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Muck Soil Management *for* Onion Production

1,512 bushels from one prize-winning acre of muck

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COOPERATIVE EXTENSION SERVICE

EAST LANSING

CONTENTS

Muck Soil Management For Onion Production

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For the past decade an average of over 3.5 million 50-pound sacks of late onions has been produced annually on the muck soils of Michigan. This production has returned a gross income of approximately $5,000,000 annually.

Average values in Table 1 show that Michigan's acreage has been holding fairly constant since the early 1930's. The values also point

TABLE 1—Average late onion acreage in five-year periods in the United States, Michigan, and other states leading in onion production

	1920-1924	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954
Michigan	1,872	3,894	7,674	11,080	8,140	8,540	9,418
Ohio	1,686	5,782	4,930	2,490	1,152	744	880
Indiana	5,669	8,454	7,402	3,240	2,270	1,800	1,060
Wisconsin	1,023	1,168	1,020	1,192	1,654	2,030	2,700
Minnesota	1,406	1,902	2,080	3,150	3,812	3,970	4,560
New York	7,757	7,750	8,262	13,072	14,280	14,180	14,600
Total late crop for U. S.	42,000	49,000	53,000	55,000	58,000	62,000	60,000

out that Indiana and Ohio have decreased acreages. On the other hand, Wisconsin, Minnesota and New York have increased their acreages.

Certain insects and soil-borne diseases are known to be on the increase which, unless controlled, decrease yields. Some management practices, however, have increased yields. Figures as reported in *Agriculture Statisics* and *USDA Yearbooks* show that average yields were 380 fifty-pound bags per acre in 1919 to 1928, 350 in 1929 to 1938 and 420 in the 1939 to 1948 period. Potentially the average can be 600 to 800 bags per acre—if recommended practices are followed.

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Production of the mature onions has changed markedly since World War II from comparatively small to larger acreages. This change, no doubt, will continue to develop further as onion production becomes more mechanized. The modern present day equipment includes multiple unit seeders with fertilizer attachments, mechanical weeders and cultivators, sprayers, dusters, harvesters, and large storages with forced-air dryers.

SELECTION OF THE FIELD

Characteristics of muck soils, as a group, make them ideal for onion production. First, the moisture supply is generally ample for good yields. Second, the land is level, free from stones and easily cultivated. Third, the soil is relatively loose, thus permitting the bulbs to adjust themselves in the row, with less need for thinning. Practically all of the commercial onions produced in Michigan are grown on muck.

In selecting an area for the production of onions, one should consider the drainage conditions, the soil reaction (acidity or alkalinity)[3], the air drainage, wind protection, weed infestation and presence of soil-borne diseases. It is sometimes not advisable to attempt onion production on deeply burned, high-lime muck or on a newly broken peaty muck, as some of the above factors may present serious problems. If special management practices are used, however, most of these problems can be remedied.

PRODUCTION AND THE "pH" OF THE SOIL[4]

Although onions as a crop are rather sensitive to extremes of soil reaction, they produce well under a rather wide pH range. Thus, very good yields can be obtained with a soil pH of 4.8 and as high as 7.2—if the proper fertilizer mixtures and the proper minor elements are applied to the soil. When the soil pH is much below 4.8, the yield of onions is not likely to be satisfactory until lime has been applied. When the soil pH is much above 7.2, yields are likely to be considerably increased by the use of sulfur.

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[3]Directions for taking muck soil samples for testing can be obtained by writing the Soil Science Department, Michigan State College, East Lansing, or by contacting your county agricultural agent.

[4]The pH of the soil is a numerical method of expressing its reaction. A muck with a pH of 7.0 is neither acid nor alkaline. An alkaline muck has a pH greater than 7.0, while an acid muck has a pH less than 7.0. It is highly desirable that the soil reaction of newly reclaimed or unproductive muck be determined before the growing of onions is attempted.

Fig. 1. On this 4-acre field of Sweet Spanish onions in Ottawa County, a prize winning acre yielding 1,512 bushels was produced. (See front cover)

Fig. 2. On this impoverished muck, the fertilizer was put under the row—but was applied with a 6-row drill ahead of the seeders, with two 3-row garden tractors seeding behind it. Wherever the seed was not sown directly above the bands of fertilizer, the onions were very yellow, curled and dwarfed.

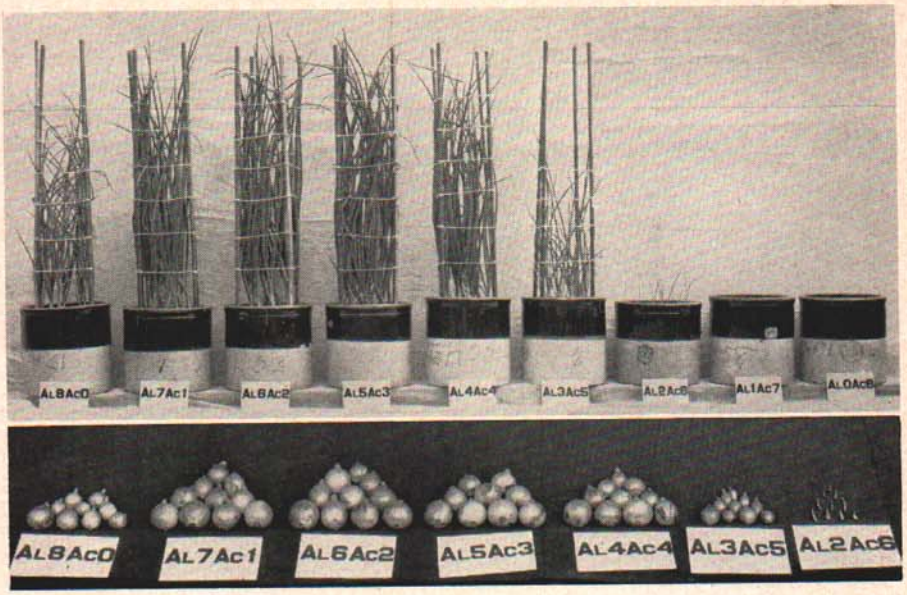

Fig. 3. Two mucks mixed in different proportions were placed in the above nine jar. The left jar received 8 parts alkaline muck; the second, 7 parts alkaline and 1 very acid. Continuing in order the parts received were, respectively, 6 and 2; 5 and 3; 4 and 4; 3 and 5; 2 and 6; 1 and 7; and the right jar all very acid.

In the lower picture are the mature onions from the seven jars which produced a crop. From left to right, the soil pH readings at harvest were 7.4, 6.5, 5.9, 5.3, 4.8, 4.3, 4.1, 3.9 and 3.8. In the same order the weights of bulbs in grams were 99, 257, 285, 247, 198, 46, 2, 0 and 0. No minor elements were used, but chemically pure phosphate and potash were applied uniformily to all jars, with nitrogen as required

Use of Lime

Lime should not be applied for onion production on muck soil unless the soil is strongly acid (pH 5.0 or less). When applied on mucks which are naturally well supplied with lime, it may delay maturity and increase the proportion of "thicknecks". Onion seed sown on unlimed, very acid muck may not germinate or, if germination takes place, growth is likely to be slow and the bulbs undersize. Reclamation of extremely acid muck for onion production may not always be advisable.

Since very acid muck soil is generally low in both calcium and magnesium, it is advisable to use a dolomitic limestone where lime is needed, rather than calcium limestone or marl. The limestone should be fairly fine, the "agricultural" grade generally being satisfactory. Although only from two-thirds to three-fourths as much hydrated lime

as of ground limestone is needed for the same permanent effect on the soil pH, its use generally cannot be recommended because of its greater cost.

Since the very strong acidity of a muck soil may extend to considerable depth and become even greater below the plowed layer, it is advisable to apply half of the amount of limestone, disk it in thoroughly, plow it down deeply, and then level the land and apply the other half and disk it in. The amount of limestone required depends on the pH of the plowed layer and of the underlying soil. From two to three tons per acre will be needed where the pH of the soil is around 4.5, while as much as 12 tons per acre may be required where the pH is around 4.0 and the acidity extends well into the second foot.

Occasionally muck soil will be very strongly acid in what would be the plowed layer and become somewhat less acid in the second foot. Under some conditions, it may be possible to correct the situation by deep breaking, preferably a year previous to the time of cropping. Again the soil pH may be satisfactory in the plowed layer but a very acid layer of 4 to 12 inches in thickness in the second foot will prevent root development, with the result that the crop matures undersize.

This situation is sometimes found on land that has produced onions for several years. Onion roots generally will not penetrate muck where pH is less than 4.7. In such a situation, it is generally best to plow the land to a depth of 18 to 20 inches with a large marsh-breaker to bring the very acid layer to the surface where the lime can be applied. If the marsh breaker does not get all of the acid layer, it may be necessary to make an application of ground limestone, disk it in and plow it down with the large breaker, and then lime the upturned surface.

Use of Sulfur

Alkaline muck soil is almost certain to give poor yields of onions, unless given special treatment. This is true whether the alkalinity is due to the burning of a high-lime muck at some recent or remote time, to the presence of marl within a short distance of the surface, to the application of unneeded lime in the soil surface, or to salts deposited on the surface from evaporating water from underlying alkaline springs. Sulfur applied on such muck will result in (1) greatly increased yields of onions, (2) earlier maturity, (3) increased root development, (4) increased disease resistance, (5) improved keeping quality, and

(6) improved color of tops and bulbs. (See Fig. 4.) The chief purpose of the sulfur is to acidify the alkaline soil and thus increase availability of the soil's manganese.

The amount of sulfur required will depend on the degree of alkalinity of the muck and on the depth to which the alkaline reaction extends. If the alkaline surface soil is underlain by muck with a pH below 6.0, deep plowing and thorough disking may correct the condition without the use of sulfur. If the pH is around 8.0 or above, it may be advisable to turn to other crops such as sugar beets, peppermint, cabbage and carrots, for several years before onions are grown.

On most alkaline mucks a sulfur application of from 250 to 1000 pounds is advisable. A total of 2000 pounds per acre in two or three applications may be required if the alkalinity extends to a considerable depth. Sulfur should be applied after plowing and leveling, and should be thoroughly disked into the soil. Sulfur should not be plowed under at the time of application, and the land should be plowed shallow the following years unless more sulfur is to be applied. Manganese is likely also to be needed if the soil pH is above 7.2.

On some mucks having a pH between 6.5 and 7.0, and occasionally down to 6.2, sulfur increases yield and improves quality of onions when applied at the rate of 100 to 250 pounds per acre. On soil underlain by marl, within a few inches of the plowed layer or extending into the plowed layer, additional sulfur may be needed each spring after plowing and leveling.

THE MINOR ELEMENTS

Of the five minor elements used on Michigan muck soils, copper, manganese and zinc are likely to be highly beneficial to onions when applied under proper conditions. The other two, sodium and boron (ordinarily applied as common salt and borax, respectively), have never in many trials produced any benefit to the onion crop. Salt is not injurious to onions when applied the preceding year—but a 1000-pound-per-acre application, made the same year the onions are sown, may cause some reduction in yield. Borax applied in the broadcast portion of the fertilizer is not likely to affect the yield but, if included in under-the-row fertilization, may reduce both stand and yield.

