THE FERTILIZER PROBLEM FROM THE
VEGETABLE GROWER'S STANDPOINT

BY C. E. DURST
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THE FERTILIZER PROBLEM FROM THE VEGETABLE GROWER’S STANDPOINT

By C. E. DURST, Associate in Olericulture

INTRODUCTION

The general principles of soil fertility apply with equal significance in both vegetable and farm-crop production, but there are marked differences respecting the specific manner of their application. In general farming, the quantity and proper maturity of the crops are the only objects involved; in vegetable growing, these are important, but added to them are such factors as earliness, quality, and appearance of the products. In fact, the latter are the sole factors in determining the profits from certain crops. A few days' gain in early cabbage or spinach, for instance, may mean an increase of 50 or 100 percent in the profit. Relatively small differences in the quality or flavor of such crops as melons, lettuce, and celery, often cause wide differences in the returns. The size and appearance, or "finish," of nearly all vegetables play a large part in the prices received.

In other words, looking at the question from a practical point of view, soil fertility is one thing from a general farmer's standpoint, and quite another thing from the vegetable grower's standpoint. In the first place, vegetables as a class require much richer soil than farm crops. Land capable of producing admirable farm crops will ordinarily produce only mediocre vegetables. We have in Illinois plenty of land that will produce 50 to 75 bushels of corn or 30 to 40 bushels of wheat in a favorable season. But plant this land to cabbage or onions and what would be the result? As every practical gardener knows, only fair crops of these vegetables would be produced. The best general farming land needs much building up before it will grow vegetables successfully, and three or four years of persistent effort are generally required to accomplish the result.

Where vegetables are grown on a very intensive basis, as on the high-priced land near the larger cities, tilled crops are grown practically all the time during the growing season. There is no "sowing down" as in general farming. The almost continuous stirring of the soil and the fact that vegetables, as a rule, shade it very little, permit a large loss of nitrogen and organic matter by oxidation. In fact, intensive vegetable gardening occasions a condition which approaches bare fallow; and it has been conclusively proved that bare fallow, while usually bringing about increased yields in the crops immediately following, results eventually in decidedly decreased yields, be-

cause of its destructive effect on the nitrogen and organic matter of
the soil.

The market gardener usually operates on land of high fertility. Within recent years, it has become well understood that the organisms living in the soil play a far greater role in its fertility than has been heretofore supposed. It is also known that the prodigality of this life increases with the amount of actively decaying organic matter, other things being equal. That this factor alone adds many complications to the problem cannot be disputed.

Experienced gardeners realize the importance of rich soil, and do not hesitate to fertilize heavily. Applications of 20 to 40 tons of manure to the acre annually are not at all uncommon. Besides this, large expenditures are often made for commercial fertilizers. The statistics of Massachusetts show, for instance, that during a period of ten years the market gardeners spent, on an average, $76 per acre annually for manures. Many individual gardeners throughout the country spend several times this amount. Such large outlays in fertilizers are not feasible in general farming, where the product is commonly not worth more than $25 to $50 to the acre; but they are feasible and profitable in intensive market gardening, where the product is sometimes worth $500 to $1000 per acre. The gardener can profitably use amounts and forms of fertilizers and methods of applying them that the general farmer could not possibly afford. The fact is that in long-continued successful market gardening, the original fertility content of the soil is often a matter of minor importance in comparison with the fertility applied.

The various factors mentioned, and others which might be enumerated, make the fertility problem in vegetable growing a distinct one in itself.

THE GENERAL PRINCIPLES OF PLANT NUTRITION

Ten elements, or fundamental substances, are necessary for the growth of plants. These are carbon, oxygen, hydrogen, calcium, magnesium, sulfur, iron, nitrogen, phosphorus, and potassium. None of our agricultural plants can grow without all of these. The three elements carbon, hydrogen, and oxygen constitute 90 to 95 percent of the bulk of most mature crops, yet plants are able to secure these in unlimited amounts (except during drought) from air and water. Calcium, magnesium, sulfur, and iron are used by garden plants in small quantities, and as most garden soils contain them in relatively large amounts, their importance becomes insignificant. The elements nitrogen, phosphorus, and potassium, however, are used in considerable quantities, and as the supply of these is usually limited, they become the controlling factors in crop production. Indeed, it is generally conceded that the supplying of these three elements to the soil in sufficient amounts and proper forms, together with favorable physical conditions, constitutes the entire problem of soil enrichment.
LOSSES OF FERTILITY IN VEGETABLE GROWING

In order to comprehend fully the nature of the fertility problem as related to vegetable growing, it is well to consider first the extent and sources of the losses of fertility from vegetable soils; for it is recognized that for continued successful crop production, it is necessary to return to the soil, in some way or other, as much fertility as is removed by the various agencies at work. Losses occur through crop removals, by drainage and leaching, and by oxidation of the nitrogen and organic matter.

LOSSES IN CROP REMOVALS

In Table 1, the amounts and commercial values of the three limiting elements removed per acre by several important vegetable and farm crops are presented.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Estimated yield</th>
<th>Plant food removed</th>
<th>Value of fertility removed</th>
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<tr>
<td></td>
<td>Estimated yield</td>
<td></td>
<td>lbs.</td>
</tr>
<tr>
<td>Potato</td>
<td>150 bu.</td>
<td>30.6</td>
<td>6.3</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>200 bu.</td>
<td>24.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Turnip</td>
<td>800</td>
<td>79.2</td>
<td>13.2</td>
</tr>
<tr>
<td>Carrot</td>
<td>500</td>
<td>55.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Parsnip</td>
<td>600</td>
<td>160.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Onion</td>
<td>600</td>
<td>92.3</td>
<td>20.6</td>
</tr>
<tr>
<td>Lettuce</td>
<td>10000 lbs.</td>
<td>23.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Asparagus</td>
<td>3600 tons</td>
<td>11.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Cabbage</td>
<td>12 tons</td>
<td>72.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Tomato</td>
<td>500 bu.</td>
<td>48.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Cucumber</td>
<td>500</td>
<td>40.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Corn</td>
<td>100</td>
<td>100.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>50</td>
<td>71.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Oats</td>
<td>75</td>
<td>49.5</td>
<td>8.3</td>
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In computing the values, 20 cents per pound has been allowed for the nitrogen, 10 cents for the phosphorus, and 6 cents for the potassium. These are the approximate prices prevailing at present for the three elements in nitrate of soda, steamed bone meal, and potassium sulfate.

