BULLETIN NO. 679 SEPTEMBER, 1937

New York State Agricultural Experiment Station

Geneva, N. Y.

POTASH AND PHOSPHORUS IN RELATION TO ORGANIC MATTER IN NEW YORK ORCHARDS

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PUBLISHED BY THE STATION
UNDER AUTHORITY OF CORNELL UNIVERSITY

ABSTRACT

MANY statements and reported results of demonstration or experiment apparently indicating an inadequacy of the so called "nitrogen only" program of orchard fertilization make it both interesting and important to re-examine the situation as regards potash and phosphorus in New York apple orchards.

The pioneer experiments of this Station in the field showed no yield response to any fertilizer element under a system of clean cultivation.

Later experiments under sod or partial sod conditions showed significant response to nitrogen.

Experiments carried on during the past 10 or 12 years and laid out according to modern statistical procedure have shown no response to either potash or phosphorus. This is true for several standard varieties and for a variety of soil types.

The reasons for this non-response are discussed and their relation to the subject of experimental design and statistical interpretation of orchard fertilizer experiments is especially stressed.

The general "let down" in orchard soil management and lack of organic matter maintenance make it increasingly important to watch for potash needs, especially in orchards on light soils.

Data from the lysimeter work of this Station are presented which show that phosphorus equivalent to over 100 pounds of superphosphate and potash equivalent to 200 pounds of muriate of potash may be made available each year thru the growth and decomposition of a growing cover crop.

Some important distinctions between static and dynamic organic matter in a soil are drawn and their relation to crop production discussed.

Altho the New York fruit grower should be on his guard as to possible potash needs, especially on some soil types, undue alarm seems unwarranted.

Practical recommendations are discussed which it is thought will cover the present status of the potash and phosphorus situation in most New York orchards.

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POTASH AND PHOSPHORUS IN RELATION TO ORGANIC MATTER IN NEW YORK ORCHARDS

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INTRODUCTION

In agricultural publications at present many statements are made to the effect that the so-called "nitrogen only" program or system of orchard fertilization is no longer adequate. Due to the re-awakened interest in minor elements, even the old trio "N-P-K" has been branded as obsolete and outworn. Trade journals and popular magazines are also voicing a note of disapproval and warning. It would seem, if we are to believe all we hear, that if an "N-P-K" program is outworn, a "nitrogen only" system must be exceedingly archaic. The latter system has been a trusted and efficient servant of fruit growers for many years, hence it seems to the author both interesting and important to attempt to analyze the factors which are apparently responsible for the change of attitude. Perhaps there is something to be said on both sides. It is hardly justifiable to involve the New York fruit grower in a considerably more expensive fertilizer program without a critical analysis of these attitudes, a careful examination of any experimental results which may bear on the subject, and without determining in what way orchard conditions in this State may modify the application of such results.

The discussion will be confined almost entirely to the three fertilizer elements of nitrogen, phosphorus, and potash. No consideration will be given to minor elements since much more work must be done on this subject before authoritative recommendations can safely be made, and also because the subject has already been dealt with in a general way in Circular No. 168 of this Station.

THEORETICAL CONSIDERATIONS

If the subject of potash and phosphorus in orchards is approached from the standpoint of theory alone, some rather strong arguments for their general use can be built up. The following six points would all be arguments in their favor:

1. Fruit trees as well as field crops use nitrogen, phosphorus, potassium, and other elements, all of which are indispensable to growth and production.

2. Potash and phosphorus, as well as nitrogen, are removed from orchard soils by wood, leaves, and fruit.

3. All plants require the various food elements in at least roughly balanced proportions.

4. The constant use of nitrogen alone, it would seem, should throw both soil and tree out of balance as to their needs for the other two elements.

5. Heavy applications of complete fertilizers pay well on many field crops, Why not on trees?

6. In some states as well as in Canada, potash and phosphorus are advised and used in orchards, Why not more generally in New York?