It is fortunate that Michigan's fertilizer law permits the inclusion of these minor elements in most of the muck soil mixtures. Growers should place their orders in advance in order to obtain delivery on

time. When manganese sulfate is included, delivery should be accepted shortly before the fertilizer is to be applied, since that material sometimes produces a "caking" of the fertilizer in storage.

Fig. 4. On this alkaline muck with pH of 7.6 (resulting from being burned over 40 years previously), a 1200-pound per acre application of 4-8-16 was applied uniformly on all plots. The plot at the left received no sulfur while the plot on the right was given 1000 pounds per acre disked in. In the upper picture note the difference in amount and type of top growth. The lower picture, taken 6 weeks later, shows the sulfured plot maturing while the unsulfured is as green as ever. The yields were 154 as compared to 518 bushels per acre in the year of application and 170 compared to 990 the following year.

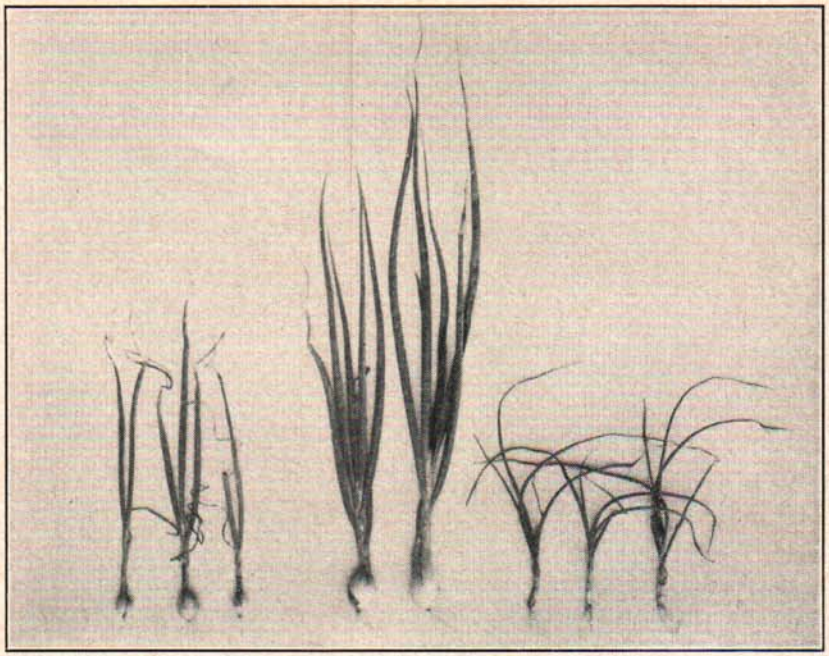

Fig. 5. The three onions on the left, with die-back of tops and premature maturity, were produced on a slightly acid, copper-deficient muck. The fourth onion from the left grew on the next plot, which received copper. The three onions on the right, produced on an alkaline area of the same muck, showed the typical curling of tops and delayed maturity indicative of manganese deficiency. The fourth onion from the right was also from the alkaline muck, but had received sulfur.

Use of Copper

Copper applied in an available form is likely to greatly increase the yield and improve the quality and color of onions on all acid muck soils—and to some extent on alkaline mucks. The copper may be in the form of sulfate, or oxide in finely ground condition, or it may be applied in the form of dusts or sprays. Trials on Michigan muck have shown that only the very slowly available, finely ground sulphide ore failed to give satisfactory results with onions.

Benefits from copper are much more evident in a hot dry than in a cool wet season, and are greater on a well-drained muck than on one having poor drainage. The greatest benefit from copper appears on those muck fields where onions have a tendency to die back at the tips during hot weather, and where the mature bulbs of the yellow varieties have a greenish-yellow rather than the desired yellowish-brown color.

Unless copper has been applied in the form of dusts or sprays in past years, it is advisable to make an initial application of 12 to 25 pounds of copper (50 to 100 pounds of copper sulfate) for onions, and to continue with at least half of these amounts annually until a total of 60 to 75 pounds of copper (equivalent to 240 to 300 pounds of copper sulfate) has been applied. With a possible exception of the more acid mucks, this total is likely to be sufficient for the life of the muck. If desired the whole amount can be applied broadcast in one year without injury.

Use of Manganese

Manganese deficiency in onions appears as a curling of the leaves so that the ends sometimes touch the soil. This is accompanied by a slow growth, a light color of the tops, and a delayed "bottoming" which results in a high percentage of "thicknecks". Manganese deficiency can be corrected either by the application of manganese sulfate or by the use of sulfur. Manganese is quicker in its action but must be used annually on alkaline muck while sulfur, over a period of years, is more economical, and generally more permanent in its effect.

On highly alkaline muck, manganese broadcast and disked in may gradually become unavailable within a few weeks after application. If the soil pH is above 7.5, it generally is advisable to use available

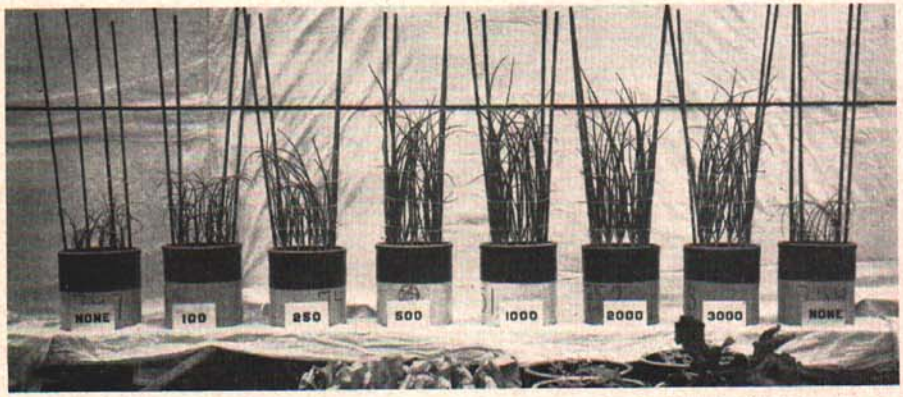

Fig. 6. These onions grown in the greenhouse on alkaline (pH 7.8) soil received manganese sulfate in amounts from none to 3,000 pounds per acre mixed thoroughly throughout the seven inch depth of soil. Yields increased with increase in rates up to the 1000-pound application and there was no injury evident from heavier applications. The same results could have been obtained with much less manganese in fertilizer banded 2 inches below the seed.

manganese in the row fertilization and to broadcast and disk in sulfur previous to seeding. Inclusion of the manganese in the row will result in its remaining available for a longer period of time. Application of 25 pounds of manganese (100 pounds of manganese sulfate) on the less alkaline and very slightly acid mucks, and twice that amount on the more alkaline mucks, is advisable.

Generally the first indication of manganese deficiency does not appear until the onions are a month to six weeks old, when the tops start curling. It is then impossible to apply sulfur effectively, but beneficial effects can be obtained by an application of 25 to 50 pounds of available manganese (100 to 200 pounds of manganese sulfate) as a topdressing. Onion leaves will absorb manganese rapidly when applied in a spray or dust. Manganese sulfate[5] can be applied in water-soluble form with beneficial results at the rate of one pound per 100 gallons spray where the soil pH is 6.0, two pounds where it is 6.5, three pounds where it is 7.0 and five pounds with a pH of 7.5 or higher. This should be used in addition to its inclusion in the fertilizer with soils of 7.0 or above. It is advisable to use a wetting agent in the spray. It can also be used in dust and can be included in spray or dust used for control of onion thrips and mildew.

The Use of Zinc

Zinc deficiency symptoms have been observed only on onions in Michigan and only on new muck for the first few years following reclamation. It is more likely to occur on muck with insufficient drainage than on properly drained soil. Before reclamation, the natural zinc present in a muck soil appears to be concentrated in the surface few inches. With the muck properly broken to a depth of 14 to 18 inches, a raw soil, low in zinc content, is exposed at the surface. Onions growing near the break between adjacent furrows may obtain sufficient zinc, but those on the crest of the furrow are likely to show zinc deficiency.

This deficiency appears as a dwarfing of the plant, with a greyish-yellow color instead of the normal green, and tops that become curled and wavy. When the roots of the dwarfed onions finally have penetrated the furrow slice, they obtain zinc from the original topsoil and suddenly recover their normal color and erect growth. This delay in recovery is usually sufficient so that complete maturity of the bulbs is prevented. Poor drainage is likely to slow up the penetration of the roots and thus delay the recovery.

[5]Use only water-soluble manganese sulfate or material that has passed a 325-mesh screen.

On new muck lands it is advisable to include in the broadcast portion of the fertilizer 8 to 16 pounds of zinc annually for two to four years, or until the land has been plowed following the first breaking. There is probably sufficient zinc deposited from the air in this industrial state so that there will be no need for further zinc applications. (Zinc sulfate is the material used in fertilizers as the carrier of zinc.)

FERTILIZATION

Although muck soil is naturally infertile, it is generally highly productive when properly fertilized. All three major fertilizer constituents—nitrogen, phosphate, and potash—are likely to be required for the production of onions. The proper fertilizer analysis and the proper rate of application depends on the soil reaction, the drainage conditions, the past fertilization, and the method of applying the fertilizer.

Recommendations for the fertilization of onions under varying conditions of soil and moisture are presented in Table 2. Ranges in the rates of application are given. In the use of lime and sulphur, the rate depends on the pH of the soil while, in the case of fertilizer and minor elements, the exact amounts required depend on the results of the soil tests and on past fertilizer and minor element usage.

Fig. 7. These twisted, curled and dwarfed onions, the first crop in this newly reclaimed field, were suffering from zinc deficiency.

In general, the higher the pH (6.7 or higher) of the soil and the poorer the drainage, the greater should be the proportion of phosphorus to potassium in the fertilizer mixture. Thus with a soil of fairly high pH, poor drainage and low fertility—as frequently found in newly reclaimed fields—a 3-18-9 at the rate of 2,500 pounds per acre may be required in order to build up the phosphorus content of the soil and insure proper maturity of the crop. After a couple of years of this fertilization, a 6-12-12 mixture will probably produce better results if the drainage is still poor, or a 4-16-16 mixture if the drainage has been improved. If broadcast, an application of 1,400 to 1,800 pounds of the former, or 1,100 to 1,300 pounds of the latter is likely to be needed.

After about four years of this fertilization, the phosphorus is likely to be built up in the soil so that better results will be obtained with a higher potash mixture, such as 5-10-20, when 1,000 to 1,200 pounds per acre should be applied. If half of the fertilizer is applied in the row 2 inches below the seed, the total application can be reduced safely to about two-thirds of the above amounts. When part of the fertilizer is applied in the row and part is drilled before seeding, it is preferable that the drilled portion be applied at an angle to the direction of the onion rows.

Onions probably are the most responsive vegetable crop to the application of fertilizer in a band directly under the row. Ordinarily from one-third to one-half of the fertilizer can be saved by using the row application, rather than the drilled-in application in 7-inch drills without respect to the row.