It should be noted that the yields assigned to the vegetables are for the most part conservative, while in the case of the three farm crops, maximum yields have been allowed. But even comparing the figures as they stand, it will be seen that vegetables remove large amounts of the three limiting elements from the soil,—in all probability more than the ordinary farm crops. Generally speaking, vegetables do not remove as much nitrogen as the farm crops; there is practically no difference in the amounts of phosphorus used; and vegetables remove much more potassium than general farm crops.
Parsnips are particularly heavy feeders, the money value of the fertilizing constituents contained in a 600-bushel crop being, at commercial prices, $42.90. Turnips, cabbage, and onions are also rather heavy feeders. Lettuce and asparagus, which are often a gardener’s most profitable crops, are very light feeders. The root crops, in general, remove large amounts of potassium from the soil.

The figures in Table 1 account for the removal of but a single crop in a season. The vegetable grower, however, commonly removes two, and sometimes three, crops in a season. For instance, the growing of a crop of both early cabbage and late turnips is perfectly feasible and often practiced. These two crops, with the yields given in the table, would remove from the land, 151.2 pounds of nitrogen, 25.2 pounds of phosphorus, and 192 pounds of potassium, the total value at current prices being $44.28. A 100-bushel corn crop, on the other hand, would remove in the grain 100 pounds of nitrogen, 17 pounds of phosphorus, and 19 pounds of potassium, worth $22.84. It is apparent, from these figures, that vegetables make heavy drains upon the fertility of the soil.

**Losses by Drainage and Leaching**

If the fertility removed in the crops constituted the total loss from the soil, the problem would not be so difficult, but unfortunately serious losses occur thru other channels as well. Any fertility existing in soluble form is likely to be lost at any time in drainage waters and by leaching downward thru a loose subsoil. The amount lost in this way depends upon the soluble fertility present, the amount of water leaving the land, either by surface or tile drainage, and the character of the subsoil,—whether “open” or “tight.” More soluble fertility exists in summer than in winter, and, except in places where the winters are fairly mild and open, as in southern Illinois, drainage and leaching are most active at that time.

The amount of phosphorus lost by drainage and leaching is generally conceded to be small, as little of it exists in soluble form at any time. Potassium is lost in larger amounts. Most soils contain large amounts of this element, but practically all of it exists in very insoluble forms; hence the loss of even part of the small amount existing in soluble condition, which is the only kind plants can use, is of vital significance to the gardener.

The greatest loss of fertility by drainage and leaching is in the nitrogen. This is the most deficient of the three elements in a great many vegetable soils, and especially in those which have been cropped without much attention to fertilizing. It is also the most expensive to supply, costing in commercial forms about twenty cents a pound. That much nitrogen is lost in this way is proved by experimental evidence from several sources. The most complete tests have been made by Lawes and Gilbert at Rothamsted, England. During
four years they found that the drainage thru 40 inches of soil from land receiving 15.7 tons of manure annually contained, on an average, 16.27 pounds of nitrogen per million pounds of water. Unfortunately, the amount of drainage from this land was not measured. From uncropped land, however, the average drainage for 31 years was 14.73 inches, but it was not likely so great as this from the cropped land. Granting a drainage of 10 inches, which is their estimate from the ordinary cropped land at Rothamsted, the above amount would result in a loss of 36.6 pounds of nitrogen per acre annually. The average annual rainfall at Rothamsted is 28.02 inches, while in Illinois it varies from 33.48 inches in the northern part to 42.19 inches in the southern part, the average for the state being 37.39 inches. Thus the drainage from Illinois soils is likely much greater than from those at Rothamsted. Furthermore, a greater quantity of manure than 15.7 tons per acre annually is often used on garden soils in Illinois. There is, therefore, a probability of much greater loss of nitrogen from Illinois garden soils by drainage and leaching than occurred in the investigations described above.

**Losses of Organic Matter and Nitrogen by Oxidation**

Besides the losses of nitrogen in crop removals, in drainage waters, and by leaching, there is a large loss by oxidation of the humus of the soil, which is organic matter in an advanced stage of decay. The loss by this means can best be understood and appreciated by reflecting how quickly a pile of weeds or other organic substance disappears. We say it "rots." In chemical terms we call the process "oxidation," and it consists in a combining of the substances composing the rubbish with the oxygen of the air. Most of the compounds formed are gases and pass off into the air. All dead plant and animal substances, including the humus of the soil, are subject to oxidation. The more contact there is with the air, other things being equal, the more rapidly oxidation proceeds. Humus contains from 90 to 95 percent of the nitrogen of the soil, and about one-sixteenth of the humus is nitrogen; hence, anything which affects the humus affects the nitrogen also. The immense amount of tillage necessary in vegetable growing is constantly bringing the humus, nearly all of which is contained in the surface, or plowed soil, into contact with the air, about one-fifth of which is oxygen. Under these conditions the loss of humus and nitrogen by oxidation must proceed at a rapid rate. Furthermore, vegetable crops shade the ground but little, and the free movement of the air and the direct action of the sun aid

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the process. It would be difficult to determine just how much loss occurs in this way, but that it is large there can be no doubt.¹

**How to Check the Losses of Fertility**

The losses of fertility in crops sold from the land cannot be checked, and no one desires that they should be. Losses in drainage waters and by leaching, however, can be checked to a certain extent by proper methods. The land should be so handled that surface drainage will be reduced to a minimum. On rolling land, plowing should be done in contour fashion, so that the furrows will extend crosswise of the slope rather than up and down it. In planting, the rows should also extend crosswise of the slope. It is a good plan to plow the land (unless it is hilly) in the fall, and to leave it "rough" thru the winter,² as this will lessen the surface drainage.

When the land is not needed for a regular crop, it is far better to sow it to a cover crop than to leave it bare. Thruout the growing season, the soil organisms are constantly converting nitrogen into soluble forms by a process called nitrification; and other plant food is becoming soluble because of other influences. Much of this plant food, as it becomes soluble, will be absorbed by a growing crop, but if the land is left bare, this plant food is largely lost by drainage and leaching. The Rothamsted drainage experiments cited show that a much larger amount of nitrogen existed in the drainage waters when the land was bare than when occupied by a growing crop. From another source,³ it is reported that the loss of nitrogen was twenty times greater from bare land than from land occupied by rape or grass. These differences were no doubt due to the fact that the growing crops had absorbed most of the soluble nitrogen, while it was largely lost from the bare land by drainage and leaching. The fertility gathered in this way by cover crops will, of course, be returned to the soil when they are plowed under.

