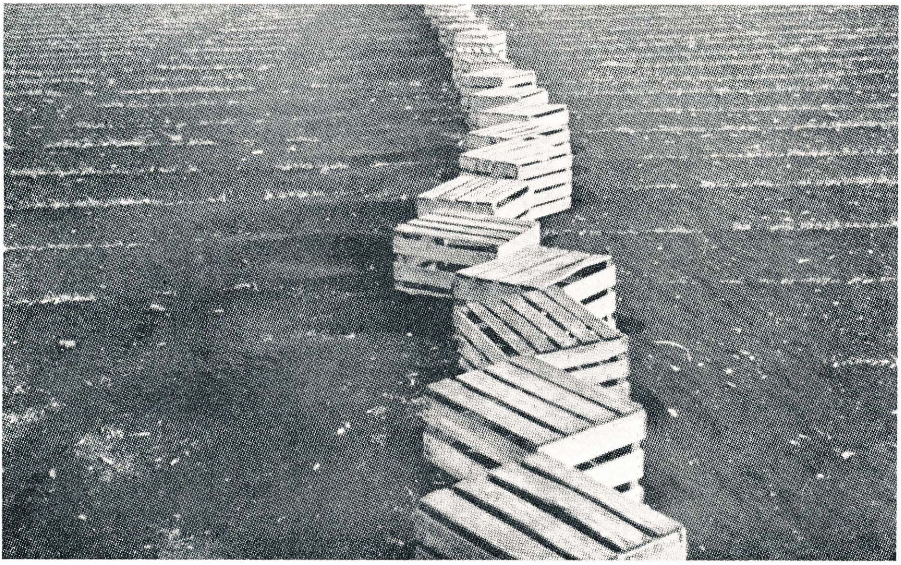

Fig. 45. Crates set out in the field as a temporary control method help protect this onion field. The soil has drifted along the crate rows.

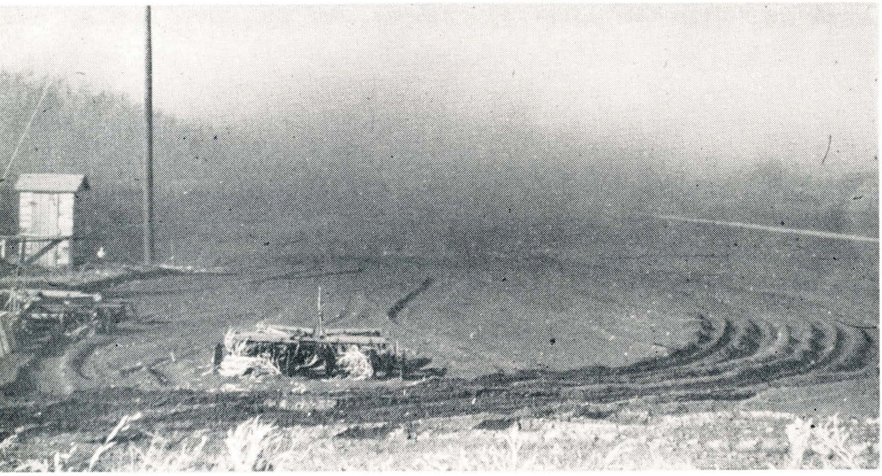

Fig. 46. Wind erosion control is a serious problem on organic soils. The ust storm is so severe that it practically hides the willow windbreak from view. 'his soil is very loose and finely divided from recent cultural operations.

Fig. 47. A drainage ditch filled as the result of one wind storm. Protecting he bank with a grass cover will help prevent filling in of the ditch.

1. Windbreaks.[6] The green willow is most frequently planted and often reaches a height of 18 feet in four years. Golden willow and box elder have also made fairly rapid growth. Transplants (18 to 24 inches in height) of Austrian and Scotch pines, established in 1941, have provided good protection at the Michigan State University Muck Experimental Farm (Fig. 48). White pines planted at the same time were slow in starting, but once established were satisfactory. White cedar suffered from dessication from winter winds, with resulting dying back of the foliage. The buds of Norway spruce have been seriously injured by frost in the spring which severely curtailed the rate of growth.

Willows are easily established and, in general, two methods are used. One is to place a branch, 4 to 5 feet long, into moist soil. In the other method, 1-inch diameter stock, 18 inches long, is placed in the soil so that 1 or 2 inches of the stock remain above the surface. The windbreaks should be placed at right angles to the prevailing wind. Spacing willow rows 200 to 300 feet apart is gen-

[6] Two types of windbreaks are recognized, primary and secondary. Primary windbreaks refer to the taller willow plantings and secondary to the lower growing shrub types.

Fig. 48. Austrian and Scotch pine 13 years after transplanting (12 feet high).

erally satisfactory. Because of the area (50 feet or more) that is taken up by the willow row or other windbreaks, they may not be practical because of the loss in area for agricultural purposes. Willow roots may enter tile lines unless wellcalked bell-joint tile are used under the windbreaks. Other disadvantages are high cost of trimming, disease problems and trash from broken limbs. Older trees do not leaf out on the lower part of the trunk, and thus, limit their value in controlling wind.

Spiraea have been successfully used by some farmers, but in general, are not tall enough to provide good wind protection under adverse conditions. Multiflora rose has recently been used and will make as much as 6 feet in growth during two seasons. Its value as a windbreak is limited because of its normal height of growth. Chinese elm has been suggested, but under conditions similar to those at the Michigan State University's Muck Experimental Farm, less than 1 percent survived.

2. **Supplemental windbreaks.** Supplementary protection to tree windbreaks may be obtained by the use of snow fences or burlap bags strung on wire. Crates spread in the field may give temporary protection and, experimentally, "Sisal-Kraft" paper has been tried. One of the objections to the use of these supplemental materials is the labor involved in setting them up in the field. They also interfere with subsequent cultivation and spraying operations.

3. **Irrigation.** The maintenance of a moist surface, either by sub-irrigation or overhead irrigation serves as a good preventive measure to aid in controlling wind damage.

4. **Interplanted grain.** Oats, barley, rye or wheat planted between crop rows provide an excellent wind erosion control measure. Oats tend to tiller and do not make as upright a growth as does barley, but are more frost tolerant. Winter rye can be used, but is difficult to control during a wet period. The interplanted grain may be planted between each crop row and is progressively cultivated out as the need for protection decreases. Rotary type blade equipment will keep the top growth under control without completely destroying the plant (Fig. 49). The previous difficulties encountered in the control of the grain after the danger of wind damage is passed have been reduced by the introduction of the rotary type cultivator. As with other means of wind erosion protection, the use of interplanted grains should be considered as one of the control methods.

The wind damage may occur before the grain has become high enough to afford protection or the grain may be killed by frost. Fall planting of rye offers possibilities where farmers have proper machinery to control and eradicate the rye.

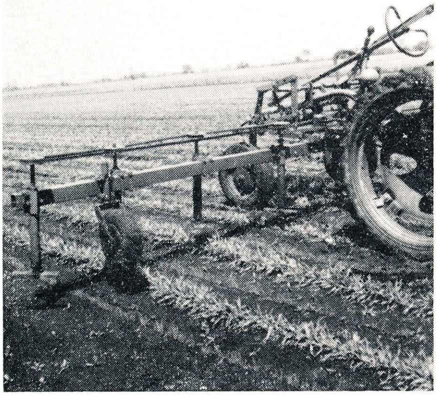

Fig. 49. Grain used for windbreaks. Left picture, spring barley used between onion rows and a mechanical trimmer to check grain growth. Fall planted rye offers better protection than spring planted grain. Right picture, spring wheat used between peppermint rows. The mint was band-sprayed with preemergence herbicide. Equipment behind the tractor is a heavy rotary tiller ("Rotavator") used to tear up wheat between mint rows as illustrated at right of picture.

5. Grain strips. Winter rye strips, 8 to 10 feet wide, may be planted in the fall at intervals compatible with the field crop arrangement. Blowing soil may lodge in the drilled strip during the winter and produce a ridged condition which is difficult to level. Some farmers use these strips as roadways for spraying and irrigating operations during the growing season.

The amount of protection that can be expected from a windbreak has not been precisely determined. It has been suggested, however, that possibly 10 feet of protection might be expected for each foot in height of the windbreak assuming that the wind is blowing at right angles to the windbreak.

6. Grass cover on the ditch bank. Planting a grass cover on a ditch bank helps prevent filling in of the ditch.

7. Cover crops. Increasing the amount of fresh organic matter in the surface soil and, thus, increasing the fiber content, will cut

Fig. 50. Rye cover crop prevents soil blowing during the winter and early spring. Spiraea used for windbreaks on this field. Lack of height limits its value.

down on wind erosions losses. Some opinions have been expressed that farm manure and green manure increase the rate of decomposition of newly reclaimed organic soil. The use of green and farm manure will increase the bacterial population in a soil. Experiments in Ohio (193) in which radioactive carbon was incorporated into green manure and added to organic soils, showed that there was an increase in total carbon. A comparison was made between the amount of carbon remaining in treated and untreated samples. This would indicate that

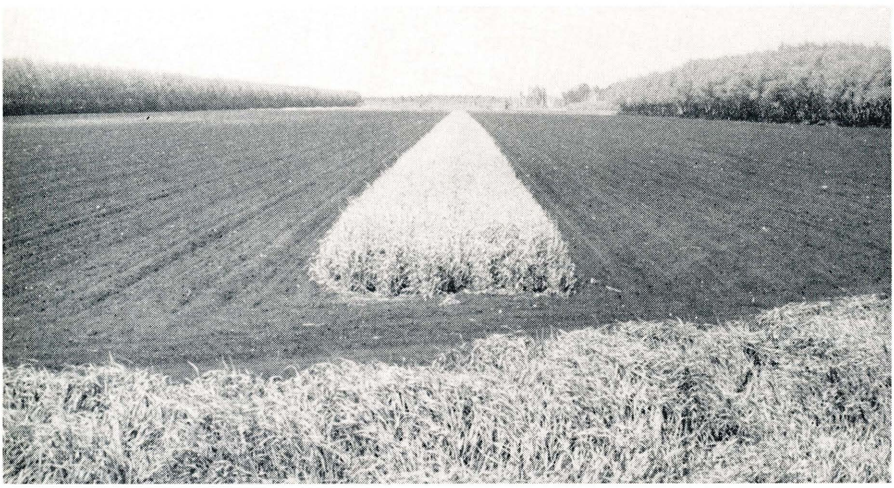

Fig. 51. Combination willow windbreak and rye strip for wind erosion control.

green manure additions did not result in the loss of organic matter. The study, however, did show that there was more nitrate-nitrogen produced using a green manure cover crop. The use of a cover, or green manure crop can save soil from blowing. The benefit would likely be much greater than any loss that might occur from any increase in rate of decomposition.

In a study of subsidence on a newly reclaimed organic soil there was no loss in elevation over a 6-year period. The field was planted to corn for 6 successive years and had a rye cover crop plowed down for the first 4 years. In addition, a 15-to 20-ton application of manure was applied annually for the last 2 years.

Planting a green manure crop on older organic soils which have become finely divided may increase aeration and improve structure.

8. **Cultural methods.** Plowing from one-quarter to one-half inch deeper each year, in order to bring up the undecomposed subsoil, aids in preventing excessive wind damage. Delaying harrowing until after the windy period will also serve to limit the damage. Ridging the soil with a cultivator or disc-hiller will give some temporary protection.