These six statements all seem logical, so if they are not applicable in practice in New York it is important to inquire the reasons, and to determine the extent to which they may be made applicable to New York conditions.

IMPORTANCE OF NUTRIENT ELEMENTS

With due regard to the exceptional cases in which the so-called minor elements may be of importance in orchards, it is obviously true, and very likely to remain so, that nitrogen, phosphorus, and potassium are the three elements most likely to worry the fruit grower. There are other factors in orchard soil management which should also worry the grower, but these will receive mention here only incidentally.

Nitrogen is in some ways unique. It comes largely from crop residues returned to the soil and from atmospheric nitrogen fixation. It is an ever-changing and fluctuating constituent. It accumulates very slowly under the best systems of agriculture and is lost from soil very easily. Crops, especially high-protein ones, remove large amounts from soil. It is not fixed to any extent by the colloidal fraction of soil, so large amounts may be lost in natural drainage waters. It may even be volatilized from soil in gaseous form. It is extremely difficult under any cropping system involving cultivation to maintain or build up the soil's supply of nitrogen. It is easily then the most important element with which the fruit grower has to deal.

Phosphorus is also indispensable to the tree. It has characteristics, however, which make it of much less practical importance in orchard soil management. Altho it is rarely present in soil in any larger degree than nitrogen and altho most soils are quite low in total phosphorus, unlike nitrogen, it is removed by crops to a much less extent, does not volatilize, and is lost in drainage waters in negligible amounts. Phosphorus is a quite stable and original constituent of soil. From an orchard standpoint the main problem with this element is to keep the orchard soil in such condition that enough phosphorus will be made available to the trees. A soil not too acid or alkaline in reaction and well supplied with organic matter is good insurance against a deficient phosphorus supply.

Potassium is present in most soils in considerably larger amounts than either nitrogen or phosphorus. Like the latter, it is an original constituent of soil, being an important part of many difficultly soluble minerals. For this reason the amount present in available form depends on the speed with which these minerals are broken up. The agencies which effect this are weather, cultivation, organic matter decay, the activities of soil micro-organisms, and the addition of some materials such as lime. Crops remove large amounts of potassium and considerable amounts are lost in drainage waters, altho this loss is small in comparison with that of nitrogen. These facts make it appear obvious that in any marked "let down" in good orchard soil management, potassium, next to nitrogen, will assume importance in the fertilizer program. This element, therefore, warrants a fuller treatment.

POTASH CHARACTERISTICS

Potassium has a number of rather definite functions in plants. General health and vigor is dependent on this element. It is vitally concerned in the production of fruit and seeds. Without it plants can not manufacture starches and sugars or transport them where they are needed for food. This carbohydrate relation is the reason potassium is looked upon as the most important element in the production of high quality in fruits. It is also significant that this element gives conspicuous results when the weather or season is unfavorable to plants; so conversely, plants which are potash starved are the first to suffer in bad seasons. Plants well fed with potassium have greater resistance to disease, especially fungous troubles.

Potash deficiency in plants is indicated by certain symptoms which differ some with the kind of plant. In fruit trees general stunting of new growth takes place and maturity of growth and fruit may be interfered with. Foliage which is potash starved may be in the early stages very dark green in color. Lighter green areas then appear along the leaf margins or tip. These areas gradually become lighter in color and finally turn brown and curl inward. This is the stage known as leaf scorch. These areas later may become ashy gray and may spread inward clear to the leaf mid-rib. Such leaves drop earlier than normal ones. It should be remembered that some other conditions may show very similar symptoms, such as over concentration of certain salts, dry weather, and spray injury, so that the cause is not always clear and definite. For example, in the Niagara Peninsula of Ontario it was several years after some of these symptoms appeared in apple and peach that the trouble was definitely assigned to potash deficiency in the soil.