Not a great deal of the loss of organic matter by oxidation can be prevented. Crops must be well cultivated; however, there should

¹These losses of fertility are partly balanced by small gains thru natural causes which should be mentioned, but which, so far as is known, are of no practical significance in solving the problem. Investigations from a number of sources indicate that probably from 5 to 10 pounds of nitrogen are brought to the earth in rain water annually. There are some indications that where legumes are grown the tubercle bacteria continue to fix a small amount of nitrogen in the soil after the death of their hosts. Soil organisms called azotobacter fix some atmospheric nitrogen besides that collected by the legume bacteria. While the gain from these sources is a help, it is generally believed to be of little significance in solving the nitrogen problem.

²There would be exception to this in the case of land to be devoted to early crops, which will dry out earlier if worked to a smooth surface after plowing in the fall.

be no more cultivation than is necessary to conserve moisture and de-
stroy weeds. Cover crops, besides locking in their tissues soluble
plant food, as mentioned above, will aid in checking oxidation by
shading the soil and by hindering the movement of the air at the
surface. Furthermore, when turned under, they will aid in replen-
ishing the supply of organic matter in the soil.

**Probable Losses of Fertility Annually**

After all feasible precautions have been taken to check the losses
of fertility from the soil, it will be found that large losses still occur.
Minnesota experiments (Minnesota Bulletin 53) indicate that for 24.5
pounds of nitrogen removed annually per acre in the crops in con-
tinuous wheat raising, a total of 171 pounds per acre was lost from
the land. There were certain circumstances in these experiments
which might admit of the figures being somewhat at error, but even
granting some discrepancy, the results are very significant. After
further tests by the same station (Minnesota Bulletin 94), it was con-
cluded that from three to five times as much nitrogen is lost from the
soil annually as is removed in crops. In Canada Professor Shutt
found that in twenty-two years, during which time six crops of wheat,
four of barley, and three of oats were grown, with nine fallows inter-
posed, practically one-third of the nitrogen content of the soil to a
depth of eight inches was lost.

There are no investigations known to the writer which indicate
the loss of fertility in vegetable growing, and it is more or less hazard-
ous to make an estimate. Taking everything into consideration, how-
ever, it will certainly be within the facts to assume that where vege-
tables are grown on an intensive basis, there is an average annual loss
per acre of 200 pounds of nitrogen, 25 pounds of phosphorus, and 100
pounds of potassium. The stock of these elements, especially that of
nitrogen and phosphorus, is none too large to begin with, even in our
best soils. Plants can use each year only a very small part of that
which is present, probably not over \( \frac{1}{2} \) to 1 percent. Hence, it re-
quires only the simplest kind of reasoning to convince one that for
the continued production of profitable crops, we must supply to the
soil, in some way, as much fertility as is removed. If we are to in-
crease the productivity we must supply, at least for a while, more
than this amount.

**Supplying Fertility to the Soil**

The supplying of fertility to the soil is not merely a matter of
furnishing fertilizers carrying a sufficient amount of the elements to
offset the needs, either in vegetable or any other kind of crop pro-

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\(^3\)Report of Dominion Experiment Farms, 1905.
duction. The amount and form of fertilizer used and the type and condition of the soil have an important bearing on the matter. This is especially true in vegetable gardening, where so many of the plants grown are peculiarly sensitive to surrounding conditions.

**NITROGEN AND ORGANIC MATTER**

The nitrogen and organic matter are so closely associated that they can scarcely be discussed separately. Nitrogen has much to do with the vegetative growth or size of a plant. Organic matter has many offices in the soil. It gives "life" to the soil; it improves the texture; it increases the water-holding capacity; it makes soils more resistant to drought; it darkens the color of light soils and makes them warmer in early spring; it promotes the growth of organisms engaged in making insoluble plant food soluble; it contains from 90 to 95 percent of the nitrogen of the soil; and thru its decay it renders mineral forms of fertility available for plant use. Its presence in large amounts is absolutely imperative if success is to be attained in the use of commercial fertilizers. The excessive use of commercial fertilizers on soils deficient in organic matter is responsible in a large degree for "soil sickness," "malnutrition," and the "physiological diseases" that are becoming so common in some trucking sections of the country. In view of the importance of organic matter and nitrogen, and the fact that large amounts of these are lost from vegetable soils, as already explained, gardeners should direct especial attention toward maintaining a plentiful supply of both in the soil. Organic matter and nitrogen may be provided by plowing under manure, crop refuse, and crops grown for that purpose. Peat, muck, and other materials rich in organic matter may be used where available. In addition, nitrogen may be furnished by commercial fertilizers.

**MANURE, ITS CARE AND USE**

Manure is without doubt the best general fertilizer for vegetable crops, tho it can usually be supplemented profitably by such fertilizers as bone meal, rock phosphate, and potassium sulfate. A ton of ordinary barnyard manure contains about 10 pounds of nitrogen, 3 pounds of phosphorus, and 8 pounds of potassium. Its composition varies much, according to its moisture content and to the kind of animals and the feed they receive. Besides the fertilizing elements, manure supplies a large amount of the very best kind of organic matter. A small quantity of actively decaying organic matter, as is furnished in manure, is often more effective in the soil than a much greater amount of older and less active organic matter. Manure also exerts a marked stimulating influence on soils at times. There are instances on record in which the increase alone in the yields caused by manure contained more of
certain elements than was supplied by the manure. Such occurrences are no doubt due to its effect in releasing insoluble forms of fertility in the soil. Manure, therefore, is valuable both for the elements it carries and for its favorable physical and chemical effects.

While every gardener recognizes the value of manure, the proper care of it is not always understood. The waste of manures in vegetable growing is tremendous. It is a common practice to haul manure from ears or from the city and to place it in great piles along the roadside or in fields, leaving it there for weeks; to allow it to lie on the soil for a long time before plowing it under; and to throw it out in the barnyard to lie over winter. These practices are all very wasteful and should be avoided. The Ohio Experiment Station\(^1\) found that in three months (from January to April) 38.75 percent of the organic matter, 30.29 percent of the nitrogen, 23.76 percent of the phosphorus, and 58.84 percent of the potassium were lost from manure placed in flat piles in the barnyard. At the Maryland Station\(^2\) eighty tons of manure allowed to lie in an uncovered pile were reduced to 27 tons at the end of the year's time. At the New York Cornell Station 4000 pounds of horse manure decreased to 1770 pounds from April 25 to September 22, and its fertilizing elements decreased in value during the same time from $5.48 to $2.03. In another Cornell test lasting six months, exposed manure lost 56 percent in weight of dry matter and 43 percent in plant-food value. In Canada, two tons of manure, containing 1938 pounds of organic matter, were exposed from April 29 to August 29,—four months. The organic matter was reduced during that time to 655 pounds, and the nitrogen content decreased from 48.1 pounds to 27.7 pounds.