One of the advantages gained from the practice of minimum seed bed preparation is partial wind erosion control (see Fig. 52). Under minimum tillage the field is likely to be rougher, to remain moist at the surface, the soil less finely divided and more resistant to wind movement.

Experimentally, seeding oats at the rate of 2 bushels per acre in the fall mixed with sufficient rye to give a plant every 3 to 4 square feet, has resulted in wind erosion control. The crop to be grown in the spring is seeded without any spring seed bed preparation, other than the planting and fertilizing operation. The oats winter kill and there are sufficient rye plants remaining to act as a windbreak. Weed control has been accomplished by the use of herbicides. When the danger of wind is over in the spring, the rye plants are removed using rotary type cultivating units (Fig. 54). The practical application of this procedure on a field scale has yet to be demonstrated. Experimentally, over a three-year period no reduction in yield of onions was observed under this method of tillage, as compared to normal tillage.

A deeper planting of seed in wind-swept areas may limit crop damage from wind, but is not helpful under severe storm conditions.

Fig. 52. Corn planted in the tractor wheel track. Rows planted in a north-south direction and on rough land help reduce wind erosion. Compaction by the tractor wheels helps bring moisture to the seed and to the surface to reduce danger from frost. Corn was preemergence sprayed with 2, 4-D to control weeds and no tillage operation was used since plowing.

Plowing

Organic soils are generally loose and open and will require less power to plow than a similar volume of mineral soil. Muck can be too loose, especially if dry. Under such conditions it will push rather than make a partial inversion pattern. Wet sticky soils will cause problems when using certain moldboard plows. The angle of the moldboard and the finish of the steel can affect scouring. Some farmers obtain better results using a slatted moldboard which increases soil pressure on the steel surface.

Trashy fields having corn stalks or straw can be a problem. Plowing deeper and using bigger plows—18 inches or larger—will be helpful. Chopping and rolling the trash a few days before plowing is advisable.

Some farmers in Northern Indiana who have been growing mint are plowing 26 to 30 inches deep. A soil borne disease—**Verticillium** wilt—has seriously affected yields. Burying the infested soil will temporarily help maintain mint yields (Fig. 53). It is essential that infested soil is deposited on the bottom of the furrow. Deep plowing can possibly be used to reduce other soil borne diseases such as onion smut. It may be advisable to deep plow fields heavily infested with weed seed.

Fig. 53. Soil in foreground deep plowed; that in background was plowed at conventional depth. Note differences in vigor of peppermint and weeds. Soil was infested with verticillium wilt disease. Photo courtesy of Horticultural Department, Purdue University.

Deep plowing requires large power equipment. Operating costs may average over $30.00 per acre. It is a mistake to deep plow many fields. If aquatic (sedimentary) peats are turned up, drainage and aeration may be poor. Peats containing tree roots present a problem because they are hard to plow and infested soil is easily mixed with clean soil. Some fields have shallow organic deposits and the subsoil turned up may be undesirable, especially if it is sand or marl. Tile lines are generally not placed deep enough and may be plowed up or pushed out of line.

Cultivation

An organic soil is cultivated for three reasons: 1) weed control, 2) drying out wet soils, and 3) improving aeration of the soil with resultant increase in nitrate formation. If the soil is in a waterlogged

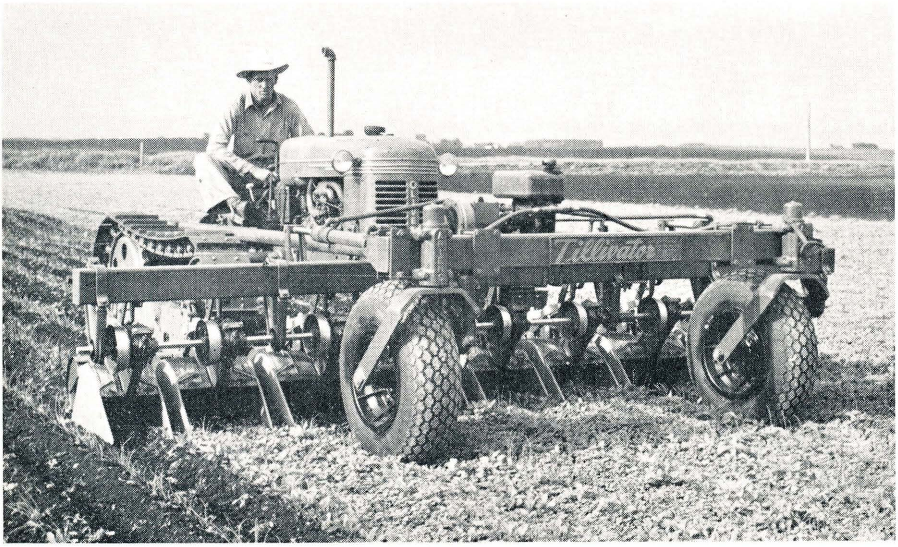

Fig. 54. Rotary-type cultivator equipment. (Courtesy Ariens Company, Brillion, Wisconsin).

condition, the use of a hook-type cultivator will loosen and aerate the soil and improve plant growth. Several types of cultivating equipment are used, varying from the sweep-type shovels to the rotary-type knives protected by hoods. Rotary hoes, finger weeders or rubber tooth drags will control small weeds in potatoes, mint, corn and similar crops. The weeder can be used in a potato field when the plants are 12 to 14 inches high provided the tractor speed is reduced so that injury to the plants is minimized.

Root pruning caused by deep cultivation should be generally avoided. However, if it is necessary to aerate the soil after a heavy rain, the sacrifice of a few roots may be overcome by the advantage gained by the deep cultivation. It is impossible to give any strict procedure to follow and a good grower will recognize the needs of his particular crop and cultivate accordingly.

NUTRIENT REQUIREMENTS OF CROPS

The measures necessary to adequately provide for the nutrient requirements of crops grown on organic soils are influenced by a number of factors:

1. Chemical composition of soils.

Fig. 55. A finger weeder controlled by the hydraulic lift of a tractor is a very effective means of weed control. Damage to potatoes is very slight even at more advanced stages of growth.

2. Sources of vegetation comprising the soil.
3. Soil reaction.
4. Depth of the soil deposit.
5. Character of the underlying material.
6. Temperature.
7. Moisture.
8. Specific crop requirements.
9. Placement of fertilizers.
10. Number of years under cultivation.
11. Cultural practices.
12. Toxic substances.

In many instances, the interaction between the various factors accounts for the behavior in growth of a crop during the season.

Major Plant Nutrients

Nitrogen, phosphorus and potassium are supplied from two sources —those residual in the soil and those applied by either commercial fertilizers or manures.

itrogen.

Organic soils may contain 3 percent total nitrogen on an oven-y basis, an amount equal to that found in 3-12-12 fertilizer. Nitro-en in the soil exists largely as a constituent of the organic matter. s a result of the action of soil microorganisms, nitrogen in the ganic matter is changed into forms available to plants. The final oduct in the soil nitrogen cycle is the nitrate form. This form is ost generally utilized by plants, although the ammonium $(NH_4)^+$ rm can be used to some extent and may be preferred by certain acid lerant crops such as blueberries. Temperature, moisture and aera-on markedly affect the activity of the soil organisms, thus, resulting a variable, seasonal supply of available nitrogen for plants. Nitro-en deficiency is most likely to occur under cool soil conditions, and ider excessively wet conditions. The rate of release of nitrogen ecreases as the soils are cultivated for a period of years. The supply the more easily decomposable organic matter diminishes, thus, ducing the rate of nitrate formation. Strongly acid soils are usually w in total nitrogen. They also inhibit the activity and numbers of ganisms associated with organic matter decomposition, thus result-g in a lower rate of nitrate formation.

A nitrogen surplus in the soil may not be desirable. Vegetative owth of potatoes and sugar beets may be stimulated at the expense tuber and root development. This can result in reduced yields of arch in potato tubers and sugar in beet roots. Excess amounts of trogen increase frost hazards and lodging of small grains and pre-ature breakover of onion tops is aggravated.

Production of nitrate-nitrogen in the Everglades muck is very pid under certain conditions. The problem of nitrate accumulation certain winter forages has been the concern of cattlemen as a esult of the death of animals. Ryegrass and oats were found to ccumulate quantities greater than 4 percent nitrate-nitrogen on a y weight basis (104).

On some of the organic soils of Central Wisconsin, it has been und that cows will abort when turned out on weedy native pas-res in late spring or early summer (103). Stinging nettles, elder-erry, boneset, goldenrod and ragweeds seem to be the chief of-nders. The nitrates are believed to change to nitrites in the cow's omach. The nitrites change the hemoglobin of the blood to meth-moglobin which does not carry oxygen to the fetus. This causes e fetus to die and it is aborted. If large quantities of nitrates are eaten the cow may die from suffocation. Veterinarians at Missouri University believe nitrates over 0.5 percent in the total ration is a potential cause of trouble. Amounts of 0.75 percent will decrease milk production and at 1.5 percent, death likely will occur.

No definite recommendation as to time or rate of nitrogen application will fit all conditions. From 25 to 200 pounds of nitrogen per acre may be required during a cropping season. Fall application of nitrogen carriers, including anhydrous ammonia, is not recommended for spring or summer crops. Experiences at the Michigan State Muck Experimental Farm which is classified as Houghton muck (pH 6.0 to 6.3) and tiled with 6-inch tile at 60-foot intervals indicate that most early planted crops respond to 50 pounds of nitrogen per acre. The degree of response varies with the season. In no case, however, has a reduction in yield of any crop been noted from the use of this amount of nitrogen. Since it is impossible to predict in advance the seasonal requirements of crops for nitrogen under conditions similar to those at the Muck Experimental Farm, the inclusion of 50 pounds per acre at planting time acts as insurance against a nitrogen shortage.

Phosphorus.

Phosphorus is particularly needed for small seedlings and transplants. Phosphorus starvation in corn and tomatoes is indicated by a reddish-purpling of the leaves, but with many crops no visible leaf symptoms occur. Plants are stunted and in some cases, the foliage is an unusually dark green because of an abnormally high nitrogen content.

From 30 to 85 percent of the total phosphorus in virgin organic soils is in the organic form (206). Organic phosphorus has to be mineralized before it can be utilized by plants. The amount of organic phosphorus in the soil is determined by the difference between the inorganic and total phosphorus before and after treatments designed to change the organic to the inorganic form. Studies of soil organic phosphorus are handicapped by lengthy and inadequate chemical procedures. Five forms of organic phosphorus (phospholipids, nucleic acid, insitol phosphates, "metabolic" phosphates and phosphorproteins) have been suggested as components of organic soils. The rate of changing the organic phosphorus to the mineralized form available for plants depends on several factors:

1. The amount of organic carbon and nitrogen in the soil.
2. Soil reaction.

3. Type of organic phosphorus.
4. Temperature.
5. Soil microorganism species and activity.
6. Enzymes.

The rate of mineralization can be temporarily decreased by microbial fixation due to microorganism consumption of phosphorus. The presence of lignin can decrease the rate. Studies show that mineralization also occurs in chemically sterilized soil, suggesting the role of enzymes in this process (173). Soluble phosphates may become "fixed" by iron and aluminum. No fixation of applied mineral phosphate as organic phosphorus was found to occur (122). The rate of mineralization of the original organic phosphorus increased with applications of superphosphate. Crops growing on most organic soils usually respond to an application of phosphate fertilizer, provided an adequate amount of potassium is included in the mixture. Phosphorus applied in the absence of potassium often intensifies potassium deficiency symptoms in plants. Lower yields than those obtained from unfertilized areas may result in an application of phosphorus alone (see Tables 11, 12). Acidulated phosphates rather than the slowly available raw rock phosphate are recommended (Fig. 56).