The amount of fertilizer that can safely be applied under the row depends upon the row spacing, the fertility level in the soil, the drainage conditions, and the depth below the seed at which the fertilizer is placed. If the soil is inclined to be droughty, but contains a good supply of residual fertilizer, it may be necessary to keep the fertilizer application in the row down to 300 to 400 pounds at a depth of two inches. However, it could be increased to around 500 pounds at a depth of 2½ inches below the seed, and 600 to 700 pounds if it is placed nearly 3 inches below. If the soil is not excessively drained and is not exceptionally high in fertility, it is safe to use 600 to 800 pounds per acre at a depth of 2 inches below the seed and 800 to 1000 pounds at a depth of 2½ inches below.

In the use of a seeder-fertilizer drill for putting fertilizer underneath the row at seeding, care should be taken to see that all adjust-

TABLE 2—Fertilizer, lime, sulfur, copper, manganese, and zinc recommendations for onions grown on muck land

Description of Muck				Lime, Sulfur and Minor Elements (Pounds per Acre)			Fertilizer Analysis and Application Methods (Pounds per Acre)		
pH of soil	Depth of muck	Time since reclamation	Condition of drainage*	Ground limestone or sulfur	Copper (Cu.) or Manganese (Mn)	Zinc (Zn.) (2 to 4 years)	With all broadcast or drilled in before seeding	All fertilizer applied in a row 3 inches below the seed	Part of fertilizer broadcast (Br.) and part in row (R.) 2 inches below seed
5.0 to 6.5	Deep and medium	Newly reclaimed	Good	Application of limestone may depress yields. With pH of 6.0 to 6.5, 100 to 300 lb. of sulfur may prove beneficial	Cu. 12 to 25 lb. as initial application. With pH of 6.0 to 6.5, Mn. 12 to 25 lb. annually in row—if drainage is only fair and no sulfur applied	8 to 16 lb.	4-16-16 *1,200-1,400 lb.*	(Not recommended)	Br. 0-20-20 *500-600 lb.* R. 4-16-16 *500-600 lb.*
			Fair			16 lb.	4-16-16 *1,400-1,600 lb.*		Br. 0-20-20 *400-500 lb.* R. 6-12-12 *600-800 lb.*
5.0 to 6.5	Deep and medium	Old muck	Good			None	5-10-20 *1,000-1,200 lb.*	5-10-20 *700-1,000 lb.*	Br. 0-10-20 *400-600 lb.* R. 5-10-20 *400-600 lb.*
			Fair			Generally none	4-16-16 *1,000-1,200 lb.*	5-10-20 *700-1,000 lb.*	Br. 0-10-20 *400-600 lb.* R. 6-12-12 *500-700 lb.*
5.0 to 6.5	Shallow	Old muck	Good			None	4-16-16 *900-1,000 lb.*	5-10-20 *700-900 lb.*	Br. 0-10-20 *400-600 lb.* R. 5-10-20 *400-600 lb.*
			Fair			Generally none	6-12-12 *1,000-1,200 lb.*	6-12-12 *700-900 lb.*	Br. 0-20-20 *400-600 lb.* R. 6-12-12 *400-600 lb.*
6.5 to 7.0	All depths	New and old muck	Good	No limestone. Sulfur, 300 to 500 lb.	Cu. 6 to 12 lb. Mn. 25 lb.	8 to 16 lb. for 2 to 4 years, if new muck	4-16-16 *1,000-1,400 lb.*	5-10-20 *700-900 lb.*	Br. 0-20-20 *500-700 lb.* R. 5-10-20 *500-700 lb.*
			Fair				3-18-9 *2,000-2,500 lb.*	4-16-16 *800-1,100 lb.*	Br. 0-20-10 *800-1,000 lb.* R. 6-12-12 *500-700 lb.*
7.1 to 8.4	All depths	New and old muck	Good	No limestone. Sulfur, 500 to 2,000 lb.	Cu. 6 to 12 lb. Mn. 25-50 lb.	8 to 16 lb. for 4 years if new muck	4-16-16 *1,000-1,400 lb.*	4-16-16 *700-1,000 lb.*	Br. 0-20-20 *500-700 lb.* R. 5-10-20 *500-700 lb.*
			Fair				3-18-9 *2,000-2,500 lb.*	4-16-16 *800-1,000 lb.*	Br. 0-20-10 *800-1,000 lb.* R. 6-12-12 *600-800 lb.*
5.0 or less	All depths	New and old muck	Good	Limestone, 2 to 12 tons. No sulfur.	Mn. 12 lb. for 1 or 2 years after liming. Cu. 25 lb.	8 lb.	5-10-20 *1,200-1,400 lb.*	(Not recommended)	Br. 3-9-27 *400-600 lb.* R. 6-12-12 *300-500 lb.*
			Fair			16 lb.	6-12-12 *1,200-1,600 lb.*		Br. 5-10-20 *600-800 lb.* R. 6-12-12 *400-600 lb.*

*If drainage is poor, improve before raising onions.

ments are properly made. Check should be made several times each day during seeding to determine that the fertilizer is flowing uniformly in all rows, at the proper depth just below the seed.

Nitrogen

Onions may develop a nitrogen deficiency if the season is exceptionally wet, the soil poorly drained, the spring cool, or the soil showing a pH less than 5.0 before liming. Nitrogen deficiency is likely to be evident in an erect growth of leaves which are pale yellow or greenish-yellow in color. Under such conditions, additional nitrogen can be applied during June on early sown onions, and as late as July 15 on late sowings.

Nitrogen-deficiency symptoms are more likely to develop if the stand is thick than if it is thin. Application of 40 to 50 pounds per acre of actual nitrogen (equivalent to around 100 pounds of 45-percent urea or around 135 pounds per acre of ammonium nitrate) is likely to be of marked benefit to the crops. In extremely adverse con-

Fig. 8. The light-colored spots in this Arenac County onion field were due to nitrogen deficiency. On better drained soil at the far left, the tops and bulbs were much better. At this state (about two weeks before harvest) it was too late to apply nitrogen, but an earlier application at the time the spots first appeared probably would have increased the yield a hundred or more bushels per acre.

ditions, two or three applications may be needed. Excessive use of nitrogen should be avoided. Topdress only when the plants are dry, using granulated or pelleted fertilizer.

If the application of fertilizer used at seeding was rather low, wet conditions may result in a leaching out of the potassium and a reduction in assimilation of the available phosphorus. In such a case, it is sometimes advisable to use a 10-10-10 fertilizer at the rate of 300 to 400 pounds per acre sidedressed, rather than straight nitrogen. Such a sidedressing is generally preferable to a topdressing. Care should be taken to apply the fertilizer down in moist soil, but without any appreciable damage to the roots. This necessitates careful examination to determine the position of the roots between the rows.

An oversupply of nitrogen at planting or during early growth tends to produce an excessive top growth, with the leaves leaning and sometimes breaking down prematurely. This excessive development of tops tends to interfere with cultivation and offers conditions favorable for the development of downy mildew.

Phosphorus

There is no characteristic symptom for phosphorus deficiency in onions. The deficiency results in slow growth, delayed maturity, and a high proportion of "thicknecks." In row fertilization, phosphorus remains more available than when it is disked into the soil. As a result, crop maturity is likely to be reached at least a week sooner with row fertilization. Thus a 5-10-20 mixture applied in the row 2 inches below the seed, is likely to mature the crop as soon as a 4-16-16 would, if broadcast and disked in. Since phosphorus is not absorbed readily by the crop in alkaline and in poorly drained soil, it is advisable to use a mixture high in phosphorus when those conditions prevail.

Potassium

Insufficient potassium in the fertilizer mixture is likely to cause the tips of the onion leaves to turn brown and die back, in a way similar to the dieback when copper is deficient. Since potassium remains largely in a water-soluble condition when applied to muck soil, it is leached out to considerable extent in excessively wet periods. For that reason, as mentioned previously, an additional application may be required in seasons of excessive rainfall.

DRAINAGE AND WATER CONTROL

The onion is sensitive to extremes of soil moisture. If the water level is too near the surface, germination may be poor, growth slow, and the onion tops yellow. The "bottoming" may be delayed, the mature bulbs stained, and there is likely to be a large proportion of "thicknecks" at harvest. If the drainage is excessive, germination may be poor in a dry spring, growth may be slow and the mature crop may contain too many undersized bulbs.

In general a water level of 28 to 32 inches below the surface during the summer months produces the best results. Even better yields may be obtained with the water at 2 feet below the surface, if the muck is well tiled and ditches are equipped with water control mechanism so that heavy rains result in little fluctuation in the water-level. A uniform water-level, permitting the onion roots to become adjusted to the supply of moisture, is highly desirable. Placing dams in the outlet ditches, fitted with boards or flood gates by which the water-level can be maintained at the desired elevation, is good insurance against crop failure. It is necessary, of course, that the ditches either contain flowing water or a source of water be available for pumping into the ditch during the droughty periods.

Fig. 9. On this poorly drained muck, the back furrow produced the only continuous rows of onions. Even there they failed to mature properly because of wet conditions.

A new muck should be properly drained for at least a year preceding cropping to onions. This is so that water channels may become established in the soil and decomposition of the raw muck will have begun. The proper distance between lateral tile lines for ditches will depend both on the nature of the substrata and on the imperviousness of the muck. If ditches 40 rods apart are cut into gravel or sand underneath the muck, the drainage may be largely taken care of by this underlying coarse layer, sometimes to the point of causing droughtiness of the muck. If the muck at a depth of 18 to 30 inches is tight and impervious to water, as occasionally happens, tile lines as close as 15 to 20 feet may be required. Tile should be placed ¼ to ⅓ inch apart in the line to permit entrance of water.

On most mucks, tile lines 50 to 100 feet apart or ditches 150 to 300 feet apart provide satisfactory drainage. On old muck the depth to the inside bottom of the tile should range from 36 to 40 inches. If the muck is newly reclaimed, the tile should be placed at a greater depth, because new muck settles on the average of about one-fourth the distance between the surface and the tile lines within a few years after reclamation. Both glazed and unglazed tile are satisfactory—but they should not be smaller than 5 inches in diameter and not shorter than 18 inches.

In general for water control, the tile lines or side ditches should run perpendicular to the elevation contour and the lateral tile lines parallel to the contour. Figure 10 suggests a layout for water control in a field where there is considerable slope from one end to the other. If the flow in the outlet drain is insufficient in dry weather to permit a supply of water in location 8, it is sometimes possible to install a dam in the outlet ditch to supply a booster pump to furnish water at the upper end of the main tile. In some fields the outlet tile may be replaced with a ditch and there are many other variations of this system that can be made in adapting this set-up to a particular location.