Thus it is seen that manure deteriorates rapidly under improper methods of management. Fortunately, most of this loss can be prevented. Broadly speaking, the greatest proportion of fertility is conserved when the manure is applied in the freshest condition possible and plowed under immediately. It would be unwise, however, to use fresh manure in large quantities just before planting in spring or summer. The ideal method is to apply and plow under all manure in the fall, for it will then rot before spring and no evil results are likely to follow. But it is rarely possible to follow this plan exclusively, for in practical market gardening, manure must be secured when available, which may be at any time of the year.

The horse manure produced at home should not be allowed to accumulate in the stalls for longer than a few days at a time. Preferably it should be applied as soon as possible after being made and should be plowed under at the first opportunity. At times when the land is occupied by growing crops, the manure is best conserved by placing

\(^1\)Ohio Exp. Sta. Bul. 183, p. 205.
it under cover or in a basin or pit in the barnyard. If, in addition, it can be firmly packed, and saturated with water occasionally, the losses will be reduced to the minimum under the circumstances. It is well to apply and plow under such manure as soon as possible.

Manure obtained during the winter should not be stored in large piles. Neither should it be dropped in small piles about the fields, as is so often done. It is best to broadcast it as hauled. Preferably, it should be used on land that is not to be planted to early spring crops, for manure applied during winter often greatly interferes with the drying out and warming of the soil in the spring and delays the planting. Land intended for early crops should be manured in the fall and plowed in narrow "lands," in ridge fashion. It is also well

![Manure Left Lying by the Roadside](image)

**Fig. 1.—Manure Left Lying by the Roadside—A Too Common Practice in Southern Illinois**

to use manure secured in winter on level rather than on rolling lands, for less loss by drainage will then occur. Rolling lands are usually best treated by manuring and plowing in the fall.

It often becomes necessary, because of contracts and other reasons, to haul manure during the summer. Its handling at this time is an important matter, and one in which many costly mistakes are made. If possible, the manure should be applied to a vacant area not needed for another crop, and plowed under immediately. But all the land is sometimes occupied with crops, and some other disposition must be made. The best way to treat such manure is to place it in flat piles not over three or four feet in depth, pack it down thoroly, and soak it with water every week or two. Crop remains and other refuse are often mixed with the manure in composting. Sometimes, soil and
manure are placed in alternate layers. These treatments aid in checking fermentation and probably effect a saving in the manure.

In traveling thru the trucking district of southern Illinois, one often sees great piles of manure along the roadside. It is placed there as hauled from the cars, usually when the roads are bad or during summer when the land is occupied. Sometimes, when the hauling distance is great, it is unloaded a short distance from town in order to empty the car in the required time. But the significant point is that it is often left in such places for weeks. This is a very wasteful practice and should be avoided when at all possible. If the manure cannot be hauled directly to the field and spread out, it should be piled inside the field in preference to unloading it on the roadside. If it must be placed on the roadside, it should be left there for the shortest time possible.

When the supply of manure is limited, the question arises as to how to make the best use of the amount at hand. This is often the case the first two or three years vegetables are being grown on a piece of land, and before there has been sufficient time to build it up in fertility. In such cases, better results as a whole will ordinarily be secured by spreading the manure out thinly over a relatively large area than by applying it heavily to a small patch. With some crops, chief among which are melons and cucumbers, the manure can be made to reach much further by applying it under the hills. In experiments conducted by this station\(^1\) with muskmelons in southern Illinois, larger yields were obtained from 4.5 tons per acre of rotted manure applied under the hills than from 16.5 tons applied broadcast before plowing. It should be emphasized that manure used in this way should be thoroly rotted, for undecomposed manure applied under hills almost invariably causes injury by its "burning" effect. There may be exception to this, however, during a cool, moist season. Manure used under hills should always be thoroly compacted before planting the crop.

The composting of manure is such a common practice among vegetable growers that it warrants specific attention. Many of the older publications on vegetable gardening place great emphasis on the superiority of composted manure, and we find many gardeners composting all or nearly all of the manure used. The process consists in placing the manure in flat-topped piles three or four feet in depth (just deep enough to prevent heavy rains from soaking thru and leaching out the plant food), and forking it over every week or two. Water is often used in addition. The result is that fermentation is greatly increased for a time, and that a uniform degree of decay is secured thruout the pile. The rotted manure obtained by this treatment is very valuable for hotbed and greenhouse work and for use under the hills of some

\(^1\) Ill Agr. Exp. Sta. Bul. 155.
crops in the field, and it may be applied during spring and summer with less danger of injury than fresh manure. One should bear in mind, however, that even with the best management a large loss of fertilizing value occurs in composting, as already shown. It is no doubt advisable for gardeners to compost sufficient manure (and it is best to use manure secured during summer, since this is the most difficult to conserve) to meet their needs for the purposes above mentioned, for even tho quite a loss of plant food occurs, nothing can take its place for such work. From the standpoint of the most economic use of the fertilizer at hand, however, composting is very wasteful of plant food and should be avoided as a general practice.

THE USE OF CROP REFUSE AND COVER CROPS

Manure is without doubt the best general fertilizer for the vegetable grower; and where it can be obtained at a reasonable figure, it is best to depend chiefly upon it, tho in any case its value may usually be enhanced by the use of the proper commercial fertilizers in conjunction, as will be described later. In intensive market gardening, where the land is nearly always high in value and must be occupied by money crops thruout the growing season, manure is also one of the cheapest sources of fertility. However, in less intensive work, as in truck farming, it is not always feasible to obtain a sufficient amount of manure to meet the needs, and it becomes necessary to turn to other sources for the nitrogen and organic matter requirements. Fortunately, there are other ways by which these may be secured.

**FIG. 2.—THE DISK-HARROW IS A USEFUL IMPLEMENT FOR CUTTING UP CROP REMAINS PREPARATORY TO FLOWING THEM UNDER**
Many gardeners remove crop remains and weeds from the land or burn them. Whatever may be said in favor of these methods from other standpoints, they are bad procedure from the fertility standpoint. All the nitrogen and organic matter contained in the growth is lost to the soil by either method. Unless it is absolutely necessary, in order to control some serious disease, injurious insect, or weed, crop refuse and weed growth should never be removed from the land. Instead, they should be plowed into the soil, and in such cases it is well to plow early in the fall, in order that the vegetation will have opportunity to rot before spring. In the case of tomato vines, cabbage stumps, and other refuse which rots slowly in the soil, it is better to mix them with manure and compost them until disintegrated, than to burn them or cast them into a ditch.