Another reason why potassium is comparatively of great importance in fruit trees, is that the ratio of potassium to nitrogen seems an important one. This, of course, is simply another way of saying that trees as well as other plants, like animals, require a balanced food supply. Altho it has been found from solution cultures of plants that they will tolerate a wide range of nutrient proportions and will even do well on quite a number of ratios, when a nutrient, say potassium, becomes excessively low the further application of nitrogen simply makes matters worse. It seems to be the general observation, too, that the reverse combination of low nitrogen and high potassium is almost as harmful. There is therefore a certain ratio between these two elements which it seems important to maintain in an orchard soil. Fortunately such a ratio has no narrowly fixed value, yet it seems best that the nitrogen should not too greatly exceed the potash. For example, such formulas as 9–5–7, 9–6–6, 10–6–4, and others, have been recommended for apples. Here the ratio in pounds of nitrogen to potash is from less than 1½ to 1 up to 2½ to 1. Potassium nitrate, which is an excellent source of nitrogen for apples, has a ratio of nitrogen to potash of a little over 3 to 1.

It has already been stated that potassium is lost from soil very much less readily than nitrogen. In fact if the soil contains a considerable proportion of clay most of the potassium applied to the surface will be so firmly held by the first few inches of soil that very little may reach the tree roots. This so-called fixation may become very striking under certain conditions. For example, in California, prune trees on rather heavy soil were given potash salts in increasing quantity and their effect noted on the trees. There was no marked improvement in the trees until the application reached 5,000 pounds per acre, an amount prohibitive at present potash prices. This amount was apparently sufficient more than to satisfy the fixing power of the surface soil and allow some potash to reach the tree roots.

More recently it has been found that soils vary greatly in their power to fix potassium in this way and that soils lose this power if they are sufficiently acid in reaction. The conclusion drawn from the experiment noted was that on such soils no ordinary amount of potash would give results large enough to be measured. This and other work of similar nature on the West Coast has resulted in some rather radical changes in orchard fertilizer practice. Some of the fertilizer at present, especially nitrogen, is dissolved in the irrigation water and so has a better chance to penetrate the deeper layers of soil. Another practice is to run a 10- or 12-inch furrow around the tree at the outer drip of the branches, place the manure or fertilizers in this furrow, and then fill in the soil. Another method is to use an implement in front of the fertilizer sower which opens up deep furrows into which the fertilizer is placed. These methods seem to get the materials down where they are more effective. To what extent this potash fixation has been responsible for the negative results with this element in orchards is difficult to say. It is undoubtedly only one factor among a number.

There seems to be another possible way in which this matter of fixation might be overcome and this is by combining elements like phosphorus and potassium in organic combinations which apparently penetrate soils without fixation. A little work has been done on this problem in the West, but it will be a long time before such materials can be prepared cheaply or in large quantity. There are also some indications which seem to show that trees would make record performances if the concentration of nutrients could be increased in the whole root zone instead of in a comparatively small fraction of it.

It was previously noted that potassium has been called the "quality" fertilizer element. Experiments on this point, however, have been rather disappointing. For many years it was generally thought that potash should be used for better fruit color. This idea has been generally disproved as we have gained more knowledge of the causes affecting fruit color. There is a considerable difference of opinion, however, on the question of the effect of potash on fruit characters as affecting shipping and keeping quality. The Dominion Government workers in Canada have taken the stand that complete fertilizers should be used in orchards to insure the keeping qualities of apples and so are generally recommending them. Yet in this country the majority of the reliable evidence lies in the other direction. Ohio, Maryland, and some other states have reported no benefit from potash on shipping and keeping qualities, even with such soft fruits as the peach and strawberry. It is true of course that an excess of some element, especially nitrogen, will affect the texture and keeping quality of fruits, also that in such cases an application of potash would improve the situation by creating a better fertilizer balance. The practice of applying an excess of any element, however, would have to be called poor orchard management.