CULTURAL METHODS

Breaking

In the first or later breakings of muck soil for onion production, the plowing should be deep enough to turn the heavy sod, or other vegetation down to a depth of 12 to 14, and even 18 inches, if the muck is hummocky or the soil pH warrants it. Onions growing on shallow-broken muck are almost certain to be a failure if the season is droughty. New muck preferably should be broken in early summer

so that the land can be fallowed for the remainder of the summer. If the breaking has been properly done, the furrows have been laid flat, with the sod down and a layer of muck free from sod left on the surface for the preparation of the seed bed. Generally all sods can be killed and the muck brought into condition by summer fallowing, so that onions can be grown the following spring. If the soil is a de-

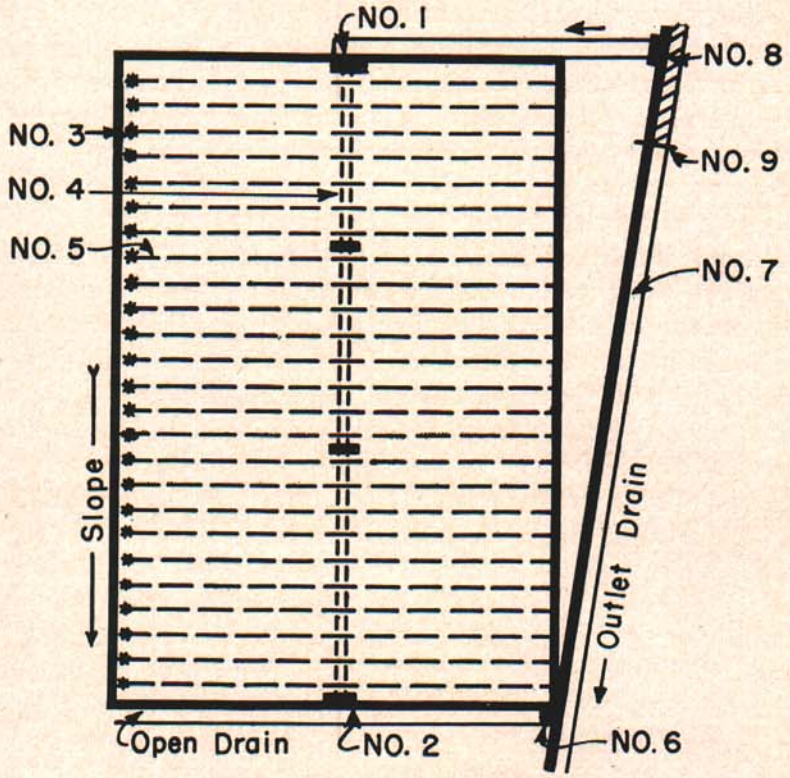

Fig. 10. Drainage—Sub-irrigation design for an 80-acre onion field.

No. 1. Start water here for sub-irrigation. Obtain water from nearby stream, if adequate supply; otherwise from deep well.
No. 2. Control well in main tile. Install whenever surface elevation changes 10 inches.
No. 3. Pine windbreak.
No. 4. Main tile—10-inch minimum.
No. 5. Lateral tile—5-inch minimum with 40 to 60 feet linespacing, placed at least 36 inches deep.
No. 6. Drain culvert equipped with floodgate. Install booster pump for drainage over culvert, if necessary.
No. 7. High levee to protect field from flooding.
No. 8. Booster pump to supply water at No. 1.
No. 9. Possible location of dam to supply water for booster pump in dry weather.

cidedly raw peat, it may be advisable to plant other crops such as cabbage, celery, head lettuce, corn, soybeans or turnips until the soil is more decomposed.

Following breaking, no plowing should be done for two or more years in order that the sod may be well decomposed before it is brought up to the surface. In later handling of the muck soil, fall plowing sometimes gives better yields than spring plowing, probably because onions can be planted earlier. On well-decomposed mucks which tend to weather to a powder during the winter months, and sometimes to become too compact, it is better to plow in the spring. Thus, the less-weathered muck will be on the surface, so there will be less possibility of soil blowing. Further, the spring-plowed muck will drain better.

Preparing the Seed Bed

If the muck area is well drained and the soil is loose and fibrous, packing with a heavy 30-inch concrete roller sometimes gives beneficial results, especially if a heavy sod has been plowed down. Do not use a roller on muck that is exceptionally heavy or well decomposed. The use of the combination fertilizer distributor-roller-seeder is generally adequate for most onion land.

The double disk is probably the most effective implement for the preparation of the seed bed. Floating the field after disking may be necessary to leave the soil in good condition for uniform seeding and straight rows. Care should be taken, however, not to float the muck too far ahead of the seeding, since the newly floated muck blows easily.

Prevention of Wind Injury

Injury by strong winds—sometimes by the removal of muck covering the seed, but generally by the blowing of particles of soil which strike and bruise the young onions—is responsible for considerable loss each year. Prevention of such injury can be accomplished by the combination of several methods:

1. Growing tree windbreaks along line fences and ditches.
2. Use of slats or boards, or of strips of winter rye.
3. Planting crops such as spring rye or spring wheat between the rows.
4. Increasing supply of organic fiber in the soil.
5. Raising water level in the field or using overhead sprinkler irrigation.

Fig. 11. A last-minute attempt to prevent wind injury to an onion crop by putting a barrier of crates across the field. Note the drifted muck on the left (east side) of the crates. The crop had wheat sown between every two rows, but the rows were sown in an east and west direction.

In beginning the cultivation of a newly claimed muck soil, most farmers feel that the muck is sufficiently raw so that it will not blow. In three or four years, however, decomposition has progressed so rapidly that the muck blows easily. Critical wind velocity is about 20 miles per hour for open unprotected fields. The early planting of trees (white pine or the green willow) along the fence lines will tend to check the sweep of the wind across the broad flat areas.

Strips of 4- or 5-drill rows of winter rye can be sown in the fall in a north and south direction at intervals of 40 to 60 feet, and the onions sown parallel to these strips in the spring. The chief objection to rye is that the drifting muck tends to form ridges where the strips are located. If the muck is quite dry, however, such rye strips are inadequate to entirely prevent wind injury. For that reason it is generally advisable to sow spring rye, barley or spring wheat between every two rows on every onion field which is in danger of being swept by the spring winds. Such interplanted grains must be removed by wheel hoes, or better still, by power-driven covered cultivators fitted

with revolving knives, used as soon as the onions are large enough to serve as their own protection.

The growing of grain crops to be plowed down tends to decrease the blowing of muck by adding organic fiber to the soil. The more woody the crop plowed down, the more permanent the fiber is likely to be. On old mucks, the crop is also likely to show a marked increase in yield as the result of the green manure. On new mucks, the plowing down of green manure is likely to hasten the decomposition of the soil. On muck which is to be left fallow after early fall harvesting, a seeding of oats will protect the soil from drifting during the winter months, yet will not interfere with the cropping in the spring, either if disked in or plowed under.

Fig. 12. Spring grain, sown between every two or three rows of onions, generally gives ample protection against wind injury—if supplemented by plantings of tree windbreaks around the fields. The onions will often make more rapid growth with the grain protection, than if exposed to the chilling winds of the early spring.

VARIETIES

Most of the onions produced in Michigan up to the present time have been of the American type. The greater proportion are produced from seed—but there is some acreage of sets, and a very few fields of transplanted onions. The yellow globe onion is generally grown from

seed—with Downing Yellow Globe, Brigham Yellow Globe, Southport Yellow Globe and Early Yellow Globe produced more than other varieties. The two first-named strains were developed by two Michigan growers and have been for many years popular because of their good color and good keeping qualities. Production of the Utah Sweet Spanish is confined to several well-drained fields in the Hudsonville area, where the crop is marketed directly from the field, as it does not store well.

A desirable onion variety for the Michigan grower is one that yields well; is solid; does not bruise easily; has a dark, yellowish-brown color and a tight-fitting skin; is late sprouting; has a globe shape; and does not stain and decay easily. The varieties at present that meet these requirements are the pungent type. In recent years a majority of the growers have found the Downing Yellow Globe to most nearly qualify in these desirable characteristics.

Eight years of cooperative trials between the U. S. Department of Agriculture, Michigan, and several other northern states have been conducted in an attempt to develop onion hybrids adapted to this section of the country. As a result ten hybrids were named for limited release in the spring of 1954 from hundreds that have been tried out. Of these named selections Aristocrat, Elite, Epoch, and Surprise have excelled in the Michigan trials. For high production but with storage qualities similar to Early Yellow Globe, Abundance was outstanding.

Some of the commercial onion breeders also have developed hybrids that show promise. Some hybrids undoubtedly will be withdrawn in favor of others that give better results, and still better hybrids are certain to be developed in the next few years. Growers are advised to try out these hybrids as the seed becomes available and in that way to select those which are best suited to their particular soil conditions.

In addition to the yellow varieties, some acreages of white and of red onions are grown. Of these the Southport White Globe and the Southport Red Globe are practically the only varieties grown.

In addition to the full-sized mature onions produced for the consumers market, a considerable acreage is grown for "boilers" and a small acreage for "picklers". White Portugal is the variety commonly used and the chief difference lies in the size of the mature bulbs, with the boilers ranging around one and one-half and the picklers less than one inch in diameter, with a three-fourths inch maximum preferred.

ONION SEEDING

Planting Time

In general, the earlier the seeding of onions, the higher the yield. In southern Michigan seeding between April 10 and 25 is considered desirable, although the time may be advanced to the 1st of April or delayed to May 10, if weather conditions warrant it. Late seeding may result in late maturity, small bulbs, poor keepers and a considerable proportion of "thicknecks".

Fig. 13. The need for windbreaks to prevent damage to the onion crop is becoming increasingly important on Michigan muck soils. The windbreak shown in the upper picture is of green willow, is four years old, and averages close to 18 feet in height. Its rapid and upright growth makes it a valuable windbreak for the growing season, but it does not offer much protection in winter. After it reaches considerable height, it takes the moisture from the soil for 20 feet on each side, and twigs blow into the fields, interfering with cultivation.

Rates

The proper rate of seeding is dependent upon a number of factors. It is important to know (1) the percentage germination; (2) the size of seed; (3) soil moisture content; (4) possible injury from insect and soil borne diseases; (5) variety. It is especially advisable that the grower check on the germination of all onion seed before planting. For yellow and red globes, a uniform stand of 8 to 15 plants per foot of row is generally considered satisfactory. To secure this stand, it is

necessary to seed at the rate of 15 to 20 seeds per foot of row. If Arasan or some other material is mixed in the seed, the drill should be calibrated accordingly. With rows 14 to 18 inches apart, it ordinarily requires from 3 to 4½ pounds of seed per acre. White globes are seeded heavier, the normal rate being around 6 pounds per acre. Rate of seeding should not be excessive as the plants will be too thick and the mature bulbs will be small.

Row Spacing and Depth

The farm equipment used, the cost of hand weeding, and the probability of mildew infection all influence row spacing. The trend in recent years has been toward wider rows, with the number of plants per acre about the same as in close row spacing. Wide rows may produce some sacrifice in yield. The hand-weeding cost using 17-inch and 20-inch rows, however, will be about 20 and 40 percent less, respectively, than where row widths are 14 inches. Wider row spacing allows better air circulation, which reduces the danger from mildew.

The depth for sowing onion seed depends on the type of muck and its moisture supply. If the muck is rather heavy and inclined to crust over on drying, a depth of one-half inch is preferable. On most mucks it is better to sow three-fourths to one inch deep so that the seed will be down in moist soil in order to obtain more uniform germination. If the field is likely to be wind-swept or if a pre-emergence spray is to be used, it is safer to put the seed a half inch deeper, i.e., one and one-fourth to one and one-half inches. For each quarter inch that the seed is sown below one inch in depth, the rate of seeding should be increased by approximately a quarter of a pound per acre in order to insure a satisfactory stand. Some growers sow without the regular coverer, depending on the press wheel to do some covering.