Fig. 56. Plot (pH 6.2) on left received 800 pounds per acre of phosphoric acid as rock phosphate in a 5-year period. Plot on right was fertilized with 400 pounds of phosphoric acid as super phosphate during the same period. Higher yields of better quality onions were produced on the plots with superphosphate as its source. Nitrogen and potassium applied on both plots.

Fixation of Fertilizer Phosphorus.

Because of fixation in the soil, the amount of phosphorus recovered by plants from fertilizer is often very low. Placement of the fertilizer can greatly affect phosphate recovery and crop yields. Using tracer techniques, it was found that liming an acid Rifle peat appreciably depressed the phosphate recovery when the pH was above 5.2 (see Table 10). It is believed the lime caused a reversion of soluble phosphate to an insoluble tricalcium phosphate.

TABLE 10—The effect of liming Sudan grass(a) grown in the greenhouse on an acid organic soil, on the yield, phosphorus content and the percent of phosphorus derived from fertilizer

Tons lime per acre	Soil pH	Grams per pot			Percent phosphorus in plant			Percent phosphorus derived from fertilizer	
		0	50 lb. P_2O_5/A.	200 lb. P_2O_5/A.	0	50 lb. P_2O_5/A.	200 lb. P_2O_5/A.	50 lb.	200 lb.
0	4.4	11.0	9.6	12.9	0.21	0.27	0.48	48.2	88.5
1½......	4.9	13.1	13.1	13.2	0.21	0.26	0.42	38.5	89.3
3	5.3	9.8	13.5	15.7	0.22	0.22	0.39	36.4	83.4
6	5.8	9.1	11.1	12.8	0.26	0.26	0.36	35.0	79.2
9	6.4	11.3	11.2	12.5	0.21	0.21	0.31	26.2	76.8
12	6.8	9.2	10.6	11.7	0.19	0.19	0.25	28.9	64.0
16	7.2	8.3	10.3	12.5	0.13	0.13	0.27	30.8	57.4

(*a*) Plants sampled four weeks after seeding. Data from Lawton and Davis (108).

Phosphate can be fixed because of soluble iron and aluminum in the soil. Studies were made in New York state on fields that received large quantities of fertilizer for a number of years. In spite of heavy treatment many soils showed a low test for phosphorus. Dawson (45) noticed that soils high in soluble iron and aluminum were easily associated with a high degree of fixation. The data would indicate that the soil pH should have been above 5.8 to minimize phosphorus fixation. Observation under Michigan field conditions and the studies made in Florida (108, 66), however, would indicate that the pH should be about 5.5. Soils differ greatly in the ideal pH necessary for best phosphate efficiency.

Potassium.

In general, potassium is the most limiting, naturally occurring, major plant-nutrient in crops grown on organic soils. The specific function of potassium in plants is not known. Most of it remains in the soluble form in the plant because practically all of it can be removed from dried plant tissue by leaching with water. Potassium applied to organic soils increases the yield of crops, increases the sugar and starch content, reduces frost hazards within a narrow range (2-3°F.), improves crop quality, and possibly increases disease resistance.

Potassium deficiency symptoms in many crops begin as a marginal yellowing of the leaves which advances until all of the leaf is affected. In severe cases, necrosis or complete death of the tissue occurs. The deficiency first appears in the older leaves and progresses to newer growth at a rate depending on the available potassium supply. The deficiency in alfalfa, clover and barley is further characterized by the appearance of white or dark colored blotches on the leaf, in addition to the yellowing and marginal firing.

The intake of potassium by plants is governed to some extent by the available supply in the soil. "Luxury" consumption by plants is not uncommon when large amounts of potassium are applied to the soil. As much as 8.5 percent potassium in oven-dry tissue of celery has been found.

The relationship between potassium and sodium is of considerable interest. Sodium appears to act as a partial substitute for potassium in that the response to sodium is sometimes obtained with some crops at low potassium soil levels.

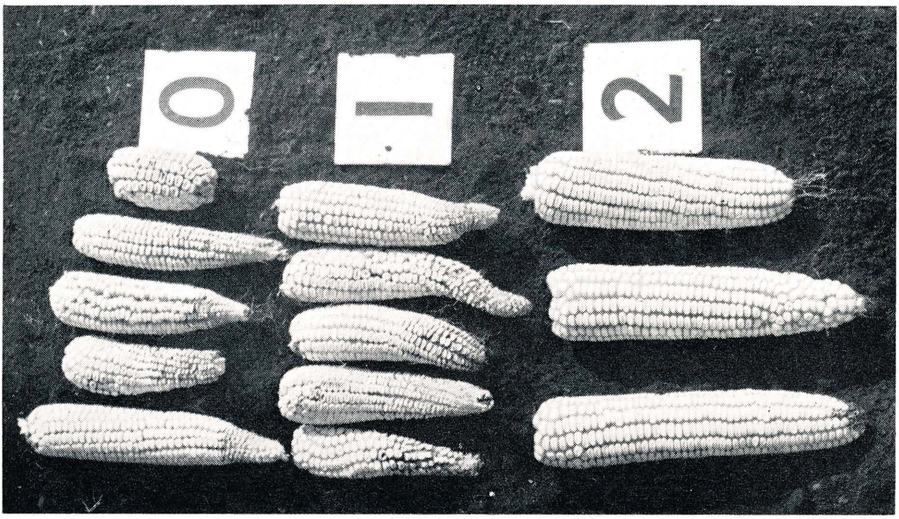

Fig. 57. Fertilizer increased corn yields over ten-fold. 0—no fertilizer; 1—500 pounds 0-20-0 per acre; 2—500 pounds of 0-10-30 per acre. Yields were 7, 8, and 110 bushels per acre, respectively. Phosphorus alone may decrease yields below those obtained from an unfertilized area.

Potassium chloride, commonly referred to as muriate of potash, is the carrier most generally used to supply potassium. Potassium sulfate is generally preferred to the chloride form for potatoes. It usually increases the starch content and may increase the yield of tubers (117).

Soil Potassium.

The total potassium content in mineral soils usually ranges from 0.5 to 2 percent. The range in organic soils is about one-tenth that found in mineral soils. When calculated on an acre 7-inch volume basis, the potassium is often less than 500 pounds for organic soils as compared to about 30,000 pounds in a clay loam soil. This low value accounts for the need of large quantities of potassium fertilizer for crops growing on organic soils. Typical crop responses are shown in Tables 11 and 12. Other properties of potassium noted in organic soils are:

A. Potassium in organic matter does not revert to non-exchangeable forms; clay minerals differ in this respect in that they revert potassium to non-exchangeable forms (55).

B. Bentonite clay holds exchangeable potassium about twice as tenaciously as soil organic matter (93). In another test on strength of adsorption it was found that corn growing for a limited period in a greenhouse recovered 67 percent of the potassium from a peat soil and only 47 percent from a bentonite clay. Both soils had equal quantities of available potassium.

TABLE 11—Effect of phosphate-potash fertilizer on yield of field crops grown on Houghton muck

Lbs./acre P_2O_5—K_2O	Crop				
	Corn Bu./acre	Soybeans Bu./acre	Snap beans Cwt./acre	Sugar beets Tons/acre	Peppermint oil Lbs./acre
0— 0....	11	13	16	3.6	11.0
100— 50....	96	29	158	12.1	29.5
50— 50....	98	31	157	11.3	23.5
50—100....	105	32	170	15.6	27.1
50—150....	107	32	176	18.4	26.2
0—150....	77	23	14	16.3	11.0
100— 0....	12	10	61	3.3	11.1
Years in test	(4)	(6)	(1)	(2)	(5)

TABLE 12—Effect of phosphate-potash fertilizer on the yield of crops grown on Houghton muck

Lbs./acre P_2O_5—K_2O	Crop				
	Potatoes Eu./acre	Carrots Tons/acre	Cucumbers Cwt./acre	Sugar beets Tons/acre	Cabbage Tons/acre
0— 0....	89	10.7	33	5.2	1.1
200—100....	376	24.1	457	18.3	24.1
100—100....	391	24.3	437	18.1	22.4
100—200....	459	26.7	516	21.3	24.1
100—300....	482	27.1	583	23.2	24.4
200— 0....	88	9.0	157	6.4	1.3
0—300....	299	20.7	95	9.7	2.5
Years in test	(7)	(5)	(1)	(2)	(4)

C. Although the potassium in organic soils is held less strongly than in mineral soils, the amount needs to be greater in organic soil because organic soils contain large quantities of calcium and magnesium which interfere with plant absorption of potassium. In other words, certain elements need to be in a reasonable balance for proper plant utilization (116).

D. Flooding and heavy rainfall can leach out soil potassium. Soil samples collected at the Michigan Muck Experimental Farm averaged 270 pounds per acre in September, 1953, and the same areas tested 237 pounds the following spring. The rainfall was about average. In another comparison nine soils averaged 370 pounds per acre in September, 1956. Whereas in late May, 1957, after a period of heavy spring rainfall the same soils averaged only 150 pounds per acre. The field had no cover crop during this period.

From a practical viewpoint no attempt should be made to build up excessively high levels of potassium and expect them to carry over for a number of years in areas of high rainfall. Fertilizer recommendations based upon soil tests need to be modified to correct for leaching following heavy rainfall or flood conditions.

MINOR ELEMENTS AND SECONDARY ELEMENTS

Minor and secondary elements that have been shown to be deficient for plant growth are manganese, boron, calcium, copper, iron, zinc, magnesium, molybdenum, and sulfur. Because soil reaction is an important factor in determining both the available and total content of minor elements, it may be used as an indirect measure of determining the minor element status.

Minor elements may be mixed with the fertilizers that supply the major plant nutrients (N-P-K), or can be applied as foliar sprays and dusts. Amounts required for foliar sprays are considerably smaller than when applied to the soil.

Copper.

The need for copper fertilizer is closely related to the total copper content in the soil. Swedish research workers report that small grain growing on peat containing over 20 p.p.m. of copper are not likely to respond to copper fertilization (119). The copper content of undeveloped acid organic soil (below pH 5.0) in Michigan is about 10 p.p.m. Amounts reported for deficient peats in Europe are 2 p.p.m. to 15 p.p.m.

Acid peats are usually lower in copper than those naturally high in lime. Liming acid soils will not decrease the need for copper. Two conditions that increase the copper content in soils are the resultant concentration from burning and organic matter decomposition.

Copper deficiency in small grains causes marked yellowing of the plants, some leaf streaking, terminal leaves that fail to unfold and tips of older leaves that appear as if frosted. In extreme cases grains will not develop a seed head. Some crops do not show any marked visual deficiency symptoms. The benefit to crops from copper when grown on deficient soils include:

A. Increase in yield.
B. Intensified color in lettuce, spinach, onion bulb skin, wheat grains, and carrot roots.
C. Increased sugar content.
D. Improved flavor.
E. Increase usually in copper content.