![Image of a field with crop refuse and weeds]

**FIG. 3.—WEEDS CAN SOMETIMES BE USED AS A SOURCE OF ORGANIC MATTER**

The amount of organic matter and nitrogen obtainable from crop refuse and weeds (in good gardening) is at best small, and it is usually necessary, where the manure supply is limited, to grow cover crops in addition in order to maintain the supply of humus in the soil. Many gardeners go to great trouble and expense in hauling manure, and neglect splendid opportunities to grow cover crops. With a little attention in this direction they could easily make possible the use of less manure. The nature of the gardening business makes the use of cover crops an extremely practicable and inexpensive method of maintaining the supply of organic matter in the soil. Many of the regular crops will admit of cover crops being sown at the time of their last
cultivation, while others mature early enough in the season to allow plenty of time for growing a cover crop afterward.

There are a number of cover crops well adapted for growth in connection with vegetables in Illinois. Perhaps the most important of these are oats, rape, rye, cowpeas, soybeans, and hairy vetch. From the standpoint of their value as cover crops these are divided into two classes, leguminous and non-leguminous.

Oats, rape, and rye are non-leguminous crops, and in this connection are valuable only for the organic matter they furnish. Oats grow rapidly, but of course die with the first freeze, and should there-

![Cowpea Root Showing Nodules](image-url)

**FIG. 4.**—COWPEA ROOT SHOWING NODULES IN WHICH LIVE THE NITROGEN-GATHERING BACTERIA
fore be planted early enough to permit them to make a good growth. Rape requires practically the same conditions as oats. It is best to plow under both of these crops as soon as destroyed by frost. Rye possesses certain advantages which make it a valuable cover crop. It may be sown later than any of those mentioned, making a fair growth when planted as late as October 1 to 15. It thrives even on poor soils, and it lives thru the winter without difficulty. When rye is used for soil improvement, it should be turned under in early spring, for it robs the soil of moisture if allowed to remain too long and in addition locks in its tissues plant food that will not again be available for plant use until the vegetation has rotted.

Cowpeas, soybeans, and hairy vetch\(^1\) are legumes. These crops not only furnish organic matter when turned under, but they are capable of adding nitrogen also. Thru bacteria living in nodules on their roots (see Fig. 4) they are capable of appropriating free nitrogen from the air, of which about 75 percent is nitrogen. They are, therefore, more desirable cover crops than oats, rape, and rye when they can be grown. The amounts of organic matter and nitrogen contained in crops of these legumes are shown by tests conducted at the Delaware and New York Cornell Experiment Stations.

In the Delaware tests, sowings of these three legumes, among others, were made on July 22. Table 2 shows the amounts of dry matter and nitrogen contained in the growth per acre in November of the same year. The tests show that soybeans made practically twice as much growth and contained twice as much nitrogen as cowpeas. Vetch made less than half as much organic matter as soybeans, but contained nearly as much nitrogen, since it was richer in that element than the soybeans.

<table>
<thead>
<tr>
<th>Legume</th>
<th>Dry matter</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In tops</td>
<td>In roots</td>
</tr>
<tr>
<td>Soybeans</td>
<td>6790</td>
<td>756</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>3718</td>
<td>310</td>
</tr>
<tr>
<td>Hairy vetch</td>
<td>3064</td>
<td>600</td>
</tr>
</tbody>
</table>

\(^1\)Compiled from Del. Exp. Sta. Bul. 60.

The Cornell tests include comparisons of cowpeas and vetch only. The following amounts of dry matter and nitrogen were contained in the growth per acre from seedage on July 18, the samples being taken November 10. Naturally, the conclusions were that vetch was the better crop to grow for soil improvement purposes.

\(^1\)Crimson clover is an admirable cover crop in some parts of the country, but unfortunately this plant cannot withstand the severe winters in Illinois.
TABLE 3.—DRY MATTER AND NITROGEN IN GROWTH PER ACRE:
CORNELL EXPERIMENTS
(Expressed in pounds)

<table>
<thead>
<tr>
<th>Legume</th>
<th>Dry matter</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In tops</td>
<td>In roots</td>
</tr>
<tr>
<td>Hairy vetch</td>
<td>6824</td>
<td>567</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>2622</td>
<td>454</td>
</tr>
</tbody>
</table>

*Compiled from N. Y. Cornell Exp. Sta. Bul. 198.*

The results obtained in the two places are not consistent, but the differences are no doubt due to differences in soil. At any rate, the results from both places serve to show that these legumes are capable of supplying large amounts of organic matter and nitrogen to the soil. Which of the three is the best to grow will no doubt be determined largely by local conditions.

There are, however, some points in favor of vetch which are not brought out by the above figures. It should be noted that in both cases the samples of all the crops were taken in the fall. But vetch lives thru the winter and makes some growth during mild periods and in early spring before it is turned under, while cowpeas and soybeans die in the fall with the first hard frost. Thus, in the above tests, cowpeas and soybeans had completed their growth and ceased operations, while vetch had not. Another point in favor of vetch is that it is better adapted for sowing between many vegetable crops before the last cultivation, for it grows slowly at the start, and therefore offers little, if any, competition before the crop reaches maturity. Furthermore, vetch will stand the trampling necessary in harvesting the regular crop. Everything considered, it appears that hairy vetch is one of the very best crops which can be grown in connection with vegetables in Illinois for soil improvement. The hairy vetch (*Vicia villosa*) is the only one that will live thru the winter, and it is therefore the only one which should be planted in this state. The one discouraging feature about the use of vetch is the high price of the seed.

It is impossible to draw any direct conclusions as to whether cowpeas or soybeans are the better. Where soybeans will grow well, they are the better crop of the two, for they make a larger growth, bear about ten bushels more seed to the acre, and are not so injured by light frosts as cowpeas. On soils fairly rich to begin with, and in the northern half of the state, soybeans are no doubt the better crop to grow. Ebony is a good variety for the southern part of the state, and Medium Yellow (also called Iota San) for the northern part. Whippoorwill and New Era are good varieties of cowpeas.

Legumes do not secure all the nitrogen they contain from the air, but they secure a larger percentage when the soil is poor in that element than when it is rich in it. Cowpeas appear to be able to obtain
as much as 73 percent of their nitrogen from the air under certain conditions, according to tests made by this station.\(^1\) Soybeans do not appear capable of appropriating such a large percentage.\(^2\) It may be

safely assumed that, as a rule, legumes secure from one-third to two-thirds of their nitrogen from the air under favorable conditions.

\(^1\)Ill. Agr. Exp. Sta. Bul. 94.
The three crops mentioned—cowpeas, soybeans, and hairy vetch—seem capable of appropriating some nitrogen from the air when grown in soils which contain some acid, but they make a distinctly better growth, and undoubtedly collect more nitrogen, in soils which have been limed.