Sets and Transplants

Sets are used to produce mature onions for either of two reasons. One is to permit the spreading of the harvesting season over a longer period because sets produce an earlier maturing crop than that obtained from sowing seed. The other is to get a crop from a nematode-infested field before the heat of the summer permits such nematode increase that the onion crop from seed would be a failure.

Ebenezer and Golden Globe are the varieties commonly grown. Sets are generally planted by hand or machine from 1½ to 3 inches

apart in rows 16 to 20 inches apart. The bulbs are entirely covered with soil firmed over them but they should not be placed too deep. They are planted the last part of April in southern Michigan. Sets should be carefully sprayed or dusted for control of thrips, which increase rapidly and sometimes move over onto an adjoining seed-sown field and ruin it after the bulbs from the sets are mature.

A few growers have raised Sweet Spanish onions from transplants grown in local greenhouses or shipped in from southern states. These are grown for a special trade. They are transplanted fairly early and spaced fairly far apart in order to obtain extra large bulbs and fairly early maturity. Transplants are set either by hand or machine in rows 16 to 20 inches apart. The transplanting is generally done when the plants are 5 to 8 inches high and are set in the soil about one and one-half inches deep, with plants 3 to 6 inches apart.

Chief objection to the use of both sets and transplants from unknown sources lies in the possible introduction to the field of smut and of nematodes, which are likely to remain permanently in the soil and to spread from field to field.

PRODUCTION OF SEED, SETS AND TRANSPLANTS

A considerable number of the onion growers of the state are producing part or all of their seed from bulbs of their own raising. This practice is desirable when the grower has difficulty in securing a variety adapted to his climatic and soil conditions. In addition to careful selection of bulbs of the desired type, the keeping quality can be improved by the planting of only those bulbs which show no evidence of sprouting. The grower is cautioned that seed produced from hybrid bulbs will not run true to type.

In the latter part of April or early May in southern Michigan, the bulbs are set out, from six to eight inches apart in the row, with rows about two feet apart. Although better yields of seed may be secured on a good loam soil, good yields can be obtained with proper planting on muck. The bulbs should be covered two to three inches deep in compact muck. If the bulb planting is adjacent to onion fields, particular care should be given the bulbs to protect them from maggots and thrips, and special care should be taken to control downy mildew with weekly sprayings from early growth to the time of harvest. An application of 300 to 400 pounds per acre of a 5-10-20 fertilizer is also advisable.

The seed balls should be harvested when the seed cells start to open, since a delay is likely to cause a loss from shattering. If convenient, the picking can be made two or three times as the balls mature. The balls should then be dried rapidly in a room having plenty of air circulation, so that they will not mold with resulting injury to the vitality of the seed. In small quantities the seed can be rubbed out of the balls when dry, and then cleaned with a fanning mill. In larger quantities, it can be threshed with clover huller or with machinery designed for that purpose.

Onion sets are produced by the close sowing of onion seed. From 50 to 65 pounds of seed per acre should be sown, the amount depending on the percentage germination and size of seed and the distance between the rows. Insufficient stand will result in the production of sets larger than three-fourths inch in diameter, which larger sets may develop seed stalks instead of bulbs. Storing the sets in a rather warm (40 to 50° F.) dry room, rather than one at near freezing, will keep at a minimum the proportion of sets developing seed stalks in the field. Care should be taken to control maggots, which thin the stand and result in oversize bulbs. Thus far it has been difficult to produce sets from the Sweet Spanish onion, for lack of which Sweet Spanish transplants are sometimes used.

Production of Sweet Spanish transplants by seeding in the greenhouse in February or early March gives satisfactory result, but some of the transplants used in Michigan have been obtained from southern growers. Consideration should be given the fact that this importation of plants may introduce serious soil-borne diseases and insect pests such as nematodes and thrips. Care also should be taken in raising the plants in the greenhouse or the hot bed, that the soil is free from disease. The house and plants should be kept free from insects.

CULTIVATION

Cultivation generally is required only for the destruction of weeds. This is accomplished by the use of power-driven, rapidly rotating blades or by the use of wheel hoes generally equipped with knives. If the purpose of cultivating is to destroy weeds, then it should be shallow (½ inch depth). For compact, wet, cool soils, one can obtain good results during early growth by using a single hook, fairly deep and half-way between the rows. This will help dry and aerate the soil.

Fig. 14. Onions being cultivated with hooks on a 3-row garden tractor. This equipment is giving way to farm-tractor-drawn, 6- to 12-row, multiple units on the larger onion farms.

Hooks should not be used for the first time after the onions have attained considerable growth. In case of excessive moisture necessitating further use of the hooks, care should be taken not to cut off any appreciable amount of white roots. Under such conditions a nitrogen application is likely to be needed.

WEEDING

A major factor to be seriously considered before attempting onion production is the probable cost of weeding. The cost of destroying weeds may be as low as a few dollars per acre per year in fields where weed control has been watched closely—but can easily be well over $100 on other fields where weed seed has been allowed to accumulate in the soil. One year of neglect in controlling weeds is likely to be reflected in 10 years of increased weeding costs. Attention should be called to the fact that, on many fields, weeds grow rapidly and produce seed in a short time late in the season at the time that onion tops are

maturing. Fortunately recent developments in the use of chemical weed killers and better machinery have reduced man-labor hours required to keep onion fields clean.

Weeds in the row should be removed while they are very small. The weeds crowd and shade the onions, and rob the plants of moisture and fertility. When a grower fails to maintain clean fields after it appears that weeds will not reduce yields, late weed growth may increase harvesting costs. In order to reduce weeding costs in later years, it is frequently advisable to carry purslane and any seed-bearing weeds off the fields.

CHEMICAL WEED KILLERS[6]

A number of chemicals have recently been developed which can be used to destroy weeds. The kind which should be used depends upon cost, equipment required, weather conditions, hazards of handling and time of application. Usually three periods of onion development are considered. The first period in the destruction of weeds before the onions appear is called pre-emergence. The second period treatments, called post-emergence, include the use of chemicals on growing onions. The third period, pre-harvest, relates to the killing of weeds in the mature onions so as to facilitate harvest operations.

At present, chemicals should be considered only as a supplement to hand weeding and mechanical cultivation. In order to reduce cost, it is frequently best to confine the spray to a 4 or 5 inch band over the row. The amount applied should be reduced in proportion to the area covered. Although some sprays produce little or no damage when applied to the onion tops, it is generally advisable to avoid spraying the tops as much as possible. The following are suggested materials which may be used.

Stoddard Solvent

Pre-emergence only. This material is an oil with a high flash point. If applied over the entire area, the rate should be 30 to 40 gallons per acre. Use 20 to 40 pounds of pressure and a fan-type nozzle. Some growers have used Stoddard solvent, without injury, on onions not more than one inch in height.

[6]The section on Chemical Weed Killers was prepared under the supervision of Dr. Buford Grigsby of the Botany and Plant Pathology Department.

C.I.P.C. (Chloro I.P.C.) (Isopropyl N [3 chlorophenyl] carbamate)

This material is very effective in killing germinating seeds, especially purslane. It does not control lambs quarter and pig weeds, nor other weeds after they have made considerable growth. It is used for pre-emergence and also as a post-emergence spray to control weed seeds brought to the surface by cultivation. An application of 6 to 8 pounds per acre is recommended for pre-emergence spray and 8 pounds per acre for post-emergence.

Sulfuric Acid

For pre-emergence prepare a 5 percent solution of sulfuric acid (by volume) in water containing a wetting agent. Mix thoroughly with a good agitator. Apply at the rate of 100 gallons per acre, using 30 to 50 pounds pressure. *Brass or bronze pump and fittings must be used.* For post-emergence, prepare 2½ percent sulfuric acid in water without wetting agent and apply after the first true leaf is visible. Use low pressure, 20 to 30 pounds. Do not spray after leaves begin to bend over toward the ground, as damage may result from the spray. Apply at the rate of 100 gallons per acre. For pre-harvest spray, use concentrations as suggested for pre-emergence.

Herbisan (Xanthogen Disulfide)—(formerly Sulfasan)

This material should be used under a shield to protect the crop when used as a post-emergence spray. Use 25 pounds of dry Herbisan in 120 gallons of water per acre. The agitator must run continuously to maintain the dispersion. Apply spray toward the row with fan-type nozzles, carried 3 inches to 6 inches on both sides of the row and about 6 inches off the ground. Avoid the onions as much as possible. Use just enough pressure on the line to permit the spray to form a fan when using a fan-type nozzle. Usually 20 to 30 pounds of pressure is required. Start spraying when weeds are ½- to 1-inch in size.

Some growers have tried liquid Herbisan as a pre-harvest spray, using 4 gallons in 100 gallons of water. With a pressure of 30 to 100 pounds, 75 to 100 gallons per acre should be applied. The minimum effective temperature is 60°F. *Until the Pure Food and Drug Administration releases it for this purpose, growers are warned that residue on the crop may prevent sale of the onions.*

ONION DISEASES[7]

Onion Smut

Smut is a serious disease in some of the older onion districts. It lives in the soil for years and attacks the young seedling. The disease is first noticed as dark streaks within the leaf; especially if held against the light. The seedling is susceptible to the disease in early growth, up to and including development of the second true leaf.

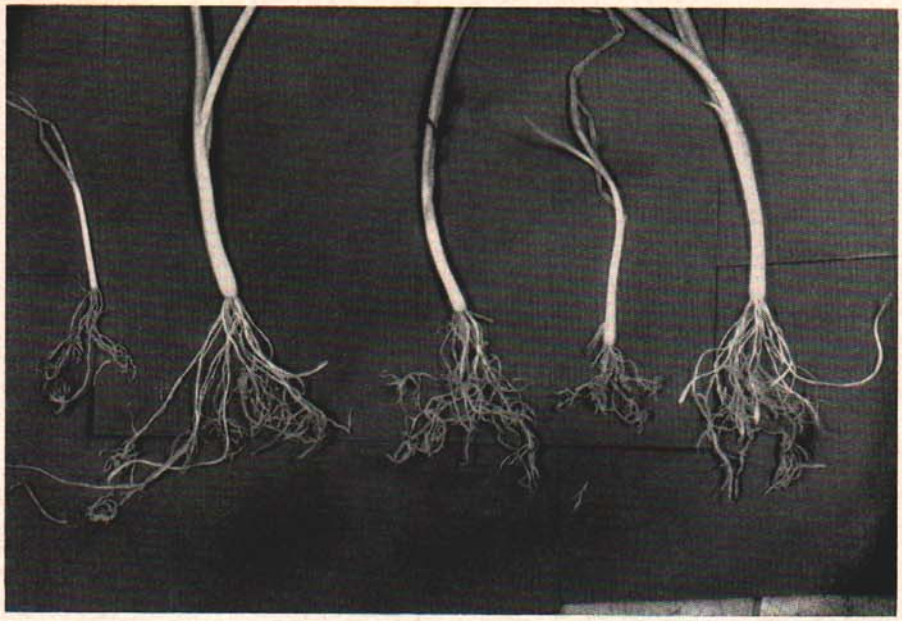

Fig. 15. Onion roots affected by root knot (nematode disease). Note the dwarfed growth of tops, restricted root development, and characteristic knot-like swellings of the roots. (Crop sown in early April; plants photographed June 24.)