NEGATIVE RESPONSE OF NEW YORK ORCHARDS TO POTASH AND PHOSPHORUS

New York was a pioneer in experimentation in the field of orchard fertilization. The original Rome orchard on the Experiment Station farm at Geneva gave negative responses to potash and phosphorus and even to nitrogen over a period of 25 to 30 years. For a further period of 10 or 12 years, or up to about 1922, similar experiments on a number of different soils, particularly in western New York, gave very similar negative results. Many other fruit-growing states at that time reported quite similar findings. Up to the date mentioned, orchards in New York were mainly clean cultivated, but thereafter there began a trend away from cultivation toward grass or legume sod, and in many cases, toward more or less neglect of cultivation and many orchards were allowed to grow up to grass and weeds. For this reason in part many new experiments by more modern methods both in western New York and in the Hudson Valley showed marked response to nitrogen but still none to potash and phosphorus. Ten to 15 years of additional cropping probably helps to account for the positive response to nitrogen.

This non-response of orchards to potash and phosphorus is brought out in summarized form in Table 1. The orchards listed are only those laid out in randomized blocks for statistical control. Six or eight other orchard experiments might have been included but are omitted here for two reasons. First, they were designed according to the older "row to a plat" method which does not eliminate or evaluate soil differences; and second, the results, in some cases covering 10-year periods, show the same negative results for potash and phosphorus as shown by the later work summarized in Table 1.

Since most of these orchard experiments were designed to show the value of different nitrogen carriers as well as combinations of the three elements, it does not seem fair to compare either the lowest or highest yielding carrier with the two or three element combinations, so the means of from four to six carriers are used in the comparisons. In most cases the complete fertilizer mean yield is also a mean for several different complete fertilizers with always the same total nitrogen per tree, however, as in the case of nitrogen alone. The N-P and N-K combinations are also strictly comparable as to total nitrogen per tree. The data are for five varieties on as many different soil types of varying texture, yet none of the differences either for or against nitrogen alone have statistical significance. No observed, nor in some cases measured, differences could be detected in fruit quality or storage and no evidence of nutrient deficiencies were seen in the trees. The fact that these orchards gave no measurable response to potash and phosphorus is important, but it is just as important to determine, if possible, what factors are responsible for this result.

REASONS FOR NON-RESPONSE TO POTASH AND PHOSPHORUS

There are undoubtedly a number of reasons for this lack of response in New York orchards. The fact that fruit trees have wide and deep foraging power as compared to field crops is so obvious that it needs no elaboration. The further fact that both potassium and phosphorus may be as plentiful in lower depths of soil as in the surface, or even more plentiful, while the opposite is true of nitrogen, is also well known and has a bearing here. It should be noted, however, that in orchard soil surveys in recent years it has been shown that, due to relatively impervious layers and high water table, or in some cases to the physical or chemical nature of an apparently well-drained layer which tree roots refuse to penetrate, this foraging area of trees may be greatly restricted. This restriction would of course also restrict a tree's potash and phosphorus range. Altho there are many orchards in New York on soils of this kind they are not the commercially profitable ones and something more drastic than applying potash and phosphorus would have to be done to make them profitable. The bulk of the stable fruit industry of New York is on the better soils of the various fruit sections.

The thought may also occur to one that the experiments have not run long enough to show potash or phosphorus needs. This may be true, altho the lack of response of orchards generally during a period of 40 to 50 years would seem sufficient justification not to involve the grower in additional expense until there is more definite evidence that potash and phosphorus are needed. Meanwhile, further experimental work with both elements is being conducted by the Station on various fruit soils.

The matter of potassium and phosphorus fixation by the colloid fraction of soils has already been discussed. The possibility that this may be a cause of non-response of trees to these elements is being studied thru various methods of their sub-surface application.