The differential response of plants to copper is, in part, believed to be associated with the type of enzyme system present in the plant. Wheat, for example, responds to copper because the ascorbic acid oxidase requires copper in order to function (12). The relationship between copper and molybdenum content of forage is important in livestock feeding. Molybdenum is reported as toxic when the copper

Fig. 58. Effect of copper carriers on yield of head lettuce growing on soil with pH 4.3. 0—no copper; 1—25 pounds of copper sulfate per acre; 2—12.5 pounds 50 percent copper oxide per acre. 2,000 pounds of 5-10-20 per acre applied in all jars (90).

content of forage is less than 5 p.p.m. and the molybdenum is higher than 3 p.p.m. (25, 105).

To some extent, the need for copper can also be predicted by the amount of copper in the foliage. Under deficient conditions, the copper content of grasses usually is less than 6 p.p.m. (119). About the same relationship has been found in tree and vegetable crops (160).

Copper deficiency can be corrected by a number of copper bearing materials. Oxide and sulfate are the two principal carriers now used for agricultural purposes. They are of equal value when compared on the basis of the copper content (68, 90). Copper applied to organic soil is not easily leached (114) nor is removal by the crop much of a factor. An application of about 20 pounds per acre should be made for low or medium responsive crops and 40 pounds for highly responsive crops. This amount of copper can be applied in one broadcast application and will not cause injury to crops. Additional copper may be needed if soil erosion is serious or the field is deeply plowed. In many instances the copper level is ample because of repeated applications of fungicide sprays or dusts containing copper.

Sudan grass shown in Fig. 59 illustrates the plant response to copper when grown on a soil with a pH of 6.2. Several crops are

Fig. 59. Response of Sudan grass to copper fertilization. Left: no copper. Right: 5 lbs. of copper per acre from copper oxide.

listed according to their differential response to copper in Table 13. Recommendations shown in Table 14 take into consideration both pH and plant response. Basic copper sulfate at the rate of 1 to 3 pounds per acre can be applied as a foliar spray in place of soil treatment.

Boron.

Boron deficiency may occur on both alkaline and acid soils. A deficiency causes a breakdown of the young growing tissue which

Fig. 60. Table beets showing "black spot" or "girdling" because of a lack of boron. Black areas may be found inside of root.

retards growth and eventually destroys the cells. This causes the roots of some crops to crack, blacken, and become abnormally shaped. Boron deficiency is usually corrected by an application of borates. Small grains, beans, peas, and soybeans require very small amounts and are easily injured from boron fertilization. Corn may respond to light applications of boron, but it should be broadcast or drilled in ahead of planting.

Boron deficiency is associated with "heart-rot" of sugar beets, "black spot" or "girdling" of table beet roots, "water core" in rutabagas and turnips, "cracked stem" in celery, and internal breakdown of the stalk of cauliflower. Crops listed in Table 13 show the relative response to boron fertilization. The amounts generally needed

TABLE 13—Crop response to minor elements

Crop	Minor element response			
	Manganese	Boron	Copper	Others
Alfalfa	Low	High	High	
Asparagus	Low	Low	Low	
Barley	Medium	None	Medium	Zinc
Beans	High	None	Low	
Blueberries	None	None	Medium	
Broccoli	Medium	Medium	Medium	
Cabbage	Medium	Medium	Medium	
Carrots	Medium	Medium	High	
Cauliflower	Medium	High	Medium	Molybdenum
Celery	Medium	High	Medium	Sodium
Clover	Medium	Medium	Medium	
Cucumbers	Low	Low	Medium	
Corn	Medium	Low	Medium	Zinc
Grass	Medium	None	Medium	
Lettuce	High	Medium	High	Molybdenum
Oats	High	None	High	
Onions	High	None	High	Zinc, molybdenum
Parsnips	Low	Medium	Medium	
Peas	High	None	Low	Molybdenum
Peppermint	None	None	Low	
Potatoes	High	Low	Low	
Radish	High	Medium	Medium	
Rye	None	None	None	
Spearmint	Medium	None	Low	
Soybeans	High	None	Low	
Spinach	High	Medium	High	Molybdenum
Sudan grass	High	None	High	
Sugar beets	Medium	High	Medium	Sodium
Sweet corn	Medium	Low	Medium	
Table beets	Medium	High	High	Sodium
Turnips	Medium	High	Medium	
Wheat	High	None	High	

TABLE 14—Copper recommendations for organic soils—elemental basis. (Soil pH before liming)

Crop response	Pounds per acre		
	pH 5.4 or less	pH 5.5-6.4	pH 6.5 or higher
High..........	12	8	4
Medium......	8	4	0
Low..........	4	0	0

are reported in Table 15. On some soils celery, table beets, and cauliflower, may need greater amounts than those suggested.

Boron in the form of sodium borate can be applied as a foliar spray. Amounts suggested are 0.1 to 0.4 pound per acre of actual boron. Rates greater than 1 pound per acre proved toxic to celery (Fig. 61).

Manganese.

Manganese deficiency in plants is likely to occur if the pH of the soil is 6.0 or above (67, 82). The manganese available to plants exist in the exchangeable manganous form or in forms easily converted to this state. Soil conditions associated with manganese deficiency are:

1. Burned-over areas.
2. Free marl or limestone.
3. Alkaline springs.
4. High content of alkaline mineral oxides such as limonite.
5. Cool wet soils.

Data in Table 7 show the effect of liming five different soils on the pH, exchangeable manganese, and yield of onions. Values re-

TABLE 15—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 16—Manganese needed for organic soils—elemental basis

Crop response	Pounds per acre		
	pH 6.0-6.6	pH 6.7-7.2	pH 7.3-8.0
High..........	10	20	40(*a*)
Medium......	5	10	20
Low..........	0	5	10

(*a*) More practical to disc in 500 pounds per acre of sulfur and use 20 pounds of manganese per acre.

Fig. 61. Boron toxicity in celery. Note fine leaf development and brown spots on petioles. Plant received a total of 4 pounds per acre of actual boron from four sprays applied during growing season. This amount of boron would not be toxic if applied as a soil treatment.

ported in Table 8 show how the liming treatment affected the manganese content of the onions.

Manganese oxidizing microorganisms play an important role in the amount of available manganese (110). Steam sterilization or chemical fumigation which destroys these microorganisms can greatly increase available manganese (67).

Plant symptoms of manganese deficiency first appear in the new growth of leaves. For a number of crops the leaves show a mottled appearance. The leaf tissue between the veins becomes increasingly

Fig. 62. Gray-speck disease of oats caused by manganese deficiency. Left, two leaves from manganese deficient plant. Right, leaf from plant sprayed with the equivalent of one pound of manganese per acre. Increases in yield of crops from manganese applications have been observed with a soil pH of 5.8 or higher.

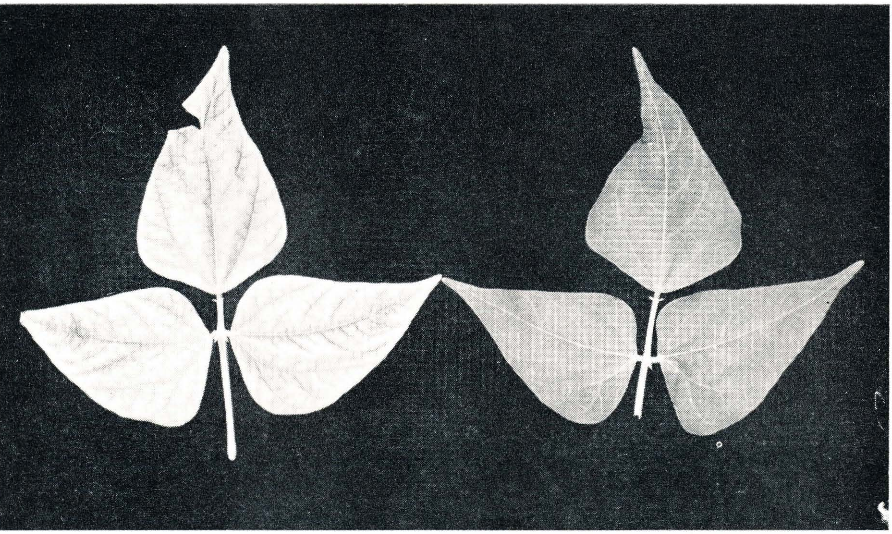

Fig. 63. Left, manganese deficient bean leaf. Right, normal leaf. A varietal difference in manganese requirements has been observed at the Michigan State University Muck Experimental Farm.

lighter green and finally yellow with the veins remaining green (Fig. 62). In extreme defiiciency levels the veins also turn yellow in color; the plants have a soft feeling and weak stems.

The crops listed in Table 13 are divided according to the degree of response to manganese. Such a listing has limitations for varieties of a given crop can show large differences in response. For example, in field experiments the Mandarin soybean yielded 16 bushels per acre without and 37 bushels with manganese. On the other hand, Norchief yielded 31 bushels per acre and showed no response to added manganese.

Manganese deficiency can be corrected by applying manganese bearing materials or by the addition of sulfur to acidify the soil. Manganese materials are more effective and cheapest when immediate results are desired. Sulfur, on the other hand, is more economical when the effects are considered over a period of years. Because of large quantities and high costs, sulfur is not advisable for soils containing considerable amounts of free calcium carbonate. (For further discussion on sulfur, see page 86.) The manganese material commonly used is the sulfate form. Tests with broadcast applications of various carriers at the Michigan Muck Experimental Farm show that manganous oxide is about 20 percent less effective than the

Fig. 64. Left, normal onion plant. Right, manganese deficient plant. Manganese deficient plants are usually high in nitrates, although light green to yellow in color. The leaves die back at the tips and do not maintain an erect growth. This aids in differentiating manganese and nitrogen deficiency.

sulfate form. However, band applications near row showed little differences between sulfate and oxide forms.

Manganese response may be obtained on some soils with a pH as low as 5.8. Very acid soils that have been limed usually show a greater need for manganese fertilization than unlimed soils with the same pH value. The amount of manganese suggested for crops as affected by pH is shown on Table 16. These recommendations assume part of the manganese fertilizer will be placed in bands near the seed at planting time. Fixation of manganese in the soil occurs particularly when applied broadcast and larger quantities may be needed than those suggested.

Manganese can be applied as a foliar treatment at 1 to 2 pounds per acre of actual manganese. Water soluble materials are preferred and several applications may be required during the growing season to meet the plant requirements. On a Houghton muck, potato yields were increased from 264 to 413 bushels per acre with manganese spray.

Zinc.

Zinc deficiency has been recognized on corn (Fig. 65) and barley and occasionally on onions. An application of 2 to 5 pounds per acre of zinc per season may be needed for several years with zinc sulfate being the carrier generally used. Some sources of fertilizer contain sufficient quantities as an impurity to correct zinc deficiency. Certain organic fungicides contain zinc and thus serve two purposes, to control disease and to act as a nutrient.

Fig. 65. Zinc deficiency in corn. Symptoms of zinc deficiency are short internodes and yellow chlorotic stripes at base of leaf. If severe, new leaves are nearly white and lower leaves are reddish. Nodes are discolored and show a deposition of iron when tested. Deficiency more severe on nearly neutral or alkaline soils.

Certain muck soils in New York state contain excessive amounts of zinc that are toxic to plant growth (184). Poor growth can be correlated with soils having a high zinc-sulfur ratio. Applying lime partly corrects the toxicity. Concentrations in the soil of less than 1,000 p.p.m. (0.1 percent) of zinc were not harmful to spinach. The amount found in some of these soils ranged up to 6.7 percent.