For smut control on soil with slight infection, use one pound of Arasan mixed in the drill with 4 pounds of seed. This treatment will not give good control of smut in badly infected soil. For such areas, liquid formaldehyde can be used at the rate of 1 pint to 10 gallons of water, applied at 100 gallons per acre. Formaldehyde reduces stands and more seed should be sown than with the Arasan treatment. With a seeding rate of 3½ to 4 pounds per acre with the Arasan treatment, a smut loss of 10 percent to 15 percent can be tolerated.

[7]The section on Onion Diseases was prepared under the supervision of Dr. Ray Nelson of the Botany Department.

Some growers are applying more Arasan with the seed by using a separate set of hoppers on their drills (see Fig. 16), which feeds the Arasan into the soil along with the seed. An insecticide for maggot control can be included in this dust mixture. Preliminary tests indicate that 3 or more pounds of Arasan (50 percent) per acre are required for good smut control.

Downy Mildew (Blight)

Under favorable weather conditions, this disease can cause extensive damage. Mildew ordinarily appears in late July or August and spreads rapidly during cool, humid weather. The disease appears first in spots where air circulation is poor and then spreads rapidly, resulting in a premature dying of the tops. The fungus can be recognized as a fuzzy, violet-colored mold, sometimes visible on the diseased leaves in the early morning while the dew is still present. The disease

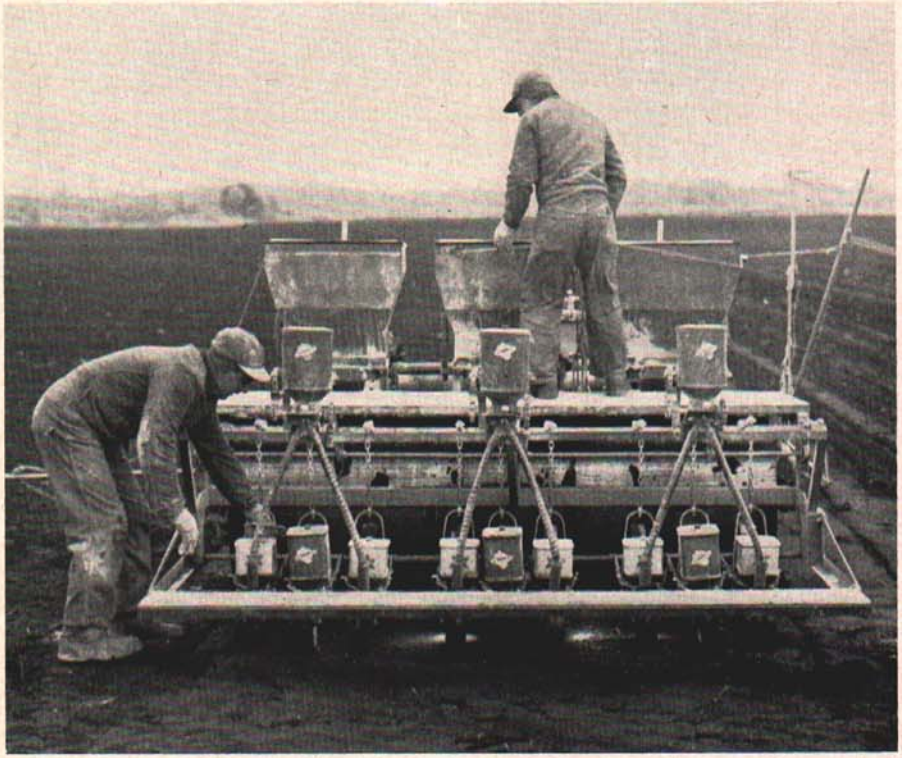

Fig. 16. Combined 6-row seeder and fertilizer drill for applying fertilizer under row, with extra hoppers for sowing grain between every two rows and extra hoppers for applying fungicide with the seed.

results in a decreased yield, generally of under-sized onions which fail to keep well in storage.

To control mildew—dust at 5 to 7 day intervals, beginning early in July with Dithane-sulphur dust containing 7 percent Dithane (Z-78) and 15 percent sulphur. About 8 applications on the average are required for good protection, with 50 pounds per acre per application. Dust in the evening and alternate the direction of the duster in successive dustings. For example, if rows run east and west, dust east to west with one application and west to east the next time.

For spraying, use 2 pounds of Dithane Z-78 to 100 gallons of water with a suitable sticker and spreader. Or use the liquid form of Dithane, with zinc sulfate added as recommended by the manufacturer.

Destruction of all diseased tops, rotation of crops, proper fertilization and improvements in drainage if needed, are control measures for mildew. Avoid excessive top growth resulting from use of too much nitrogen. Do not cultivate or weed the crop while water is on the foliage. It is advisable to eradicate all plantings of perennial Egyptian and all wild onions in the vicinity of extensive onion acreages. In spite of these precautions onions can become infected, because the spores of mildew are light and are readily carried great distances by the wind.

Pink Root

This disease is present in practically every field where onions are grown year after year. At first it causes abnormal yellowing of the roots which shrivel, die, and finally take on a characteristic pink color. The disease causes a gradual decay of the roots which does not ordinarily kill the plants—but retards their growth so that only undersize bulbs are produced. High temperatures and either low soil moisture or excessive moisture tend to favor the growth of the organism.

Attempts to treat the soil or plants to control pink root have proven ineffective. The best control is to maintain moisture and fertility at favorable levels for rapid growth. Crop rotation will partly control serious attacks by the organism. To prevent infection in new fields, it is advisable not to use transplants or sets.

Nematodes

Several species of nematodes, sometimes called "eel worms", attack the roots of onions. One called *root-knot* causes swellings or enlargements of the affected roots. Another specie called the *meadow nema-*

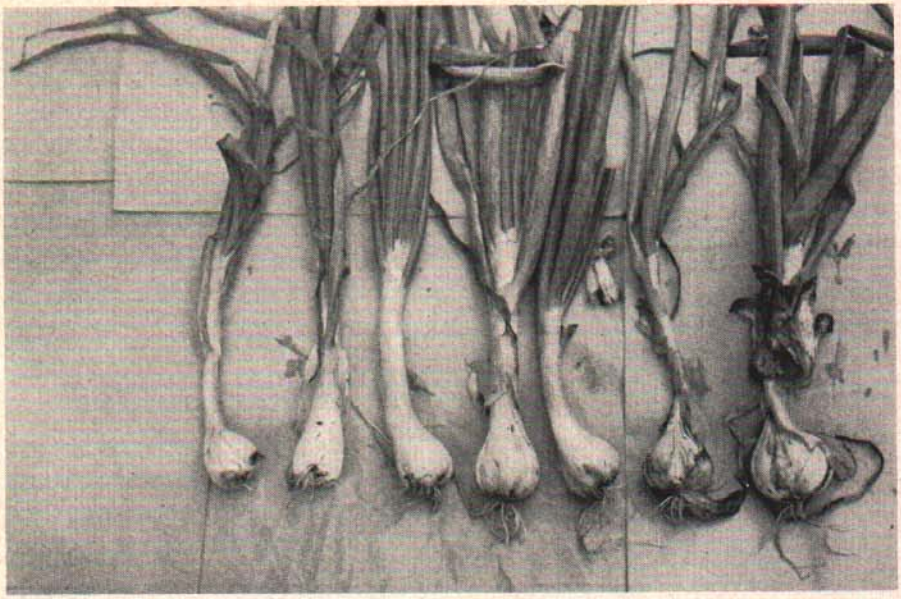

Fig. 17. Onion bulbs affected with the "stem and bulb" nematode. Note the distorted shapes, with decay evident on some of the bulbs. These bulbs were from sets. Onions from seed are generally killed before they reach this size.

tode is both a surface and internal root feeder but does not cause swelling. The *root-knot* species is easy to recognize, but identification of the others requires the use of a microscope.

A third species recently discovered for the first time in a Michigan field, is known as the "stem and bulb" nematode (see Fig. 17). It attacks the onion bulb in various stages of growth and causes a granulation of the tissue in neck and bulb, with a soft rot and odor which attracts maggots. This nematode can be spread in the shipping of the mature infected onions.

These parasites attack young seedlings and cause distorted growth, loss of vigor, and even death. Older infected plants show stunting and a wilted appearance. To prevent these pests from getting a start in a field, extreme care should be taken to avoid carrying infested soil, plants, sets, crates, or bags into clean fields. The best control in infested fields consists in fumigating the soil with a chemical mixture called "DD" (dichloropropene-dichloropropane) at the rate of 35 to 40 gallons per acre. The chemical should be applied the previous fall. It must be handled carefully and applied as recommended by the manufacturer.

Neck Rot

This disease causes a softening of the tissue, generally around the neck of the bulb but sometimes around the roots or in wounds. It appears as a gray mold on the surface, later as black kernel-like bodies which are usually on the outer skin. The disease attacks bulbs which are not properly matured and field-cured, or which are brought into storage while wet. It frequently occurs as an internal breakdown (see Fig. 18) which is very difficult to recognize in grading. It is generally more severe in poorly ventilated storages.

Control measures include proper drainage; proper fertilization; use of solid, long-keeping varieties; early seeding to produce well-matured bulbs; and harvest of the crop as soon as mature. If the tops die without breaking over, as happens in a wet period, they should be harvested immediately or rolled with a light roller. Otherwise the rain will carry infection down into the upright neck from which it may extend into the under layers of the bulb. Care in handling the crop to prevent injury of the bulbs, rapid curing, and storing in properly ventilated storages will aid in preventing further infection.

Fig. 18. These onions are suffering from internal breakdown in storage due to neck rot. The left onion, only slightly infected, recovered while the other three show increasing degrees of infection.

Onion Smudge

This disease appears as a dark green or black smudge on the bulb or neck of the onion. It is most conspicuous and serious on the white varieties, while the colored varieties are resistant. Crop rotation where practical is recommended. Thorough and rapid curing of the bulbs in storage reduces this disease to a minimum.

Fig. 19. Smudge, a disease of white onions which generally appears in storage. The yellow and red varieties are immune to it. Rotation of crops and good ventilation in storage are the best aids in preventing it.

INSECT PESTS[8]

Onion Maggot

Although the true onion maggot is the most important of the several maggots which infest onions, the corn-seed fly maggot, the false stable-fly maggot, and the lesser bulb-fly maggot also infest onions. The last named sometimes becomes important late in the growing season and in storage. Control measures are the same for the different maggots.

Maggot flies start laying eggs at the first emergence of the young plants, therefore application of control measures at that stage is very important. The eggs are deposited on the ground close to the onions. Control must be aimed at killing either the flies before they lay their eggs, or destroying the newly hatched white maggots before they burrow into the onions.

Infestation of onion fields may come from cull onions left in the field or around storages. These should be destroyed by burning or burying under at least a foot of soil. Onion piles should be given frequent and thorough dustings with dieldrin until they are buried. Other sources of infestation include wild onions and a number of other perennial weeds in neighboring fields or fence rows which also serve as host plants. Choice of three control treatments to be used in field or on piles of refuse onions is given on page 38. Very effective soil treatments for controlling maggots have been developed.