It may be possible to throw further light on the reasons for this lack of potash or phosphorus response by inquiring into the conditions under which positive responses have been reported outside of New York. Such an inquiry requires considerable discrimination, both in the evaluation of reported experiments and statements and in the application of the findings of such experiments or demonstrations to orchard conditions in New York. It is only comparatively recently that a very marked advance has been made in the improvement of the technic in design and interpretation of field experiments. Some of these methods are now generally accepted and used more and more thruout the world. They show very definitely that most of the older work in plat technic is very limited in value and must be accepted only with decided reservations. A significant statement by Sir John Russell in "Fifty Years of Field Experiments at Woburn" published in 1936 well illustrates this point. He says, "The design of the Woburn field experiments was almost the perfection of the old method of single plats systematically arranged. It is admirable for demonstration of ascertained facts. Unfortunately it takes no account of differences in the nature of the soil and the subsoil; it assumes that these are equal over the whole area; it assumes also that differences resulting from different treatment of the various parts of the area prior to the commencement of the experiments will not long continue. Both assumptions are now known to be false . . . . There is therefore an element of doubt about many of the conclusions that can be drawn from the figures because of the possibility that the results are really attributable to soil variations, and not to the direct treatment at all." He further significantly adds "A conclusion can, of course, be strengthened if supporting evidence can be adduced, but it never loses its element of uncertainty. This difficulty can probably never be entirely overcome, but in modern designs of field experiment it is obviated by repeating and randomizing the plats in such a way that the significance of differences in yield can be estimated."

The vast majority of experiments reporting either positive or negative response to potash and phosphorus in orchards are laid out on the old lines which Russell describes. Their design does not permit of a valid estimate of error, therefore the uncertainty in their conclusions. This is not a criticism of the workers who designed the older experiments before more modern tools were available, but one would think that the present experimentalist would endeavor to make use of more approved and reliable tools when they are available. It is true that many differences between fertilizer treatments which are now interpreted as positive effects of treatment would disappear if compared with a valid standard estimated from the experiment itself, but this fact should be welcomed if it is going to give more dependable results.

There are undoubtedly orchard soils in eastern America deficient in various plant foods. The fact that experiments in New York have not shown potash and phosphorus deficiency does not prove that this is true of all orchard soils or all orchards in the State. It does show, however, that many of our ordinary fruit soils will carry an orchard for several generations without commercial potash and phosphorus and perhaps almost indefinitely if the proper attention is paid to organic matter maintenance. This seems to the writer a much more striking fact than finding an isolated soil somewhere in the State deficient in potash. One cannot therefore indiscriminately apply the results secured for example in the Niagara Peninsula of Ontario or on the Coastal Plain of New Jersey or in other fruit sections to our own State without critically examining both the results and the soil and other conditions under which such results were secured.

Many New York fruit growers are using potash in their orchards either experimentally or on a larger scale and many others are seriously thinking of doing so. This is due partly to reported results outside the State and partly to other factors. Fertilizer companies naturally want to sell more complete fertilizers so are looking for information, opinion, or result of demonstration which will further that end. Advertising propaganda plays no small part in selling potash or phosphorus to the fruit grower.

POTASH AND PHOSPHORUS MAINTENANCE

There is a saying that "where there is so much smoke there must be some fire", so in the matter of potash and phosphorus in orchards there are some indications in New York that the grower should seriously consider. Many orchards in the State, especially in the Hudson Valley but also in western New York and in the Champlain Valley, are on light sandy soils low in humus. These soils may be expected to show need for elements other than nitrogen sooner than the heavier soils, especially if regularly supplied with nitrogenous fertilizers as they usually are. In such a soil near Kinderhook, N. Y., this Station has some rather definite indications of potash need on apples, altho it must be pointed out that the experiment was originally laid out along the older lines already referred to which leaves an element of uncertainty.

This matter of humus is a particularly important one. There has been a general let down in the use of manure and regular cover crops in orchards. The dry seasons for the past several years have stimulated considerable interest in mulching and many growers are beginning to use this very excellent system of orchard soil management. One would like to advise more livestock for the fruit farm, since farm manure is such a valuable source of the much-needed organic matter, but this would hardly be in keeping with present trends which are in the opposite direction. This general neglect of organic matter in New York orchards is one of the most important reasons for being on the lookout for potash need.