The soil must be well inoculated with the proper bacteria if legumes are to accomplish the best results in gathering nitrogen. Frequently the large seeds of those mentioned have sufficient bacteria clinging to them for this purpose; but it is wise, when a legume is being grown on the land for the first time, to introduce these organisms artificially. This may be readily accomplished by securing soil from an area which has recently grown a well-inoculated crop of the legume (indicated by an abundance of nodules on the roots), and scattering it over the land to be planted. It is well to do this on a cloudy day, and to harrow or disk the land as soon as possible after the application, for the bacteria are quickly killed by the sun.

It is generally held that legumes contain as large a percentage of nitrogen when they are in full bloom as they ever will contain. So far as their nitrogen-gathering power is concerned, therefore, it is as well to turn them under at this time as at any other. No disadvantage results, however, from allowing them to grow longer.

The amount of nitrogen which legumes can collect from the air depends, therefore, upon the legume used, the amount of growth made, the amount of nitrogen in the soil, the character of the soil,—whether acid or neutral,—inoculation with the proper bacteria, and the time the crops are plowed under. Under favorable conditions, the legumes which might be grown in connection with vegetables (if all the growth is plowed under) could probably be depended upon to add to the soil from 50 to 100 pounds of nitrogen per acre in a season. In addition they will add large amounts of organic matter. Thus it will be seen that these crops are of very great value to the gardener in maintaining the high state of fertility so necessary for successful vegetable growing.

**THE USE OF COMMERCIAL FORMS OF NITROGEN**

Besides using liberal quantities of manure and paying close attention to crop refuse and cover crops, the gardener will often find commercial forms of nitrogen profitable. The following are among those in most common use.

**TABLE 4.—IMPORTANT COMMERCIAL FORMS OF NITROGEN**

<table>
<thead>
<tr>
<th></th>
<th>Pounds nitrogen(^1) per ton</th>
<th>Cost per ton</th>
<th>Cost per pound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate of soda</td>
<td>310</td>
<td>$60.00</td>
<td>$.193</td>
</tr>
<tr>
<td>Dried blood</td>
<td>280</td>
<td>54.50</td>
<td>.194</td>
</tr>
<tr>
<td>Sulfate of ammonia</td>
<td>400</td>
<td>75.00</td>
<td>.187</td>
</tr>
</tbody>
</table>

\(^1\)The amount of nitrogen varies, of course, with the grade.
Generally speaking, nitrate of soda is the most desirable form of commercial nitrogen to use. In tests by Voorhees it was found that a number of plants recovered from the soil, on an average, 62.09 percent of the nitrogen applied in nitrate of soda, 43.26 percent of that applied in sulfate of ammonia, and 40 percent of that applied in dried blood. Several other prominent investigators report similar results. These figures, besides favoring nitrate of soda, show that a considerable part of the nitrogen applied in commercial forms is never recovered by the crop.

Another advantage of nitrate of soda not possessed by other commercial forms of nitrogen is that it tends to correct the acidity of the soil. While its help in this direction is not great, it is well to know that its influence is on the right side.

Marked benefit commonly follows the use of nitrate of soda early in the spring in connection with very early crops. This is due to the fact that plants can make use of nitrogen in nitrate form immediately, and that there is little nitrate nitrogen in the soil at this time of the year. The soil organisms engaged in changing organic and other forms of nitrogen to soluble or nitrate form are practically inactive at the soil temperatures commonly prevailing in early spring. Below 50° F. their action is practically at a standstill, but their activity increases with the temperature up to about 100° F. Thus, little nitrogen is becoming available during early spring, and, as practically all of the small amount existing in the soil in soluble condition the fall before has been lost by drainage and leaching during the winter, nitrate of soda will supply this element in proper form at a time when plants cannot obtain a sufficient amount of it from other sources for the best growth.

Nitrate of soda is often applied in relatively large amounts for general fertility purposes before planting the crops, but it is better economy to use this form for top dressing to the growing plants. It is instrumental in hastening the development and in increasing the size of the specimens in certain crops. In New Jersey it was found that in soil already very fertile, and to which liberal amounts of complete commercial fertilizer were applied in addition, nitrate of soda applied at intervals to the growing crops caused very marked increases in the yields of cabbage, celery, tomatoes, turnips, and peppers. Experiments conducted by this station, at Urbana, on brown silt loam heavily manured each year but receiving no other fertilizer, indicate that nitrate of soda may be used with benefit on early cabbage, cauliflower, radishes, beets, turnips, and spinach. Tests made in several places indicate that lettuce is markedly improved by the nitrate except when the soil has received heavy applications of manure. Fresh

1 N. J. Exp. Sta. Bul. 221.
horse manure contains organisms which decompose nitrates and convert their nitrogen to gaseous forms. It is advisable, therefore, to avoid its use in large quantities immediately before planting when nitrate of soda is to be used for top-dressing purposes.

In order to secure the best results from nitrate of soda, it should be applied to the growing plants in from two to four top dressings, depending upon the length of the growing season of the crop treated. The first application should be made when the plants are well started, and succeeding applications should be made at intervals of about ten days to two weeks. From 80 to 100 pounds per acre should be used each time. The nitrate should be ground or pounded into small particles. To prevent "burning" the leaves of the plants, it is best to apply it in such a way that it does not come into direct contact with the foliage. There are machines on the market made especially for handling this fertilizer; they apply it in drills and cover it at one passage. A very satisfactory way to use the nitrate on a small scale is to scatter it about the plants by hand. Some report success from broadcasting the nitrate over the patch when the foliage is completely dry, claiming that the particles bounce off the plants. Others state that they distribute it during a rain and that the nitrate washes off before any damage has resulted. Where an overhead system of irrigation is at hand, two additional methods present themselves. One is to apply the nitrate broadcast and irrigate immediately; the other is to dissolve it in a storage tank and apply it directly thru the system. One should finish with clear water when using the latter method. The use of the irrigation system, however, is not always practicable, since it is sometimes not advisable to irrigate at the time one wishes to apply the fertilizer. Whatever the method of application, nitrate of soda should be worked into the soil as soon as possible.

It is far better to use the nitrate in small amounts at intervals, as explained, than to apply the full amount at one time early in the season. Applied in the latter fashion there would not only be danger of injury to the plants, but there would likely be an excessive waste of the nitrate as well, for nitrate of soda is very soluble and much of it would be lost by drainage and leaching before it could be utilized by the plants. In the case of some crops, particularly those which produce fruit, it is usually not advisable to continue the application of nitrate of soda until too near the time of maturity, for it may continue to stimulate vine growth at the expense of the fruit.