[8]The section on "Insect Pests" was prepared under the supervision of the Entomology Department.

Onion Thrips

These exceedingly small insects feed on the leaves by sucking in the plant juices. When the population is small, thrips stay at the base between the new leaves. In heavy infestations in warm weather, the insects are found anywhere on the leaf surface. The life cycle is completed in two weeks. For this reason the population may increase very rapidly, especially during hot, dry weather.

Onion thrips feed upon a large number of plants and winter over in grass, leaves, and rubbish. Damage to onions first appears next to the borders and in the drier parts of the field. The leaves first show silvery streaks, then take on a grayish-white (bleached) color. Large populations may suddenly invade and rapidly destroy seedling onions, immediately following harvest of adjacent set onions, grain or hay.

Control should begin when the average population is less than 10 per plant, preferably as a preventive rather than a cure. A regular dust or spray program will completely control the insect. Effective materials are dieldrin, parathion, chlordane and DDT (see page 39).

Cutworms

Where good control methods are used for maggots, cutworms will not be a problem. On the other hand serious outbreaks in onions have been reported. For control use 1.5 pounds of actual toxaphene or 0.5 pounds of actual dieldrin per acre.

Wireworms

Attacks from wireworms are often very serious, especially after onions are sown on newly broken June grass sod. If there are scattered, living sods left in the field, the injury may be slight the first year. With the complete killing of all sods by the second year, however, destruction of stand is likely to be more severe.

In the third and fourth years, the wireworms are likely to become less numerous as the worm enters the adult stage—the click beetle—which flies to June grass sod to lay its eggs. For that reason June grass around the edges of the field should be destroyed.

A mixture of wheat and spring rye, sown rather thickly between every two rows of onions (as for protection from wind), supplies sprouting wheat as a food preferred by wireworms. The rye is left for protection from wind. If the attack is severe, it may be necessary to repeat the sowing of the wheat. For chemical control of wireworms

apply 12 pounds per acre of 25 percent wettable aldrin powder. Prepare as a spray and disk into the soil before the onions are sown. If one is using a row application of dieldrin for maggot control, it is not necessary to use the aldrin soil treatment.

MALEIC HYDRAZIDE FOR PREVENTION OF SPROUTING[9]

Recent studies in the Horticulture Department have shown that a a single pre-harvest foliage spray of maleic hydrazide will eliminate sprouting and root growth of onions in storage. Four years of study have shown no harmful effects of maleic hydrazide on color, flavor or general appearance of the onions when treated according to directions, and have proved it is non-injurious to man or animals.

Fig. 20. Wireworm injury in an onion field on muck sod, newly broken the preceding year. Still greater injury may be done the second year when the sods on which the worms ordinarily feed are entirely dead.

To be effective the chemical must be absorbed by the green leaves and translocated to the interior of the bulb. It is important that it is applied during fair weather, at least 24 hours before rain. Application should be made from 10 to 15 days before the tops are fully mature. If the treatment is applied too early, the bulbs may become hollow or puffy and will not keep in storage.

At present, a white powder, MH-40, containing a wetting agent, has been accepted by the U. S. Department of Agriculture. It is recom-

[9]The section on the use of Maleic Hydrazide was prepared under the supervision of Sylvan H. Wittwer of the Horticulture Department.

mended that the growers use approximately 5 pounds of MH-40 per acre. This amount of material may be applied in 50 or more gallons of water per acre, thorough covering of the tops being important. The use of maleic hydrazide will permit the storing of certain hybrids and varieties that are good keepers but which ordinarily sprout early.

DUSTING, SPRAYING AND TREATMENT IN SOIL

Whether dusting or spraying is likely to give better results depends upon the onion acreage, the soil conditions, and the thoroughness of the grower in following out the respective procedures. In many cases it is advisable for growers to be equipped for both dusting and spraying. Dusting requires lighter and less expensive equipment. Spraying, on the other hand, lends itself to more uses, can be applied at any time of the day, and shows about a 50 percent saving over dust in the cost of material.

A sound program requires the use of spray or dust weekly from the time onions are planted until they are mature. Such a program may produce as much as 10 percent increase in yield, even though diseases and insects do not become a problem. Because of the rapid advancement in the development of new materials, new techniques and new equipment at the present time in control of weeds, diseases and insects, the grower is advised to keep in close contact with the college in order to have the latest recommendations.

SPRAY SCHEDULE

A. PRE-EMERGENCE and POST-EMERGENCE spray for weeds. (See pages 28, 29).

B. MAGGOT CONTROL. Start spraying as onions start to emerge. Continue weekly applications until June 15 or later in a cool wet spring. Water pressure and the amount used per day are not too important but the amount of insecticide recommended should be maintained.

Selection 1. One-half pound per acre of actual dieldrin (equivalent of 2 pounds of 25% dieldrin—or 3 pints of 18½% solution).

Selection 2. One pound per acre of actual chlordane (equivalent to 1½ pints of 72% chlordane emulsion, or 2 pounds of 50% wettable powder).

Fig. 21. These onions were thought to have become affected with a new disease. Note one white leaf on each plant. This leaf was located on the south side of the onion, and was traced to an extremely hot day which occurred in the early growth of the leaf.

Selection 3. One-third pound per acre of actual parathion (equivalent to 2 pounds of 15 percent wettable powder).
Caution: Be sure to use mask and take other precautions when using parathion. Manganese sulfate can be included in the maggot spray.

C. MILDEW, BLAST, LATE MAGGOT and THRIPS CONTROL. Start spraying the latter part of June. Thoroughly wet the leaves. This usually requires 100 to 150 gallons per acre. Use high pressure, 300 to 400 pounds per square inch, with cone-type nozzle preferable because of its sticking ability. Growers may wish to try doubling the concentration of chemicals used in the spray formula. This would require a reduction in the amount of spray applied to half of that ordinarily used.

Formula for a 100-gallon mixture:

1. Two to three quarts of liquid Dithane or Parzate.
2. Three-fourths pound of zinc sulfate.

3. Three to six ounces Triton B-1956.
4. Insecticide choice of 1½ pounds of 15 percent wettable parathion, 3 pounds of 50 percent DDT, or 1½ pounds of 25 percent dieldrin powder.
5. Use manganese sulfate if soil pH is above 5.8. Ingredients 1, 2 and 3 are necessary for mildew and blast control and should be applied on onions until they are mature. You *must use a mask and follow all precautions in applying parathion.*

D. FOR PREVENTION OF SPROUTS IN STORAGE.
1. Use 5 pounds per acre of MH-40 powder (maleic hydrazide) 10 to 15 days before crop is mature.

DUST SCHEDULE

A. MAGGOT CONTROL.
1. *Soil treatment.* Growers may apply in the row in contact with seed at time of planting for production of bulb onions only the actual technical grade of Dieldrin at the rate of one-half to one pound per acre. This can be used in the same dust with Arasan (see page 31) and can best be applied from a separate hopper feeding into the same spout as the seed is sown.
2. *Foliage treatment.* Start treatments when onions start to emerge. Apply weekly at the rate of 30 pounds per acre. Choice of 1½ percent dieldrin, 5 percent chlordane or 2 percent parathion.

B. MILDEW, BLAST, and THRIPS CONTROL. Start weekly schedule late in June. Apply at the rate of 50 pounds per acre. Use 7 percent Dithane (or Parzate), 15 percent sulfur dust containing either 1 percent parathion or 1.5 percent Dieldrin. For those who prefer copper, use 14 percent Tribasic copper, 2 percent neutral zinc, and 15 percent sulfur—and one of the insecticides.

HARVESTING

The value of an onion crop depends to a great extent on successful harvesting. Careful handling of onion bulbs is essential at all times as they bruise easily. Bruising often causes storage rot and detracts from their appearance. If they are planted early and are properly fertilized, it is generally advisable to allow them to mature in the

Fig. 22. Blower-type onion harvester in operation in Jackson County in the fall of 1953. When the crop is well matured and dry, the machine does very good work.

ground and then they can be topped either by machine or by hand. Onions should not be allowed to remain in the row after maturity until a new root growth starts to develop. If the crop is in danger of not maturing properly in the ground, they should be pulled. Four to eight rows generally are placed in one windrow so that the tops lie over the bulbs in order to protect them from frost damage and sun scald.

The topping of onions is to a great extent done with hand shears, leaving about three-quarters inch of top on each bulb. To prevent excessive "peelers", hand topping should be started while the tops are slightly green. The onions are then placed in sacks or crates.

When crates are used, best results are obtained with a slatted 4 or 5 peck crate built especially for storage. The crates are then stacked one above the other in groups of 3 to 5 and generally are left in the field for further curing. Two to four stacks are often placed together in a north to south row. For protection onion tops may be placed on top, or a strip of tough paper may be tacked over them if the crates are to be left in the field for some time.

If open mesh bags are used for curing in the field, they must be turned several times in the 10 to 14 days usually required for proper curing.

Because of the expense of hand labor which is usually in critical supply during harvest, an increasing proportion of the onion acreage is being topped mechanically. The onions are not disturbed until tops

are mature, then two or three rows are placed in a windrow by a mechanical lifter. There they are left from one to three days before being machine-topped.

Many growers who have used machines have found that their good onions had excessive shrinkage in storage because of bruising and peeling. Unfortunately, many of the mechanical harvesters now in use are equipped with rollers designed for harvesting other vegetables as well as onions. When a machine is designed that will handle onions lightly and will take the tops off with a quick, sharp break, harvesting will be completely mechanized. At present an air-blast-type of harvester is showing promise, but it will not operate satisfactorily under wet or weedy conditions.

Grading

The grading of onions is for size and quality. Usually onions are run over sizer belts or over a 1½-inch grading rack to remove the small bulbs. A few growers have developed special markets for large onions over 3 inches in size. The small onions can be regraded into "sets" and "boilers". A high quality pack is one in which "peelers", "doubles", "sprouters" and all decayed and bruised onions have been removed.

For U. S. No. 1 Grade, unless otherwise specified, the minimum size shall be 1½ inches in diameter—and in the case of yellow, brown or red onions, 40 percent or more by weight in any lot shall be 2 inches or larger (60 percent on the Onion Exchange). Not more than 10 percent, by weight, in any container may be damaged by peeling, and not more than 5 percent may be below the remaining requirements of this grade—but not more than 2 percent affected by decay.

In addition not more than 5 percent by weight may be below the minimum size specified, and not more than 15 percent above maximum size. Boilers shall not be less than 1 inch nor more than 1⅞ inches in diameter. Picklers must be less than one inch in diameter.

Storages

Most growers who have been producing onions for a number of years have found it pays to be prepared to store onions. Present tax arrangements have also induced growers at times to spread the sale of their product over two taxable years. Furthermore, by placing a portion of the crop in storage, the harvest can be moved in an orderly manner and the market can be furnished with an even supply, which

results in increased consumption. The least-matured bulbs and the poor-keeping varieties should be sold first.