The ability of a plant to absorb any food element depends on the activity of its roots. It has been shown that actively functioning roots will absorb all the potassium a plant needs from almost insoluble combinations of this element in the soil. However, if the activity of the roots is reduced by impervious subsoils, water logging, surface soil compaction, or deficient moisture, potassium absorption is correspondingly reduced. Organic matter prevents soil compaction to a great extent and aids water penetration and is therefore directly concerned in potash absorption. Indifference to organic matter supply and compaction of orchard soils by heavy tractors and spray machinery, especially when the soil is too wet, will hasten the appearance of potash needs. Besides the increasing use of hauled in mulch materials there is also another hopeful sign in the fact that many more growers are establishing more or less permanent legume sod in their orchards. It is probably little realized how a growing crop of this kind may help in making plant food constituents available to trees. In one way they may compete with trees for nutrients, but if they are cut regularly and if no growth is removed or if they are plowed down, they absorb large amounts of nutrients and leave them in available form in the root zone of the tree. Table 2 presents the results of some lysimeter studies at this Station which bring out the importance of this function of cover crops, as well as the conservation of potassium and phosphorus thru soil fixation.

In the table, lysimeters Nos. 1, 2, 3, 4, 5 and 6 received liberal applications of fertilizer phosphorus and potash thruout the 16 years, while No. 7 received none. In addition sequence No. 4 received regular applications of nitrogen.

It will be noted in the first place that only traces of phosphorus were lost in the drainage from the two soils, which were both medium loams. Soil 2, in fact, Ontario loam, is a favorite orchard soil of western New York. Potassium was lost in rather constant amounts regardless of soil or cropping system. This amounted to from 67 to 85 pounds potassium per acre for the 16 years or only 4 to 5 pounds per acre per year. The larger amount of potassium lost from lysimeter No. 3 is due to the fact that no crop at all occupied the soil during two years out of four. Furthermore the application of liberal amounts of both potash and phosphorus did not appreciably increase the loss of either element in the drainage. Nitrogen, however, was lost in more variable and much larger amounts. Mean losses of nitrogen for all crop sequences and both soils were several hundred times greater than for phosphorus, and 6½ times greater than potassium losses.

The amount of potassium and phosphorus in the crops represents the turn-over or circulation of these two elements which would be available to trees growing in the presence of such crops, if the crops were not removed. For example, if the amounts of potassium and phosphorus taken up from and then returned to the soil by the crops are calculated to their equivalents in standard commercial fertilizers, it will be found that very liberal applications are represented. The figures in the table are for top growth only, so to them would have to be added the amount of each element in the roots, which can be conservatively estimated at 25 per cent more. Thus, combinations of legume and cereal crops would keep in circulation an amount of phosphorus equivalent to applications around 160 pounds of 16 per cent superphosphate per acre per year and potassium equivalent to applications of over 300 pounds of muriate of potash.

In like manner combinations of grass sod followed by cereal crops would contain phosphorus equivalent to applications of 115 pounds of superphosphate per acre per year and potassium equivalent to 190 pounds of muriate of potash. Even in the crop sequence which received no application of fertilizer phosphorus or potassium, the amount of these elements in the crops would be equivalent each year to over 100 pounds per acre of superphosphate and 200 pounds of muriate of potash. In this case it can be said definitely that a large part of such potassium and phosphorus was, thru the growth of the crop, made available from soil minerals.

Green manure crops have another, altho more indirect, effect on potash and phosphorus conservation. By their binding effects they prevent erosion in orchards with appreciable slope. This means not only better water penetration and therefore more water for trees, but the prevention of loss of the most valuable surface soil, which contains the minerals in most available condition, made so by centuries of weathering and biological agencies. Soil erosion authorities estimate that it requires from 400 to 1,000 years to make an inch of top soil from parent material. It should be remembered that simply applying commercial potash or phosphorus to an orchard soil which has become deficient in these elements will not solve the difficulty if that soil is in very poor physical condition due to depletion of organic matter or to sheet erosion.