Dried blood is probably the best form of commercial nitrogen to use when it is desired to make relatively heavy applications before planting the crops. It is not likely to be injurious to plants when used in this way, and its nitrogen, which exists in organic form, is not so subject to loss by drainage and leaching as that in nitrate of soda. Again, thru the action of the soil organisms, its nitrogen is
changed to nitrate form gradually and can be utilized by the growing plants throughout a longer period.

Sulfate of ammonia has become low enough in price for consideration as a fertilizer only within late years, and not a great deal is known about its use. Some persons have employed it with success, while others make very unfavorable reports. It seems essential that the soil contain plenty of lime for success with this form of nitrogen. In view of the conflicting information concerning its effect, it is well for gardeners to proceed cautiously with its use, for the present at least.

**Phosphorus**

Applications of phosphorus do not usually prove of very great value until the soil has been fairly well built up in organic matter and nitrogen. Nearly all of our soils are low in phosphorus content; manure furnishes this element in relatively small proportions; and since it cannot be obtained from the air, as in the case of nitrogen, we must turn to other sources for our supply. Phosphorus appears to have an intimate relation with life itself, for it is found in very considerable amounts in the reproductive cells of plants and animals. It plays an important part in the development of fruits and seeds. The principal commercial forms of this element are given in Table 5.

<table>
<thead>
<tr>
<th>TABLE 5.—IMPORTANT FORMS OF PHOSPHORUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pounds phosphorus per ton</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>Acid phosphate..............</td>
</tr>
<tr>
<td>Steamed bone meal..........</td>
</tr>
<tr>
<td>Rock phosphate.............</td>
</tr>
</tbody>
</table>

For the quickest results, acid phosphate is the best form to use, for it supplies phosphorus in more soluble condition than the other two forms mentioned. However, it is also the most expensive, and it adds acidity to the soil. While its use may be more justifiable in vegetable growing than in general farming, it should be employed with caution. Steamed bone meal is a much safer form, and furnishes phosphorus somewhat more cheaply as well, and in a form which plants can use almost as quickly as that in acid phosphate. Bone meal tends to correct soil acidity, but its influence in this direction cannot be great because of the relatively small amount used. Besides the phosphorus it contains, steamed bone meal also carries about twenty pounds of nitrogen to the ton. As a source of phosphorus, it is preferable to raw bone meal.

The above forms of phosphorus are valuable for use where immediate results are desired, but if the gardener will provide for his phosphorus needs a year or two in advance, he may make use of rock
phosphate, which supplies the element far more inexpensively than either acid phosphate or bone meal. The chief requirement for success with this form of phosphorus is a large amount of actively decaying organic matter in the soil. The large amounts of decaying organic matter and manure used by vegetable growers, therefore, can be made of very great service in changing the insoluble phosphorus in rock phosphate to soluble forms. The beneficial effects occurring two or three years after the application of rock phosphate, especially where it can be applied in connection with large amounts of actively decaying organic matter, are so well established that no detailed discussion nor data need be presented on this point.

There is evidence to indicate that some of our vegetables are able to utilize phosphorus from rock phosphate almost immediately. Tomato experiments were conducted by this station\(^1\) in Union county, for five years. The data presented in Table 6 show the average annual results secured from supplementing manure with rock phosphate, as compared with other treatments.

**Table 6.—Fertilizer Experiments with Tomatoes: Union County, Illinois**

<table>
<thead>
<tr>
<th>Treatment:</th>
<th>Pounds of market-</th>
<th>Number of crates per acre increase over check</th>
<th>Net profit per acre over check</th>
</tr>
</thead>
<tbody>
<tr>
<td>acre basis</td>
<td>marketable fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>per plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td>2.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manure, 10 tons</td>
<td>3.16</td>
<td>58</td>
<td>$10.79</td>
</tr>
<tr>
<td>Manure and 545 pounds bone meal</td>
<td>3.52</td>
<td>94</td>
<td>12.69</td>
</tr>
<tr>
<td>Manure and 545 pounds rock phosphate</td>
<td>3.72</td>
<td>122</td>
<td>33.55</td>
</tr>
</tbody>
</table>

In these experiments the tomatoes were grown on different land each of the five seasons; hence the gains made were derived entirely from an immediate use of the fertilizer. The results show that rock phosphate in connection with manure caused a larger yield of fruit than a similar quantity of bone meal used in the same way, and it gave a very much greater net profit because of the lower cost of the phosphorus.

The Department of Agronomy of this station reports that in experiments conducted with potatoes at Dixon and Mt. Morris, Illinois, during the season of 1913, there were marked increases in yield where rock phosphate was used in addition to manure and lime. In these cases the materials were all applied in the fall of 1912.

It is very likely that some other vegetable crops besides tomatoes and potatoes can make immediate use of the phosphorus in rock phosphate, but it is probable that many of them would not be markedly benefited by it the first year. For the majority of vegetable crops it would in all probability be advisable to use acid phosphate or steamed

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\(^1\)Ill. Agr. Exp. Sta. Bul. 144.
bone meal for an immediate source of phosphorus and to apply at the same time the much cheaper rock phosphate for the needs two or three years hence. Where it is believed that the phosphorus content of the soil is low, and this is usually the case, the first application should consist of about one ton of rock phosphate per acre. If this is followed by applications of 1000 pounds per acre every two years, the phosphorus needs of vegetable crops will be met and the soil will gradually grow richer in this element. It is a very good practice to apply rock phosphate in connection with manure or crops turned under for soiling purposes.

**Potassium**

Potassium is abundant in all Illinois soils except in some small areas of peat and sand lands, tho practically all of it exists in very insoluble form. Manure and organic matter are the most instrumental agencies in rendering these insoluble forms soluble, and, except in the peat and sand soils referred to, vegetables will ordinarily obtain sufficient amounts of potassium from that existing in the soil for good growth. However, applications of potassiums often prove profitable. This element is used in considerable proportions by root crops, and, as a rule, may be employed more profitably with them than with other crops. Table 7 shows the principal forms of potassium which may be used.

<table>
<thead>
<tr>
<th>Table 7.—Important Forms of Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Pounds potassium per ton</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>Muriate of potash..........</td>
</tr>
<tr>
<td>Sulfate of potash.........</td>
</tr>
<tr>
<td>Kainit.....................</td>
</tr>
<tr>
<td>Wood ashes.................</td>
</tr>
</tbody>
</table>

Sulfate of potash is probably the most satisfactory form of potassium for general use. The majority of investigations reported favor this form, tho some of them favor the muriate as strongly. The kind of crop grown appears to make some difference; some of them succeed better with sulfate of potash while others are able to use the muriate to better effect. The large quantity of chlorids carried by the muriate is injurious to some plants, especially when applied immediately before planting. This is also true of kainit. Another objection to kainit is the high percentage of foreign substances, for which unnecessary expense must be incurred in the freight and handling.