A well-constructed onion storage protects the crop against sudden temperature changes. Double doors and insulated walls help to maintain a uniform temperature throughout the building. The temperature should remain as nearly as possible between 31° and 33° F. during storage. Generally no damage is done with the temperature as low as 29° F. If freezing should occur, the onions should be gradually thawed out. Care should be taken so that the temperature does not get into the 40's for any length of time as this will encourage sprouting.

With present conventional type storages, onions preferably should be sufficiently dry so the skins crackle when they are moved into storage. It is sometimes advisable to use warm, dry air in storage for several days in the fall to complete curing. Once the temperature in the storage is lowered sufficiently, then the doors and ventilators should be kept closed during warm days—if the humidity inside will permit it. It is especially hazardous to allow warm, moist air to come in contact with cold onion bulbs because of condensation of moisture. Thermometers should be kept on hand so that temperature changes may be noted.

The storages should be well ventilated so that a relatively low humidity (70 to 75 percent) may be maintained. Keep the air circulating inside the building, because the air at the top of the storage gets warmer than the lower air. If crates are used in storage, they should be arranged to allow air spaces on both sides of each stack. Onions stored in open mesh bags should be stored on false floors. These floors are built in sections so that each floor will store one or two bags high and three or four bags wide, with about 4 inches of air space between each floor.

Because of the large investment required for crates and sacks and the expense of handling, the trend is rapidly toward the use of bulk storages or pallets of 25 to 50 bushels capacity. As often happens in adopting new methods, some growers have encountered adverse results in bulk storages because of improper construction and handling. These problems generally are:

1. Lack of sufficient volume of circulating air.
2. Improper air distribution caused by dirt and trash.
3. Condensation of moisture on top of the pile when warm air comes in contact with cold bulbs.

4. Bruising of onions from dropping, rough handling, or piling too deep.
5. Walls not sufficiently reinforced.
6. Insufficient openings to relieve air pressure.

With greater experience and more attention to handling, most of the problems are being solved. If bulk handling of onions is to be undertaken, it is advisable to discuss the numerous problems involving any particular storage with an experienced grower or competent engineer.

SOME ECONOMIC ASPECTS OF ONION PRODUCTION

The price received for onions is directly affected by the size of the nation's crop. Figure 23 depicts graphically the average annual prices received by growers for onions since 1924. A relative value is also shown for the price received for all food products, as calculated by the Agricultural Economics staff.

Two features may be observed from this graph. One appears in the price of onions which has been generally favorable since 1940. The second feature lies in the two-year price cycle. The notable exception

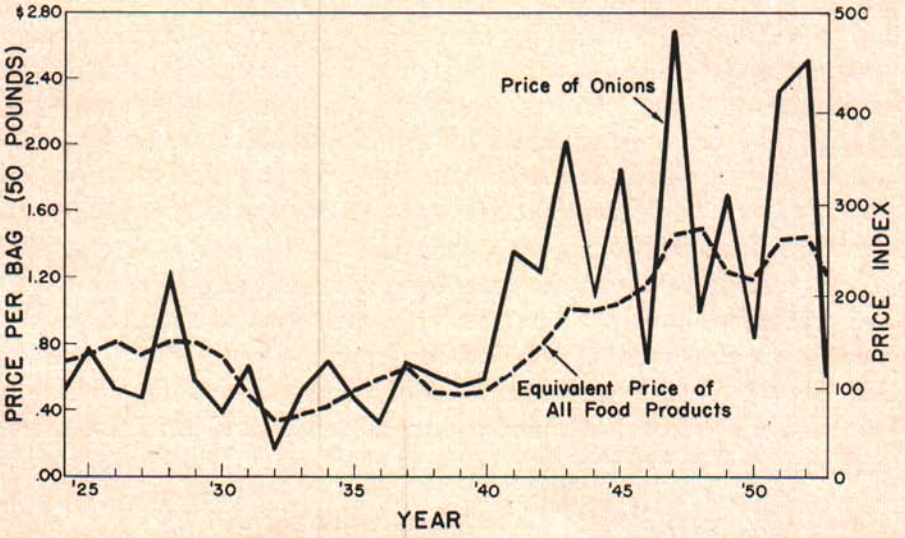

Fig. 23. Average yearly price of onions received by Michigan growers, 1924-53, and the relative index of other farm products. (Values obtained from the Agricultural Economics Dept., M.S.C., and the Statistical Yearbook.) (Average prices for 1935-39 = 100.)

TABLE 3—Average monthly onion prices received by Michigan growers (50-pound bag)*

Month	1938-1953	Poor years (*1940-'44-'46-'48-'50-'53*)	Good years (*1941-'43-'45-'47-'51-'52*)
August	$1.18	$1.09	$1.55
September	1.05	0.73	1.45
October	1.13	0.70	1.66
November	1.28	0.71	2.00
December	1.32	0.77	2.12
January	1.51	0.78	2.54
February	1.65	0.87	2.90
March	1.80	0.83	3.25
Average for years	$1.37	$0.81	$2.19

*Data summarized from monthly figures supplied by the Michigan Agricultural Statistician, C. J. Borum, in charge. The prices received in 1942 and 1949 were intermediate.

to the cycle occurred in 1952 which was a good year. Presumably either many growers had become aware of the cycle or scarcity of labor had resulted in decreased production. In spite of the exception, it would be a good management policy not to increase acreages following high onion prices. The very low prices for the 1953 crop suggest a disastrous drop following a two-year buildup from high prices.

Once a crop of onions is produced, a grower faces the all-important question of when to sell the crop. If stored, the shrinkage, storage costs, labor, and the general keeping condition of the onions must be considered. Table 3 lists averages of prices received for onions for the 16-year period from 1938 to 1953. Onion prices are also shown for good and poor years. A 16-year average of 60 cents more was realized for onions sold in February over September prices, which is a 57 percent increase. A very striking observation is that the poor years produced only 14-cents increase per bushel in the five months of storage. On the other hand, storing in good years gave $1.45 more in February, a 100 percent increase in the selling price.

Since it has not been profitable to store onions in poor years, the question then arises—Is it possible to determine in September if prices will be good or poor for the rest of the season? Generally speaking the answer is Yes; for, as shown in Table 3, onion prices averaged about 100 percent higher in September for the good years as compared with the poor years. One big exception to this trend occurred in 1949, when onions sold for $2.00 a bag in September but fell to 95 cents by February. So all in all it may be rather hazardous to attempt indicating

general rules for the price of onions, since the "futures market" is sensitive and quite speculative.

No survey has been made recently on detailed analysis costs among onion growers. In the figures obtained in 1925 by the U. S. Tariff Commission, it was reported that the cost of production in Allegan County, Michigan, was $209.15 per acre or 83 cents per bag. Figures published by Purdue University Experiment Station showed similar costs in Indiana in 1941.

Wright and Taylor of the Michigan Agricultural Economics Department found for the years of 1934-36 that 274 man hours were required to produce, harvest, and screen an acre of onions. The growers cooperating in the study had an average acre-yield of 394 bags. A successful grower storing all the crop and producing about 800 bags of onions per acre, on 100 acres, had these approximate labor-hour requirements:

Plowing	150	Hand Topping	7000
Fertilizing	150	Turning Sacks	1000
Preparing Seedbed	100	Hauling and Storing	6000
Planting	200	Screening and Marketing	12,000
Spraying and Dusting	400	Miscellaneous	3000
Rotary Cultivating	800	TOTAL	44,800 hours.
Hand Weeding	14,000		

Labor costs are the largest item in the production of onions, amounting to 40-55 percent of the total costs. From the above figures, approximately 450 labor-hours were required per acre. In addition, approximately 20 equipment-hours and 35 tractor- and truck-hours per acre were required to produce and store the onions. These values are higher than for the average grower, because of the high yields. When mechanical harvesters and bulk storages are used, the hours of labor for harvesting and packing are greatly reduced. Likewise the use of chemicals for weed control can reduce the hand-weeding costs.

In addition to labor costs, one must include such items as bags, fertilizer, seed, spray material, fuel, electricity, crates, machinery, storage, rent, insurance, drainage, cover crops, taxes, etc.

SUMMARY

1. **Adaptibility.** Michigan muck soils in general are ideally suited for the production of onions which in most years can be produced at a profit (pages 2 and 44).

2. **Reaction.** Since reaction (acidity or alkalinity) plays an important part in determining suitability and treatment of muck soil, having soil tested at intervals of 2 to 4 years is strongly recommended pages 2 and 13).

3. **Liming.** Its use is not advisable except on very acid mucks. High production may not be obtained for several years after liming (pages 4 and 13).

4. **Copper.** Its use, as sulfate or oxide, will increase yields and improve quality and color of bulbs (pages 8 and 13).

5. **Sulfur and manganese sulfate.** Their use on alkaline and near-alkaline mucks will result in increased yields, better maturity, and better keeping quality of crop (pages 5, 9 and 13).

6. **Zinc.** Zinc is beneficial to onions on newly reclaimed fields (pages 10 and 13).

7. **Fertilization.** Use of commercial fertilizers is absolutely necessary for production of good yields. Proper analysis and rate of application best adapted to your conditions depend on several factors (pages 11-15).

8. **Drainage.** Proper drainage is essential for good yields. Uniform water-level is desirable, with dams to give complete control of moisture supply (pages 16-18).

9. **Cultural methods.** Deep breaking, heavy rolling, fairly deep plowing, and shallow cultivation to control weeds are essential in onion production (pages 17-21 and 26, 27).

10. **Wind Injury.** Injury can be lessened by windbreaks along fence rows, interplanting of grain between every 2 or 3 rows of onions, by increasing content of organic fibre in soil, and by raising water level (pages 19-21).

11. **Varieties.** Although a few strains of Yellow Globe have constituted a large part of the crop in Michigan, newly developed

hybrids probably will replace them within a few years (pages 21, 22).

12. **Planting of seed, sets and transplants.** Early sowing of seed of high germination is essential for high yields. The use of sets and transplants may not be advisable (pages 23-26).

13. **Chemical weed control.** Several chemicals can be used for pre-emergence, post-emergence, and pre-harvest sprays that will aid in controlling weeds (pages 28, 29).

14. **Disease control.** The 6 most important diseases—downy mildew, neck rot, nematodes, pink root, smudge, and smut—can be largely controlled by proper rotations, use of suitable fungicides, and fumigation of soil (pages 30-34).

15. **Insect pests.** The 4 most important pests—maggots, thrips, cutworms and wireworms—can be largely controlled by proper soil management and the use of insecticides (pages 35, 36).

16. **Maleic hydrazide.** This material properly applied in the field will eliminate sprouting and root growth in storage (pages 37 and 40).

17. **Dusting, spraying, and soil treatment.** A schedule for control of various pests of onions is outlined (pages 38-40).

18. **Harvesting, grading, storing.** Methods of harvesting, grading and storing in frost proof dry storages are discussed in detail (pages 40-44).

19. **Economic aspects.** Yearly price fluctuations and labor requirements (pages 44-46).

The authors wish to thank the following persons for contributing the sections in this bulletin containing recommendations in their respective fields of specialization:

B. H. Grigsby, Botany and Plant Pathology Department—*Weed control*

Entomology Department—*Insect control*

Ray Nelson, Botany Department—*Control of plant and soil-borne diseases*

S. H. Wittwer, Horticulture Department—*Maleic hydrazide treatment and variety trials.*

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