Molybdenum.

Much of the research on molybdenum has been concerned with excessive quantities found in plant material. Winter forages grown on Everglades peaty-muck contained from 6.0 to 27.9 p.p.m. of molybdenum. Two factors that cause greater uptake by plants growing on acid soil with a given molybdenum content are an increase in pH (less acidity) or a slower rate of plant growth (105).

Areas of molybdenum deficiency are also under investigation. An acid Michigan peat classified as Spalding (pH 4.8) required 0.5 pound of sodium molybdate per acre to grow normal head lettuce. Onions growing on a problem peat contained only 0.05 p.p.m. molybdenum in the leaves (tops) while normal plants contained 0.7 p.p.m. Molybdenum deficiency in crops may exist in soils that do not appear to need lime even though the pH is greater than 5.0.

Organic soils with a high iron content as indicated by a rusty color show a great need for molybdenum for responsive crops.

The recommended rate of actual molybdenum is about 0.4 pounds per acre applied in the fertilizer band near the seed. Foliar sprays and seed treatment at several ounces of sodium molybdate per acre may also meet plant requirements.

Sodium.

A response to sodium, applied normally as sodium chloride—common salt—has been obtained with a number of crops. These are usually members of the beet *(chenopodiaceae)* family and celery. Other crops that show less response are cabbage, wheat, rape, cotton, flax, rutabagas, and chicory (81). The degree of response is generally associated with the potassium level in the soil which indicates a partial replacement of potassium by sodium in the plant. The addition of salt increases the sodium content of plant tissue, imparts a salty flavor, may increase yield, acts as a deterent to wilting in hot, dry weather, and may slightly reduce the incidence of certain diseases such as leaf spot in sugar beets.

Data reported in Table 17 show the effect of sodium chloride and potash on the yield of beets and celery. Crops growing in high levels of potassium are not likely to respond to sodium applications.

TABLE 17—The effect of salt (sodium chloride) on the yield of crops grown on Houghton muck. (All plots received 100 pounds of phosphate per acre.)

Treatment (pounds per acre)		Tons per acre		
Potash-K_2O	Salt	Table beet roots	Untrimmed celery	Sugar beet roots
100	0	22.7	27.1	13.8
100	500	27.7	34.1	16.0
200	0	25.9	33.5	18.7
200	500	29.0	38.1	21.7
300	0	27.1	33.0	20.7
300	500	27.6	38.6	22.3
600	0	30.6	38.6	23.5
600	500	30.4	40.0	23.0

Manure.

Manure is a lowgrade fertilizer requiring a heavy application of 10 to 20 tons per acre to be generally effective. If nitrogen is not needed, manure will encourage excessive top growth in potatoes and lodging in small grain. Manure usually contains considerable quantities of weed seed and if used, increases the problem of weed control. If both mineral and organic soils are farmed, the manure should be applied to the mineral soil.

Manure contains many of the minor elements but not in sufficient quantities to satisfy the needs of a crop growing on a deficient soil. In general, more profitable increases in yields can be obtained from commercial fertilizers than from manure, if it must be purchased.

Green Manure and Cover Crops.

Green manure and cover crops are important for many reasons:

1. Reduce leaching of residual plant nutrients and when incorporated into the soil, release plant nutrients for subsequent crop utilization.
2. Prevent soil loss by wind erosion.

3. Improve soil structure of the older, well-decomposed muck soils.
4. Act as a partial weed control measure after a crop has been harvested.

The most important value of green manure crops on newly developed soils is wind erosion control.

The preferred stage of maturity of the crop to incorporate in the soil depends somewhat on the length of time the land has been farmed. For the older areas, it may be advantageous to plow under more mature materials so as to provide for a longer lasting effect on soil aeration.

Occasionally, the opinion is expressed that a green manure crop on recently developed soils hastens decomposition of the soil and thus increases the rate of subsidence. Data obtained from the Ohio Agricultural Experiment Station (193) indicate that green organic matter added to organic soil increases the amount of residual carbon.

Winter rye is an excellent green manure crop. The seed is inexpensive and it can be seeded late in the fall and is winter-hardy. The rye should be carefully plowed under. Other suitable cover crops are oats, barley, white sweet clover, Sudan grass and soybeans. Corn planted thickly in 7-inch drills after early harvested crops is a popular cover crop with some growers.

FERTILIZER PLACEMENT ON MUCK SOILS

The method of placing the fertilizer in relation to the seed may account for as much as 100 percent difference in yield (Table 18). Fertilizer can be applied in several ways.

1. Broadcast and disked in or plowed under.
2. Drilled in.
3. In contact with the seed.
4. Band placement near seed or plants.
5. Foliar applications.
6. Sidedressing or topdressing.

Onions and spinach are crops responsive to band placement, whereas carrots are not as responsive. Theoretically, soluble phosphate fertilizer is more efficiently utilized by plants if placed in local-

BLE 18—The effect of placement of fertilizer nutrients on the yield of Yellow Globe onions grown on Houghton muck

Treatment (pounds per acre)		Number of 50-pound bags per acre			
N—P_2O_5—K_2O inches below seed)	N—P_2O_5—K_2O Broadcast	1954	1955	1956	Ave.
50—100—200	0— 0— 0	874	701	811	795
50— 0— 0	0—100—200	781	461	549	597
50—100— 0	0— 0—200	935	752	745	811
50— 0—200	0—100— 0	783	518	581	627
0—100—200	50— 0— 0	821	692	711	741
0—100— 0	50— 0—200	800	741	583	708
0— 0—200	50—100— 0	669	355	529	518
0— 0— 0	50—100—200	557	241	458	429

ed bands and not mixed with the soil. Mixing with the soil tends tie up the phosphate in a form unavailable or very slowly available plants.

Broadcast method of application.

This is the least efficient method of applying phosphate fertilizer. case of severe wind erosion a large proportion of the fertilizer may lost. The method has a desirable feature in that the equipment simple and the fertilizer can be applied rapidly. The inefficiency of e broadcast method may be compensated, in part, by the ease of plication and by better distribution of farm labor. Broadcast applitions of potash have proven equally as effective as band applications.

Drilled in.

Fertilizer drilled in is usually applied with a grain drill which aces the bands about 7 inches apart and places the fertilizer om 3 to 4 inches deep. This is a good method to use for supplemental applications for many crops and as a means of applying ferizer for all those crops that do not respond to band placement of rtilizer near the seed. Experiments have shown that placement of rtilizer by this method often resulted in an increase in yield when mpared to applying fertilizer broadcast.

Contact with the seed.

Fertilizer is sometimes placed in direct contact with the seed. ecause of the large quantities commonly used on crops grown on organic soils, this method of application is seldom applicable except possibly on small grains. Nitrogen and potassium salts are especially injurious to small seedlings. Certain minor element carriers such as copper sulfate and borax are often injurious when applied in contact with seed.

4. Band placement.

In general, the recommended placement of part of the fertilizer is in a band, 2 to 3 inches below the seed (Fig. 66). Some crops which develop extensive root systems early, such as potatoes and corn, should be fertilized 2 inches to the side of and about 2 inches below the seed. This may be a band on one side or both sides of the row. Results at the Michigan Muck Experimental Farm indicate that about 1,000 pounds per acre of a 5-10-20 fertilizer is the maximum amount that should be applied where crop rows are spaced 14 inches apart. With the wider row spacing the amount of fertilizer per acre that can be tolerated in the band is decreased proportionately. It is especially hazardous to apply large amounts of fertilizer to soils that are dry or where conditions are favorable for evaporation of moisture which will carry soluble salts to the surface. If

Fig. 66. Placing the fertilizer in a band 2 inches below the seed promotes earlier and more even maturity of onion bulbs, (background) as compared to fertilizer applied with the fertilizer attachment of a grain drill, (8 rows of late maturing onions in middle foreground).

ıdditional fertilizer is needed over that which can be placed in the ·ow, then it should be broadcast or drilled in prior to planting.

The fertilizer elements most needed as band applications are ɔhosphorus, and to a lesser extent, nitrogen. Experimental results ;how that if the nitrogen and phosphorus are applied in the band ɔelow the seed, potassium can be broadcast without any yield re-luction. Similar data have been reported for small grains, sugar

TABLE 19—Fertilizer placement for muck crops

Crop	Remarks
3roccoli Cabbage Cauliflower Spinach Swiss chard Leaf lettuce	Drill in 7″ bands, 4″ deep before seeding or transplanting. For cabbage or cauliflower on muck well supplied with moisture, 400 to 500 lbs. per acre can be applied in row 4″ deep before or at transplanting. Spinach responsive to band fertilization. All crops responsive to nitrogen side-dressing.
Head lettuce	Place fertilizer 2″ to 3″ below seed. Heavy fertilization increases tip-burn. Use little fertilizer if well fertilized previous years.
Celery Radishes Table beets	Broadcast and disc-in or drill-in fertilizer. Celery usually requires 0-10-30 supplemented with nitrogen.
Onions	Drill-in or broadcast and disc-in a fertilizer high in potash such as 0-10-30 or 60% potash. Apply in row up to 800 lbs. per acre 2″ below seed of a high phosphate fertilizer such as 5-20-10. Top-dress with nitrogen if needed when foliage is dry.
Mint	Fertilizer needed to maintain stand, as well as to increase oil content. Fertilizer usually applied broadcast or drilled in.
Potatoes	Drill-in 7″ bands, 4″ deep or place up to 800 lbs. per acre beside row at planting time. Usually 3-9-27 or 0-10-30 made from sulfate of potash is recommended.
Carrots Parsnips	Drill-in 600 to 800 lbs. per acre in 7″ bands, 4″ deep or plow-down. Sow parsnips early for good yields.
Field corn Sweet corn	Apply in a single band 2″ to the side and 2″ below the seed level. Maximum possible with a split boot applicator is about 250 lbs. per acre. Also possible to plow down or drill in a fertilizer high in potassium and use in band a material high in phosphorus.
Grain Soybeans	Apply fertilizer in 7″ bands, 4″ deep.
Meadows Permanent pasture	Broadcast or drill-in.

TABLE 19—Concluded

Crop	Remarks
Reed canary grass	Adapted only for wet soils. Use 400 lbs. per acre of 10-10-10 fertilizer.
Sugar beets	Plow down or drill-in table salt and potash (60%). Apply in row away from seed a fertilizer high in phosphorus such as a 5-20-10. If all fertilizer goes in band 1" to side and 2" below the seed, then use 3-9-27, 5-10-20, 0-10-30 or similar grade.
Beans Cucumbers Squash Tomatoes	Drill in 7" bands, 4" deep or apply in bands 2" to the side and 2" below seed.

beets and corn grown on mineral soil. A small amount of nitrogen mixed with phosphate increases the recovery of applied phosphate by plants (136).

Many Michigan growers are using fertilizer placement equipment for cultivated crops. This equipment is built on a land roller with the fertilizer placement applicators mounted ahead of the roller and the seeding units located to the rear of the roller. Additional units are sometimes attached for the purpose of seeding an intercrop of small grain. One objection to this equipment is that it leaves the ground very smooth and subject to wind erosion. The use of some cultivator hooks between the planted rows helps overcome this objection.

5. Foliar application.

The fact that plants can absorb nutrients through the leaves has been demonstrated by many workers. There are two problems to consider:

(1) How much of the requirement of any plant for any particular nutrient can be taken in through the leaves?