The whole question of soil organic matter in fruit production and in the production of field crops is at the present time an especially important one. Extreme differences of opinion exist as to its real value. It should be made clear that there may be very important differences between the effects of static and dynamic organic matter in soil. By static organic matter is meant that which has become more or less a part of the soil and in which further changes are slow. Dynamic organic matter, on the other hand, is that which is added in a fresh condition and whose carbonaceous matter so stimulates the increase of micro-organisms that very rapid changes take place. When organic matter in the form of animal or green manures is added to soil, biological and chemical changes take place which are very important in changing the physical and chemical properties of soil. These changes have an important effect on the performance of plants on such a soil. Organic matter of this type has a wide ratio between carbon and nitrogen. The changes mentioned tend constantly to narrow this ratio until it reaches the basic carbon-nitrogen ratio of the soil itself. This basic ratio is fairly constant and it takes rather drastic measures to change it permanently. This static soil organic matter which has reached the basic carbon-nitrogen ratio is much less valuable to a soil than the changes thru which it has passed. This is undoubtedly the reason why correlations between the actual amount of organic matter in a soil and crop production on that soil are often disappointing. If some measure of the amount of organic matter added annually or of the changes thru which it passes could be secured, such correlations might be quite different.

It is also probable that transition materials of organic nature formed during these changes from the organic matter itself or perhaps even more from the micro-organisms which effect these changes, have an important bearing on crop growth. Such materials would be only temporary in character and largely dissipated by the time the basic carbon-nitrogen ratio was reached.

Organic mulches seem to be an almost ideal method of orchard soil management. The annual application of such mulches brings about the dynamic changes just mentioned and these changes in turn make potash and phosphorus available. Even when the mulch practically disappears each year these desirable changes have been effected. This is strikingly shown in the Jensen McIntosh orchard near New Paltz, N. Y., where mulches have replaced all commercial fertilizers for the past 25 years with such splendid results. In this orchard the amount of mulch left after each season is quite small and the surface accumulation of 30 to 35 years is also surprisingly small.

A growing cover crop may not contribute permanently to the basic or static organic matter in a soil, but it nevertheless brings about the changes already discussed in addition to its effect on water penetration and to bringing available nutrients to the surface soil.

CONCLUSIONS

In conclusion it may be well to enumerate some points which the New York fruit grower should have seriously in mind.

First, the use of potash and phosphorus is at present unnecessary or the need for them will be greatly delayed in orchards which more or less meet the following conditions:

1. In orchards on the better fruit soils of New York. It is becoming increasingly apparent that orchards should not be set on so-called marginal lands in which fertility, drainage, or topography are limiting factors.
2. In orchards where farm manure or hauled in mulch materials are used liberally. Both these materials not only contain potash and phosphorus but their presence in soil helps to make available what is already present.
3. Where good cover or green manure crops can still be and are grown in the orchard. Such crops have the effects on soil potash and phosphorus which have already been noted.
4. Where a good grass sod can be maintained. A good sod indicates good soil and also conserves soil humus.

On the other hand, the need for potash and phosphorus may be present or will be hastened under the following conditions:

1. On light-textured and poorly drained soils or those naturally low in these elements due to derivation. Light soils are lower in minerals which carry these two elements, poor drainage limits root range, and a few soils derived from water laid, leached out materials may be naturally low in these two elements.
2. On land subject to sheet erosion. Such orchard soils should have a permanent sod of some kind to prevent erosion and to add humus.
3. On soils which are excessively cultivated and in which the organic matter supply is neglected. The remedy in this case is obvious. Do not hesitate to aid the seeding and growth of cover crops or sod by using complete fertilizers. In fact the use of potash or phosphorus to increase organic matter production is a splendid way to use these elements.
4. Under excessive use of nitrogen fertilizers. Use only enough nitrogen to insure good growth and production.