Wood ashes are an extremely good form of potassium, and they also contain a large percentage of lime. It is unfortunate that their
supply is limited. If any are produced at home, they should be kept under cover until they can be applied and immediately worked into the soil; for when exposed in the open, the potassium content is quickly reduced by leaching. Buying wood ashes in preference to sulfate or muriate of potash will not pay unless the ashes can be bought at a lower figure than that named in Table 7. The amount of potassium they contain varies from about 3 to 8 percent, and in buying them due consideration should be paid to this point. It should be mentioned in this connection that coal ashes have no value as a fertilizer.

Whether or not it will pay gardeners in Illinois to use commercial forms of potassium must be determined largely by local conditions. Certainly this element will not give the increases in this state (except in the peat and sand soils mentioned, where it commonly gives large gains) that it gives in some other sections of the country, and it is no doubt best for gardeners to test it on a small scale before investing heavily in it. If applications seem profitable, an amount of fertilizer supplying about 100 pounds of potassium per acre annually will suffice under ordinary circumstances. Potassium sulfate or wood ashes should be applied in the spring after plowing, and harrowed into the soil thoroughly before planting the crop. If muriate of potash or kainit is used, it will be better, as a rule, to apply it the preceding fall.

LIMESTONE

Besides having a sufficient stock of the limiting elements and organic matter in the soil, it is necessary, for the best growth of nearly all vegetables, that the soil be free from acid. This condition is best imparted by the application of ground limestone, which costs from $1 to $1.50 per ton delivered in almost any part of Illinois. The presence of lime in the soil is directly beneficial to most vegetables; it is necessary for the welfare of soil organisms engaged in changing other forms of nitrogen to nitrate form; and it is essential for the best results with legumes.

Practically all vegetables grow best in a limed soil. Potatoes, sweet potatoes, sweet corn, and turnips appear capable of growing fairly well in soils containing some acid, tho they are usually benefited by applications of limestone to a greater or less extent. Carrots seem to grow equally well in limed or acid soils. Watermelons are injured by liming.

It should be mentioned in this connection that potato scab is favored in its development by liming. This is because the disease flourishes best in an alkaline condition of the soil, while an acid soil checks its development. In contrast to this, the club root of cabbage, a serious disease in some places, is checked by lime; in fact, the most satisfactory method of treatment known for it is the application of lime.
As a general proposition, the application of limestone in vegetable growing is a profitable practice, unless, of course, the gardener specializes on such crops as carrots or watermelons. If the soil has received no lime before, about two tons per acre should be applied the first time; after that one ton every two or three years will usually suffice, except in some of the strongly acid soils in the southern part of the state.

There are a number of forms of lime, but the most satisfactory for general use is ground natural limestone. Besides being one of the safest forms, it is one of the lowest in price. Air-slaked lime may often be secured, especially near lime kilns, for a lower figure than the ground limestone. This is also a satisfactory form. Unslaked or lump lime is undesirable, being very destructive to the organic matter of the soil.

**DRAINAGE AND CROP ROTATION**

Good drainage and proper crop rotation are essential factors in the production of any crop, however well the land may be fertilized. If the land is not naturally well drained, it should be tile drained. Even on rolling land, tile drainage often proves highly beneficial. An adequate system of crop rotation is as necessary in vegetable growing as in general farming. Continuous planting to the same crop, or to the same class of crops, is not only unwise practice from the fertility standpoint, but it allows serious diseases and insects to become established in the soil as well. Gardeners should so arrange their planting that the same crop or class of crops does not occupy a given area more than once in three or four years.

**SUMMARY**

The fertility problem in vegetable growing is one of the most important of the many difficulties confronting the gardener. The general principles underlying the fertilizing of farm and vegetable crops are the same, tho on account of the wide differences in the two branches of agriculture, there are marked differences with respect to the specific manner and degree of their application.

Vegetable crops remove large amounts of fertility from the soil, and comparatively large losses occur also thru drainage and leaching and by oxidation of the nitrogen and organic matter. These latter losses may be checked to a certain extent by careful methods, but even with the best attention there will still be large losses. Hence, the maintenance of the highly fertile condition necessary for successful vegetable production is not a simple matter.

The organic matter content of the soil can be maintained by plowing under manure, crop refuse, and cover crops. Nitrogen can
be furnished by manure, by leguminous crops, and by the various commercial forms of this element. Manure is without a doubt the best general source of fertility for the vegetable grower, tho it is somewhat low in content of the mineral elements. Large losses in manure occur thru improper handling, and its proper treatment under the circumstances met with in practical vegetable gardening is a rather difficult problem, and one in which many serious mistakes are made.

It is practicable for gardeners to utilize cover crops as a source of organic matter. If legumes, such as cowpeas, soybeans, and hairy vetch, are grown, they will serve as sources of nitrogen also.

Commercial forms of nitrogen, even tho expensive, can often be used with profit by the vegetable grower. Nitrate of soda appears to be the most satisfactory form when used in the right way. On account of its soluble condition and the fact that plants can use it directly, it is particularly helpful in forcing the growth of early spring crops. However, it must be applied in proper amounts, at proper times, and by proper methods, or serious harm to the plants will almost certainly result.

Since the amount of phosphorus contained in most soils is small, and since manure is low in that element, applications of some commercial form usually prove profitable. For immediate results, acid phosphate and steamed bone meal are the best forms to use, but if the gardener will provide for his needs two or three years in advance, he can employ the very much cheaper raw rock phosphate. The phosphorus in this form is insoluble, but the large amounts of manure, crop refuse, and cover crops ordinarily plowed under in vegetable growing will be instrumental in changing it to soluble forms. There are even some experiments on record which indicate that certain vegetable crops give marked increases in yields the season immediately following its application.

Potassium is abundant in nearly all Illinois soils, but applications of it sometimes prove profitable. Sulfate of potash appears to be the most satisfactory form for general use, tho muriate of potash seems to give equally good results with some crops. Unleached wood ashes are a most satisfactory form of potassium, but unfortunately the supply is limited.

Lime benefits practically all vegetable crops and should be used in liberal amounts by gardeners. Ground limestone is the cheapest form and one of the most satisfactory as well.

Finally, the land should be well drained, either naturally or artificially, and an adequate system of crop rotation should be practiced.

The factors mentioned each bear an important relation to the welfare of the plant. It is only after all of them have received proper attention that maximum crops of high-quality vegetables can be produced.