(2) How practical is the application of this method to the overall fertilizer program when timeliness and extra labor costs are considered?

Foliar application is more applicable for minor elements than for major elements, because of the small amounts required by the plant.

Efficiency in the use of minor elements such as manganese that is asily fixed in the soil can be greatly increased by leaf feeding. Foliar pplications of many of the plant nutrients can be applied in con-ınction with the regular pesticide program. In order to correct ıagnesium deficiency in certain varieties of celery (Fig. 67), it is ecessary that the magnesium be applied as a spray. Soil applica-ions of 2 tons or more per acre of magnesium sulfate have failed to orrect the deficiency symptom.

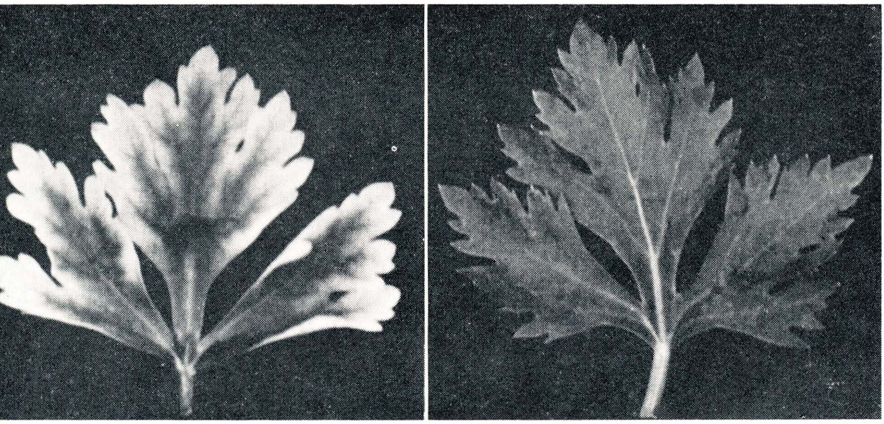

Fig. 67. Magnesium deficiency in Utah 10B celery illustrated by the leaflet n the left as compared to a normal leaflet on the right.

It is suggested that when foliar applications of plant nutrients re to be applied that the toxicity of the particular carrier and the olerance of the crop itself should be thoroughly ascertained. The pplication of nutrients in a spray is more efficient than when applied s a dust. It is difficult to incorporate certain materials into dust and naintain uniformity and good physical condition.

. Sidedressing and topdressing.

Fertilizer may be applied either as a side dressing or top dressing fter the crop has been established. Many growers follow the prac-ice of applying part of the fertilizer at planting time and part as a idedressing. Data obtained at the Michigan Muck Experimental 'arm have not shown that split applications of phosphate and potash re better than applying all at planting time. Nitrogen materials pplied as a sidedressing may be helpful especially under wet condi-ions. Minor elements can be applied as a supplemental application if the condition of the plant indicates their need. Many crop failures have been averted by topdressing or sidedressing when conditions indicated a nutrient problem.

Fertilizer in the pelleted form is generally available. If applied as a topdressing when the foliage of the plant is dry, very little injury will result. If the fertilizer tends to stick to the plant, it may be necessary to follow the application with a harrow or some other drag equipment to knock off the pellets. Mint is often fertilized in this manner. An airplane can be used for applying supplemental nitrogen when the soil is too wet to permit the operation of ground equipment.

SOIL TESTING[7]

Undeveloped organic soils are usually low in available phosphorus and potassium. Changes in fertility levels brought about by application of fertilizer can be measured by soil tests. They are a valuable diagnostic aid in determining whether crop production has been limited because of a low or unbalanced fertility level. Routine soil tests should include pH, phosphorus and potassium. The nitrate test may be advisable under certain conditions, especially if a growing crop is to be sidedressed. By using more elaborate methods one can also determine magnesium, calcium, iron, aluminum, boron, manganese, chlorides, sulfates and copper.

Analysis of water, salt or dilute acid extracts are generally used in soil tests. Two forms of soil nutrients are recognized: 1) the immediately available or "active" form, and 2) the fixed or less soluble form often designated as the "reserve".

Several soil testing methods are used. The carbonic acid extraction and water extracting methods have worked out satisfactorily in Florida Everglades soils (66). Workers in New York use a sodium acetate-acetic acid extracting solution buffered at pH 4.8. In Ontario, Canada, a press has been used to extract the soil solution (63) for organic soils. Data in Tables 20 and 21 show the effect of soil fertilization on the amount of extractable phosphorus and potassium when soils were extracted with three different reagents. A good correlation with similar sampling variabilities was found. (See Tables 11 and 12 for yielding ability.)

Soil test results obtained in the fall are usually higher in content

[7] See Fertilizer recommendations for Michigan crops, Extension Bulletin 159, for more specific information.

TABLE 20—The influence of extracting reagent, fertilizer treatment, and depth of sampling on the amount of extractable phosphorus. (Houghton muck) Plots fertilized and cropped for 10 years before sampling

Pounds per acre annually P_2O_5—K_2O	Extracting reagent: 0.018N CH_3COOH Spurway active			0.135N HCl Spurway reserve			0.1N HCl 0.03N NH_4F Bray P_2		
	Sampling depth in inches								
	0-6	6-12	12-18	0-6	6-12	12-18	0-6	6-12	12-18
	(p.p.m. of phosphorus)								
0— 0	5	3	1	12	11	6	43	13	6
50— 50	11	4	3	37	16	8	68	27	8
100—100	22	5	2	101	15	8	112	15	10
200—100	47	6	3	202	26	15	221	26	13
200— 0	70	6	1	240	60	11	330	56	12

Data from Bigger, et al. (5).

than those from spring sampling, although the effect of sampling on the phosphorus test is much less than that on potassium.

In general grasses and soybeans grow normally on moderate fertility levels. Celery, on the other hand, requires very high levels.

TABLE 21—The influence of extracting reagent, fertilizer treatment, and depth of sampling on the amounts of extractable potassium. (Houghton muck) Plots fertilized and cropped 10 years before sampling

Pounds per acre annually P_2O_5—K_2O	Extracting reagent: 0.018N CH_3COOH Spurway active			0.135N HCl Spurway reserve			23% $NaNO_3$ Bray		
	Sampling depth in inches								
	0-6	6-12	12-18	0-6	6-12	12-18	0-6	6-12	12-18
	(p.p.m. of potassium)								
0— 0	10	13	14	68	66	42	30	20	8
100—100	46	19	11	124	56	41	123	14	7
100—200	87	34	21	201	92	72	209	38	25
100—300	210	62	45	406	207	89	398	158	75
0—300	340	133	119	399	227	173	540	410	180

Data from Bigger, et al. (5).

Tables 22 and 23 show fertilizer recommendations based on the fertility requirement of different crops.

The following soil test method was used (182): One level teaspoon of air-dried (approximately 1.3 grams) was added to 20 milliliters of 0.018 normal acetic extracting solution. One-fourth gram of carbon was then added and the mixture shaken for 1 minute. The chemical analysis was made on the extract and to convert to pounds per acre, the values in p.p.m. in solution were multiplied by 8. The use of volume instead of weight measurements partly correct for differences in soil densities and moisture content.

TABLE 22—Phosphate fertilizer recommendations for muck crops, based on available soil phosphorus using the Spurway "active" method (0.018N acetic acid extractant)

Pounds available soil phosphorus per acre				Pounds P_2O_5 per acre recommended
			1	250
			4	200
			8	175
		1	12	150
		5	16	125
	1	10	20	100
1	5	15	24	80
5	10	20	28	60
10	15	24	32	40
15	20	28	36	20
20+	25+	32+	40+	10(*a*)
Barley	Alfalfa	Asparagus	Cauliflower	
Blueberries	Beans	Broccoli	Celery	
Clover	Carrots	Cabbage	Onions	
Corn	Cucumbers	Endive		
Grass	Horse radish	Lettuce		
Oats	Mint	Potatoes		
Rye	Parsnips	Pumpkins		
Soybeans	Peas	Spinach		
Sudan grass	Radishes	Squash		
Wheat	Sugar beets	Table beets		
Pasture	Sweet corn	Tomatoes		
	Turnips			

(*a*) Starter fertilizer for transplants and new seedings only.
To use this table, look for the crop grown. Then find position of the approximate soil test in the same column above crop listing. To determine amount of phosphate fertilizer needed, follow line to right column and read figure just opposite soil test.

EXAMPLE: Recommend 80 pounds per acre of phosphate for broccoli if soil test is 15 pounds per acre. If no soil test is made and soils are low in fertility, use amounts suggested for 5 pounds of available phosphorus.

Recommendations in this table assume the proper placement of fertilizers.

TABLE 23—Potash fertilizer recommendations for muck crops based upon soil tests using "active" method (0.018N acetic acid extractant)

Pounds available soil potassium per acre					Pounds K_2O per acre fertilizer recommended
				50	600
				125	500
			25	200	400
			100	250	300
		50	130	300	250
		90	175	350	200
	25	125	200	400	160
25	50	150	225	450	130
50	75	175	250	500	100
75	100	200	280	520	80
100	130	225	310	540	60
130	160	250	340	560	40
160	200	280	370	580	20
200+	240+	320+	400+	600+	0
Barley Blueberries Grass Oats Rye Pasture Soybeans	Beans Clover Corn Mint Peas Sudan grass Sweet corn Turnips Wheat	Alfalfa Cabbage Carrots Cucumbers Endive Horse radish Lettuce Parsnips Pumpkins Radishes Spinach	Asparagus Broccoli Cauliflower Onions Potatoes Sugar beets Table beets Tomatoes	Celery	

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 reserves can change greatly. Leaching may be serious following flooding or heavy rainfall.

Soil Sampling

Reliable soil tests depend to a great degree on how accurate the sample represents the area being tested. Equipment needed for collecting samples includes a clean bucket for mixing, pint jars or ice cream cartons, and a spade or sampling tube. Composite samples should be taken (0-6 inch depth) consisting of 10 or more borings taken at random from each area. On an undeveloped field, sample each area having different types of vegetative cover. A sample from a uniform area may be representative of 10 acres. Samples from small areas not representative of general field conditions should be avoided.

ADAPTED CROPS

Some crops, such as sweet potato, pepper, eggplant, melon, and tomato, are not well adapted when grown on organic soils primarily because of the frost hazard. Some vegetables that do well if properly managed are potato, onion, carrot, parsnip, cabbage, cauliflower, table beet, sweet corn, lettuce, radish, and spinach. The information shown in Table 24 gives some variety and seeding recommendations for crops grown in lower Michigan.

Some of the adapted field crops are corn, sugar beet, mint, and small grain used for summer pasture. A large proportion of the organic soils in Michigan is used for hay and pasture production. Unfortunately, much of the hay land is in native grass, poorly drained and not fertilized. Well managed pastures can carry two to three animal units per acre during the growing season. The legume in legume-grass stands is difficult to maintain with the possible exception of alsike clover because of winter killing of the legume and competition of the grass.

Fig. 68. Curing onions in crates on a Michigan muck farm. Crates can be decked for further curing or moved to a storage. On far right onions are stored in large pallet boxes covered with waterproof paper. Onions are a crop well adapted for organic soils.