If the grower feels dissatisfied with orchard performance and wishes to use potash or phosphorus, it would be wise and more economical to try first on a small scale an application of 150 to 200 pounds of muriate or sulfate of potash or 300 to 400 pounds of superphosphate per acre, or both, as a supplement to the nitrogen program, before adopting such a procedure generally. Even when the two elements are found necessary, applications may not be needed every year. If a complete mixed fertilizer is favored it should be remembered that it requires 20 pounds of a 5–10–5 fertilizer to furnish as much nitrogen as 5 pounds of sulfate of ammonia and from 10 to 12 pounds of such formulas as 9–5–7, 9–6–6, and 10–6–4 which are sometimes recommended for fruit. Applications of potash and phosphorus, especially if made for cover crop growth, should be applied over the whole surface and preferably plowed or well worked into the soil.

It should be especially noted that in some fruit regions outside New York increasing leaf scorch symptoms have been found during the past year or two. This fact can probably be ascribed to constant or excessive use of nitrogen in the orchard program on soils originally low in potash. Since this is true it is well for the New York grower also to be on the lookout for similar symptoms of potash need.

On the one hand, a dogmatic attitude on the part of the investigator is unwise in the face of the great variation in soil, variety,

TABLE 1.—YIELD RESPONSES IN BUSHELS PER TREE OF ORCHARDS ON VARIOUS SOILS TO N-P-K COMBINATIONS.

Variety	Soil	Period	No. of nitrogen carriers averaged	Extremes for nitrogen carriers	Mean for N only	Means for combinations		
						N-P-K	N-P	N-K
McIntosh	Medium heavy loam	5 years	4	29.3–34.1	32.6	35.0	33.7	
Greening	Medium loam	3 years	1		14.5	14.8	13.2	16.7
Greening	Medium loam	3 years	1		17.9*	20.0		
Baldwin	Stony sandy loam	4 years	6	34.1–44.7	40.6	38.0	35.4	
Baldwin	Stony sandy loam	4 years	1					47.5†
McIntosh	Sandy loam	6 years	5	46.3–48.5	47.8	47.6	46.9	
McIntosh	Sandy loam	6 years	1		49.2*			
McIntosh	Silt loam	5 years	6	79.8–97.1	86.7	84.3	76.3	
McIntosh	Silt loam	5 years	1					87.6†
Delicious	Sandy loam	3 years	6	7.6– 9.9	8.7			8.0

*Double nitrogen.
†Carrier was potassium nitrate.

TABLE 2.—AMOUNT OF NITROGEN, PHOSPHORUS AND POTASSIUM IN CROPS AND IN SOIL LEACHINGS DURING 16 YEARS OF VARIED CROPPING, POUNDS PER ACRE.

Lysimeter No.	Crop sequence	Nitrogen		Phosphorus		Potassium	
		In crop	In soil leaching	In crop	In soil leaching	In crop	In soil leaching
	1. Ontario Loam						
1	Alfalfa sod 2 yrs., followed by barley, then by wheat	2,512	350	315	Trace	1,441	76
2	Timothy sod 2 yrs., followed by barley, then by wheat	702	131	186	Trace	895	77
3	Alfalfa sod 2 yrs., followed by 2 yrs., clean cultivation	1,807	1,146	185	Trace	1,175	106
4	Alfalfa sod 2 yrs., followed by barley, then by wheat; alfalfa fertilized with nitrogen	2,725	400	341	Trace	1,564	85
	2. Valusia Soil						
1	Alfalfa sod 2 yrs., followed by barley, then by wheat	2,891	331	341	Trace	2,132	65
2	Timothy sod 2 yrs., followed by barley, then by wheat	1,106	229	238	Trace	1,337	85
5	Barley, wheat, each 1 year, followed by 2 yrs., alfalfa	2,918	314	330	Trace	2,028	69
6	Clover sod 2 yrs., followed by barley, then by wheat	2,314	730	324	Trace	2,069	79
7	Clover sod 2 yrs., followed by barley, then by wheat	1,817	930	222	Trace	1,300	67

culture, and care which characterize New York orchards. On the other hand, it seems equally unwise to involve the grower generally in a more expensive program of fertilization until reliable evidence indicates its advisability. Meanwhile the best policy seems to be one of watchful but active waiting, with an experimental trial of potash fertilizers where their need is suspected.