TABLE 24—Adaptable crops; suggested varieties, time, depth and rate of seeding for Lansing, Michigan area

Crop	Recommended varieties	Time of planting in field	Rate of seeding or plants per acre	Distance between rows (inches)	Distance between plants (inches)	Depth of planting (inches)	Comments
Asparagus	Mary Washington	April 10 to May 10	3 or 4 lb. (seed)	48-84 16-20 (seed)	12-18 2-3 (seed)	6-8 1-1.5 (seed)	Spears susceptible to wind and frost damage. Muck soil good for crown production.
Barley	Mars (Spring)	April 20 to May 15	4-5 pecks	7	..	1.5-2.0	Lodging, weeds could limit production.
Beans	Field: Michelite or Sanilac Snap: Tendergreen Contender Black Valentine	May 20 to June 15	Field- 50 lb. Snap- 60 lb.	24-32	1-2	2	Beans are easily frosted. Responsive to manganese fertilizers.
Blueberries	Jersey (late) Earliblue or Bluecrop (early)	April	..	120-144	36-50	..	Preferred pH is between 4.0 to 5.0 Water table 15-20 inches. May need to use cover crops in late summer to lower soil nitrogen content.
Broccoli	Italian green sprouting	June 15 to July 1	12,000	32-36	15-20	0.8-1.0	

TABLE 24—Continued

Crop	Recommended varieties	Time of planting in field	Rate of seeding or plants per acre	Distance between rows (inches)	Distance between plants (inches)	Depth of planting (inches)	Comments
Cabbage	Marion Market, Racine Market, (Mid-season) Ferry's Hollander (late)	May 1 to 20 (early) June 15-July 10 (late)	14,000	28-36	10-18	0.8-1.0	Direct seed if seed is plentiful and not costly.
Canary grass	Northern strains	August (fall) April (spring)	5 lb.	..	..	0.3-0.6	Recommended only for poorly drained fields.
Carrots	Royal Chantenay or Long Chantenay (processing) Gold Pak or Nantes (fresh market)	April 15 to June 15	2-3 lb.	18-24	1-2	0.5-0.8	Plants easily burnt-off if planted late.
Cauliflower	Super Snowball, Snowball Imperial or Snowball X	June 15 to July 1	12,000	32-36	15-20	0.8-1.0	Fall maturing crop is preferred to summer crop. Boron fertilizer needed.
Celery	Utah 52-70, Utah 16, Green Lite (green) Cornell 19, Resistant Golden Plume (yellow)	April and May (early) June (late)	40,000	28-36	4-8	..	Plants are started in the greenhouse or bed 10 weeks before transplanting. Celery requires a moist soil.

Field corn	85 to 100 day hybrids	May 15 to June 1 (mature)	20,000	36-42	6-10	2.0-2.5	Use good standing hybrids. Organic soil well suited for silage corn.
Cranberries	Early Black, Howes, Bugle, McFarlin	Spring	..	6-8 inch vines pressed into sand	..	..	Cover acid peat with sand. Have water control so as to flood field if danger of frost. Cost may exceed $4,000 per acre.
Cucumbers	Marketer (slicing) scab and mosaic resistant pickles such as Wisconsin SMR-12	May 25 to June 15	Usually drilled and thinned	48-60	6-10	0.8-1.0	Avoid excess nitrogen and frosty locations.
Lettuce	Great Lakes 659, Cornell 456 (head) Big Boston (butterhead) Bibb	April 1 to July 10	2-3 lb.	16-24	14-20	0.5-0.8	Grown in cool areas. Brown peaty soils preferred. Aster yellows is a serious disease.
Oats	Clinton 59 or Clintland	April 15 to May 15	2.5 to 3 bu.	7	..	1.0-2.0	Generally not a profitable grain crop. Lodging and weeds are problems. Suitable for grass hay or pasture.
Onions	Downing, Brigham, Epoch hybrid, Elite hybrid, Southport red, Southport white, White Portugal, or White Ebenezer (for sets)	April 10 to May 15	3 to 4.5 lb. (yellow) 5 to 6 lb. (white) 60 to 80 lb. (sets)	14-24	0.5-2	1.0	Young plants easily damaged by wind.
Parsnips	Model Hollow Crown	April 10 to May 10	4 lb.	18-24	..	0.8-1.0	Roots easily damaged by root-knot, nematodes.

TABLE 24—Concluded

Crop	Recommended varieties	Time of planting in field	Rate of seeding or plants per acre	Distance between rows (inches)	Distance between plants (inches)	Depth of planting (inches)	Comments
Peas	Maragreen, Victory Freezer, Thomas Laxton	April 20 to May 15	180-240 lb.	7	1-2	1-1.5	Avoid frosty areas.
Peppermint	English	November, April or May	..	30-36	6-10	2-3	Mint is started from roots or from transplants.
Potatoes	Sebago, Katahdin, Tawa, Cherokee, Irish Cobbler	May 1 to May 25	20-30 cwt.	30-36	6-12	2-3	Under adverse soil conditions, "B" size certified seed is preferred.
Radishes	Cherry Belle, Comet, short top Scarlet Globe	April 15 to Sept. 1	10 lb.	8-10	0.5-1.0	0.5-1.0	Requires about 21 to 25 days to reach marketable size.
Rye	Balbo Rosen	September October	1-1.5 bu.	7	..	1-2	Used for cover crop and for wind breaks.
Soybeans	Flambeau (early) Norchief Ottawa-Mandarin (late)	May 20 to June 10	50-70 lb.	18-32	1-3	1-2	Seed easily injured by fertilizer. Good crop for conditioning new land.
Spinach	Nobel, Bloomsdale, Viking (Spring) Hybrid 7, Virginia Savoy (Fall)	April 10 to May 10 July 15 to August 15	10-15 lb.	16-20	0.5-2.0	0.5-1.0	Spinach leaves are easily shredded when harvested.

Sudan grass	Piper	May 20 to June 20	20-30 lb.	7	. .	1.0	Used both for summer pasture and for green manure.
Sugar beets	U. S. 400	May 1 to May 20	20,000 10-15 lb. (whole seed)	24-36	8-12	1.0-1.5	Need phosphate near seed to help prevent "black root".
Sweet corn	North Star (early) Carmel-cross, Seneca Chief, (late) Golden Security (shipper)	May 10 to June 15	18,000	30-40	8-10	2.0	
Table beets	Detroit Dark Red, Early Wonder	May 1 to July 15	15 lb.	16-24	1-2	1.0-1.5	Need boron to prevent black spot or girdling.
Turnips	Purple top White Globe	April 15 to May 20 July 1 to August 10	1-2 lb.	14-16	2-3	0.5-1.0	
Wheat	Cornell 595 Yorkwin Henry	Sept. 15 to October 1	1.5 bu.	7	. .	1-2	Lodging and winter killing can be serious.

In a feeding experiment on reed canary grass, steers did not make satisfactory gains regardless of management—see Fig. 69. In another feeding test, comparing canary grass and northern smooth brome grass, lambs gained an average of 0.35 pound per day on canary grass and 0.45 pound per day on brome grass. The carrying capacity of the canary grass, however, was greater. It averaged 250 pounds per pasture season and the brome grass averaged 226 pounds.

If the hay crop is spring sown for southern Michigan, it is advisable to sow about 3 pecks of spring wheat per acre to serve as a companion crop. If the land is weedy, it is preferable to summer fallow until mid-August and then seed without a companion crop.

A 5- to 6-pound per acre rate of seeding for brome grass is suggested in a grass-legume mixture, 2 to 3 pounds of brome or timothy, 5 to 6 pounds of alfalfa, 2 pounds of alsike and ½ pound of ladino clover per acre are adequate. Because of the differences in the size of the seed, brome grass should be sown separately from the legume. Reed canary grass at the rate of 5 pounds per acre is recommended on land that is too wet for brome grass. A grain drill set to deliver 10 to 12 pounds per acre of alfalfa seed will deliver approximately this rate of seeding for canary grass.

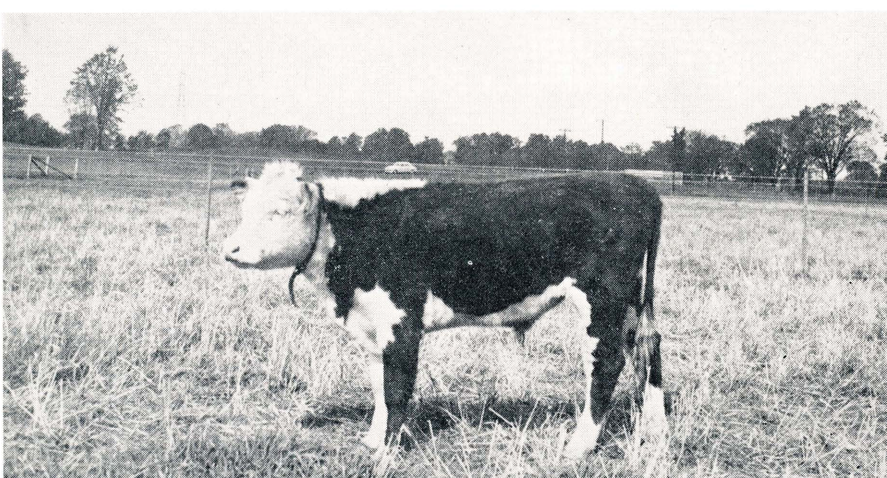

Fig. 69. A Hereford calf which did not gain in 5 months on reed canary grass pasture even though there was plenty of feed. Cattle were not thrifty in appearance. Fertilizing with 500 pounds of 0-10-30 per acre or with fertilizer plus manganese and copper did not remedy the situation. Farmers report conflicting results regarding the value of reed canary grass pastures (198).

There is interest in growing grass on organic soils and selling the sod. Merion and Kentucky bluegrass are the recommended varieties. Merion bluegrass is more likely to produce a beautiful turf. It produces a dense, dark green turf which resists weeds, especially crabgrass. Merion bluegrass is fairly resistant to injury from leaf spot disease, but is attacked by cereal rusts and fading out disease *(curvularia)*. Kentucky bluegrass is maintained successfully with less fertilizer than is required for Merion bluegrass. In general, the best time to seed is August on a field which is smooth and firm. The seed is usually sown at the rate of 20 to 40 pounds per acre with a Brillion seeder or other suitable equipment. Seed planted in August should be ready for sale as sod the following July. Harvesting of the sod may be accomplished with a power cutter. The usual size of strip is 12 to 18 inches wide and 4 to 8 feet in length. A convenient size strip is 16 inches by 81 inches, which contains 1 square yard.

Cranberry production is a specialized industry found in New Jersey, Washington, Wisconsin and Massachusetts. Cranberries are grown in beds on acid peats which have been covered with a layer of several inches of sand. The beds must be perfectly level with adequate ditches, bulkheads for rapid flooding and draining, plus a large and constant water supply. This is usually in the form of reservoirs several times larger than the area under cultivation. Flooding is necessary to prevent frost damage.

Reforestation has received considerable attention in Europe during the last 40 years. The reason is the need for timber in such countries as Great Britain and Ireland and a low selection of adaptable agricultural crops in the northern countries. About 14.7 million acres of organic soils in Finland grow forests (88). Of this acreage, 6.6 million acres are productive and 7.9 million acres are poorly productive forest. In addition, there are 9.6 million acres of wasteland. Drainage could improve the poor forest area and expand forest into the wasteland. Trees, like field crops, need aerated soils. Low grade trees require a water table at least 18 inches below the surface while high grade trees require drainage to a greater depth. Other helpful practices are ridging and the use of phosphate. Windthrow is a danger on the deep peats. Some of the adapted forest species in Europe are ash, poplar, Sitka spruce, and Scotch pine. *Pinus contorta* is suggested for the severely exposed areas. The various peat types differ greatly in the success of reforestation. When adequately drained, reed (phragmite) peat offers excellent conditions for the growth of most species of trees. Reed peat is loose in structure and permits easier water movement and soil aeration than the other types. Reforestation is difficult on moss peats especially on highly decomposed Acutifolia moss peats.

The English Forestry Commission has prepared a good bulletin on tree planting (223).

COMMERCIAL USES OF PEAT

Many uses other than for agricultural purposes have been found for organic soils. Some of these uses are:

1. Gasification of peat for power.
2. Production of peat briquettes for fuel.
3. Packing and insulating material.
4. Production of charcoal to be used as an absorbent in filter beds.
5. Fertilizer filler and also as a source of organic nitrogen.
6. Distillation to obtain many chemicals such as ammonia, acetic acid, alcohol, waxes, pitch, and tar.
7. Imparting characteristic odor for certain kinds of whiskey.
8. Clean sphagnum peat has been used as an absorbent for surgical pads and dressings.
9. Certain deposits in Europe are popular as places for health baths.
10. As litter and bedding material.
11. Acid sphagnum peat may be shredded and used for starting plant cuttings and growing seedlings.
12. Increasing the organic matter content of mineral soils and for improving texture.
13. Top dressing of lawns and flower beds.
14. Press peat pots for transplants.

The world production of peat for commercial uses in 1952 amounted to nearly 54 million tons (23) and 70 million in 1957.[8] In some countries peat is the primary source of fuel. The high cost of labor in North America has not made it profitable for peat to compete with coal, oil, and water power as sources of energy.

[8] Mineral Market Report, No. 2769, U. S. Dept. of Interior Bureau of Mines.

Peat is often steamed so as to destroy weed seeds and soil borne diseases. This treatment will help break down the more resistant organic matter. Steaming increases the ammonia content of the soil which can be toxic to small seedlings. Sterilization greatly increases the amount of available manganese, which also can be toxic to plants.

Sphagnum peat is recommended for seed germination and for rooting cuttings. The preferred peat is Cymbifolia group (larger leaved sphagnum). The pH should not be below 4.0. Sphagnum is a particularly desirable material since damping-off and other plant disease organisms are usually not a problem. Furthermore, the high moisture holding capacity of the peat eliminates the need for frequent watering. Plants, however, need occasional watering with an all-soluble dilute fertilizer solution. Such a solution can be made by dissolving one level tablespoon of a 10-20-10 fertilizer in one gallon of water.

Peat may be used in building new lawns and should be applied at the rate of ½ cubic yard or one bale for each 1000 square feet, or a surface application of 1 to 2 inches. The peat is then worked into the soil for a depth of 6 inches. Mucks and peats by themselves are not suitable on the surface because the turf would easily tear. The peat will also become finely divided and will easily blow or wash away. Peats used for lawns should have a pH between 4.8 to 7.0. An acid peat (pH 4.0 to 4.8) can be used if the mineral soil is nearly neutral or alkaline in reaction and the proportions of mineral soil to peat are greater than 3 to 1 by volume.

Peat is used in many potting mixtures. The following mixtures by volume have worked out well in the production of roses: Two parts loam soil, 1 part peat and 1 part sand. To 1 bushel of the soil mixture is added 1 quarter pound of fertilizer containing (by weight) 1 part ammonium sulfate, 2 parts of 20 percent superphosphate and 1 part potassium sulfate.

Certain plants such as azaleas, camellias and rhododendrons require acid soils for proper growth. The ideal mineral soil should have a pH between 4.5 and 5.5. Because the soil around buildings often contains plaster, calcareous subsoil and particles of limestone, it is advisable to use acid forming materials such as peat in the production of such plants. When individual plants are used they are placed in holes that have been fortified with a mixture of peat and acid forming fertilizers. Organic fertilizers are also recommended. An excellent mixture is 1 bushel of acid peat, 5 pounds of cotton-seed meal, 1 pound of ammonium sulfate and 4 ounces of ferrous sulfate. This mixture is applied as a mulch around the plants during the winter.

Peats are often used as mulches around conifers, roses and other ornamentals. In addition to the benefits previously listed, peats used as mulches help to keep plant roots cool in the summer and warm in the winter. The dark color of the peat mulch enhances the esthetic value of the planting.

Glasshouse operators in Europe find that acid fibrous peats (pH 4.0 to 5.0) are most helpful in vegetable production. Acid peat is especially needed when "hard" water is used for irrigation. It is more likely to leave the soil with a more favorable pH than when animal manures are used. Usually 1 or 2 inches of peat are spread on the surface. To prevent manganese deficiency to the crop, 30 pounds of manganese per acre is applied on the peat. After the cropping season is over, the peat is worked into the soil.

Peat Specifications

The value of peat depends upon a number of factors and its use. Moss peat absorbs and retains liquid more completely than other kinds of peat. Good commercial peat is usually fibrous, free of wood, low in weed seed count, has been screened or shredded and is low in ash and moisture. Sedimentary peats, including materials found in the bottom of ponds or lakes, are generally not recommended. The pH for preferred woody and grass peat ranges from 5.0 to 6.5. Undecomposed moss peat can be as low as 4.0. Acid peats should be used for acid loving plants such as blueberries, azaleas, rhododendrons, and most conifers.

When evaluating peat material, the buyer usually wants to know: 1) Kind of peat (sedge, moss, humus[9] 2) acidity or alkalinity (pH), 3) percent organic matter, 4) percent moisture, and 5) percent ash humus,[9] content.

Additional properties that may be requested are the nitrogen content, physical characteristics which describe texture, color, and the moisture holding capacity.

The moisture content of peat varies and should be below 60 percent. Sales are often made on the basis of volume; by the cubic yard, cubic foot, or bushel. Volume measure partly corrects for differences in moisture, but does not correct for compaction or shrinkage on

[9] The term "humus" is used to describe a peat that is fairly well decomposed and consists of a mixture of grass, sedge, woody and moss peat.

drying. It is not practical to dry peats excessively as this will increase cost. Furthermore, certain peats should not be too dry as they are difficult to rewet. The example below illustrates how moisture affects the amount of organic matter in two samples of the same peat.

	Peat No. 1	Peat No. 2
Percent organic matter	60	30
Percent ash	4	2
Percent moisture	36	68
Total	100	100

Anyone considering entering into the peat business should become familiar with Federal Trade Commission rulings and also with state laws governing sales of soil amendments. A Federal Trade Commission ruling effective as of January 13, 1950 states that peat shall not be sold as moss peat if it contains less than 75 percent of plant material derived from mosses (58).

Soil Preparation

Market possibilities and outlets should be investigated before attempting the sale of peat. Some producers have rather crude operations. They can make a satisfactory income by giving the consumer more individual attention in the proper use of the peat. Large opera-

Fig. 70. The construction of a road over bog to excavate peat. Fill dirt is placed over brush and logs to a depth of 3 to 4 feet.

tors, on the other hand, have to use efficient mechanical mining operations. Dragline operations are seldom competitive because of the problem of getting the peat air-dried.

Drainage and clearing the land of brush and roots are the first steps required before peat is excavated. After draining, the land is usually plowed, which helps to loosen and dry the soil. The field then is disked several times to hasten drying and to break up large peat clumps. The roots and woody debris are removed. The loose soil is rowed by a triangular shaped wooden float. After further drying in the ridges, the soil then can be picked up by a tractor equipped with lift scoops, Fig. 71. The soil is placed on wagons or trucks and can be sold in bulk directly from the field or it can be further shredded and screened. The production of peat under this system is seasonal and can take place only during periods of favorable weather. Some operators store peat in piles outside or under a large shed. This permits sales to continue during the less favorable winter and spring seasons (Fig. 72). Moisture content in reed-sedge peat should be 60 percent or less to prevent heat charring in the pile.

Peat can be shredded by a forage chopper or by placing between two fast rotating drums equipped with heavy metal prongs. The shredded soil then is elevated to a vibrating machine that is equipped with a sloping screen, which separates out wood or coarse clods. The

Fig. 71. Loading field dried peat into railcars. It is hauled to packing shed or to the stockpile. Before loading, the peat was plowed, disked several times and then windrowed. Trucks usually are preferred to railcars. Photo courtesy of Michigan Peat Inc.

Fig. 72. Loading peat from stockpile. Peat is hauled into shed nearby where it is chopped, screened and packaged. Stockpile material is used when there are adverse weather or field conditions. Photo courtesy of Michigan Peat Inc.

mesh size of this screen is usually about one-half inch. The equipment may be so arranged that a truck can drive under the screen and collect the soil for bulk delivery. Peat sold in small quantities is packed in plastic containers. Quantities in 50 or 100-pound parcels are often sold in burlap bags lined with a plastic inner liner (Fig. 73). Moss peat is usually sold in bales that have an overall dimension of 36 x 22 x 23 inches.

Future Trends

The commercial use of peat as a soil conditioner will probably expand rapidly. Farmers and city people alike have recognized the need for organic matter. Garden clubs have found the subject of "organic farming" to be particularly fascinating. The automobile, modern highways, shorter "work week" and higher living standards have resulted in our present suburban home development. The people living in these areas want beautiful surroundings. They will use greater quantities of organic materials.

Organic soils will have to be handled as a natural resource. Prevention of fire and needless drainage are major conservation objectives. Because of the large acreage of organic soils found in the northern states, the value of undeveloped land will continue to be low. Wise development of the soil will include uses for agriculture, mining, wildlife, recreational and water storage.

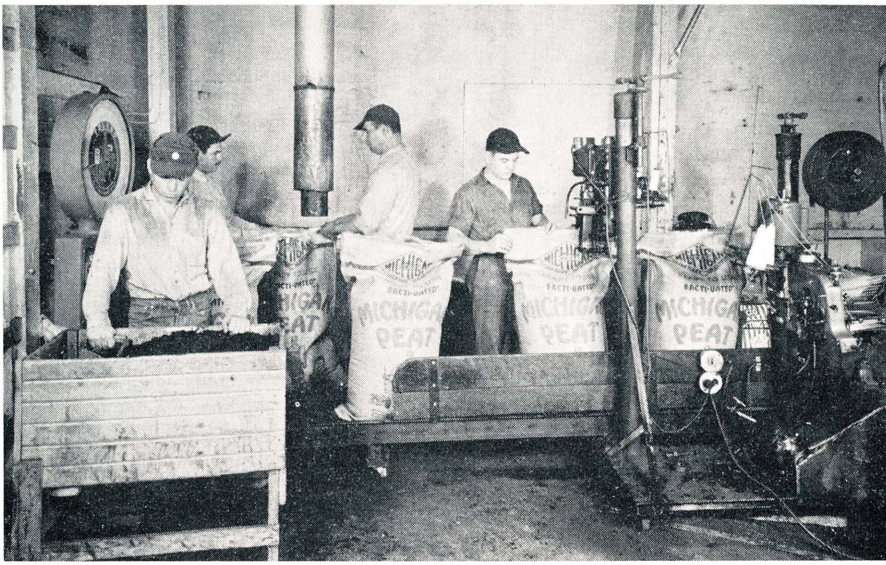

Fig. 73. Packaging field dried, screened peat into burlap bags lined with a plastic interliner. Photo courtesy of Michigan Peat Inc.

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