Station Bulletin 166 February, 1920

Oregon Agricultural College
Experiment Station

Fertilizers for Oregon Orchards

By
C. I. LEWIS, Chief
Department of Horticulture
F. C. REIMER, Superintendent
Southern Oregon Branch Experiment Station
G. G. BROWN, Horticulturist
Hood River Branch Experiment Station

CORVALLIS, OREGON

Fertilizers for Oregon Orchards

INTRODUCTION

By

C. I. LEWIS

A large percentage of the fruit raised in the Pacific Northwest is produced on the so-called light soils. These soils tend to be deficient in nitrogen and organic matter and if this deficiency is allowed to remain very long serious complications will arise and the grower will be confronted with serious problems connected with soil fertility and the nutrition of the trees. In the orchard surveys made of Jackson and Wasco counties in 1908 and 1909 the writer called attention to the need on the part of growers of supplying their soils with more organic matter and keeping up the supply of nitrogen. In the orchard survey of Wasco county, published in 1909, the following suggestion was made:

"The analysis shows that the soils of the county are, on the whole, of average fertility, but they are also soils that will wear out easily and generally seem to be deficient in humus. Practically none of the growers are as yet using cover crops, but something must be done before long to furnish the soils with humus and plant food. Cover crops are one of the best agencies of bringing about these results. A rotation of such plants as vetch, cowhorn turnips, and rye has been effectual in other localities. Unless some such system is adopted stable compost must be added, or else some such method as is being used at Payette, Idaho, where clover is being grown to supply the humus, must be adopted."

Little attention was paid to such advice, few of the growers taking steps to keep their soils from becoming depleted, and as a result the orchards gradually deteriorated. By 1912 a crisis arose. Low prices ruled in the market and coupled with the low prices many of the orchards were producing small yields of fruit, often of very poor quality. Many of the trees were making feeble growth. The leaves were thin and yellow. The bloom was poor and there was a very small percentage of set. Much of the fruit was pitted with the so-called fruit pit, or bitter pit, sometimes called core rot. The apples tended to be small, smooth, and dull colored, and the trees were being attacked by various functional troubles, such as little leaf, apple rosette, and die-back, sometimes called winter-kill. Previous to 1912 a few experiments with mixed fertilizers had been started in some of our valleys, and some of the growers were just starting to use a few of such fertilizers. By the spring of 1913 the Oregon Agricultural College Experiment Station inaugurated an elaborate system of experiments in which various fertilizer ingredients were used. These experiments were divided into two classes: (1) experiments with mixed fertilizers, and (2) experiments with nitrates. The results of the experiments with mixed fertilizers were published in the Hood River reports for 1913-14, 1914-15, and 1916. The results obtained were in general negative. These experiments included a study of the value of various elements such as nitrogen, potash, superphosphate, lime, and land plaster. Some of these elements were added in various forms. Experiments were conducted in the Rogue River, Hood River, and Willamette valleys, and gave practically uniform results; namely, no response except where nitrogen was used. Wherever nitrogen was used there was almost uniformly a response depending to a large degree upon the amount and availability of the nitrogen used. These experiments bore out the soil analyses and surveys which had been made by the United States Bureau of Soils and by the Oregon Agricultural College Experiment Station. Analyses almost invariably proved that the lighter soils tend to be low in nitrogen and relatively rich in the other plant foods. Nitrogen, seemingly, is the weak link in this class of soils. Possibly on some of the heavier soils we may later obtain results with mixed fertilizers, that is, fertilizers containing potash and superphosphate in addition to nitrogen. Up to the present time, owners of such orchards have not complained, however, as their orchards are not showing signs of needing additional plant food. It may be that with the growing of alfalfa and clover in our orchards we may find that these crops can be aided later by the addition of potash or superphosphate, possibly lime or land plaster, or, as has been shown in some cases, by the use of sulfur. A bulletin concerning the use of sulfur in the growing of such crops has recently been issued.*

MIXED FERTILIZERS FOR FRUIT PRODUCTION

In addition to the fertilizer experiments which the department of Horticulture has been conducting in various parts of the State, observations have been made in various orchards where the growers were using mixed fertilizers. In almost all instances such fertilizers have not given results. It is hard to determine why many growers persist in the use of such mixed fertilizers. It may possibly be due to the fact that they expect to obtain certain results from these fertilizers, such for example, as more color from the use of potash, whereas experiments which have been tried all over the United States seem to show rather conclusively that potash is not a controlling factor in the production of color in fruit; at least, where large amounts of potash have been used the color has not been increased. As far as the influence of any fertilizer on color is concerned, nitrogen seemingly has a great influence in that a too large amount of nitrogen causes the trees to produce fruit of poor color, whereas when the amount of nitrogen is reduced to more nearly the real needs of the tree the color again becomes normal. Color in fruit seems to be due on the one hand to a happy combination of climate and soil conditions, and on the other hand to proper orchard methods such as thinning, tillage, irrigation, etc. It is true that potash is found in large quantities in the ash of an apple tree, in some cases at least 50 percent of such ash consisting of potash salts; it is thought that potash is important in helping form fruit acids and that the phosphoric acid may be of aid in maturing fruit since it is found in very large quantities in the seeds. The condition that really exists here on the Pacific Coast is, that most of these soils seemingly are already sufficiently rich in such salts to meet all the demands and needs of the tree, and consequently we do not get a response from application of potash and superphosphate. There may be some soils in which the potash and superphosphate content is too low,

* Sulfur as a Fertilizer for Alfalfa in Southern Oregon. F. C. Reimer and H. V. Tartar. Oreg. Agr. Col. Exp. Sta. Bul. 163, July, 1919.

and there may be orchard shade-crop conditions whereby certain intercrops or companion crops may be greatly improved by the addition of such foods; these facts will have to be determined later.

LIME FOR FRUIT PRODUCTION

In addition to the general interest in mixed fertilizers, fruit growers of Oregon are showing much interest in lime. Since it is now possible to obtain lime through the State Lime Board at a much lower price than that at which growers could formerly secure it there has been a tendency on the part of the growers to want to try lime on a rather large scale. It is well for us to analyze this question carefully. It is a common opinion that lime is essential to fruit production and that most of the successful fruit districts have a limestone formation which accounts for their special adaptability to fruit growing. While this may be true to a large extent, there are undoubtedly many other factors such as climate and general soil conditions that contribute largely to success in fruit growing. Nevertheless, many fruits are great feeders on lime. As to just how this lime benefits the plant there is more or less disagreement. Some feel that it is largely of indirect benefit, that it mainly affects the acidity of the soil, makes plant food more available, and improves the physical condition of the soil. Voorhees in his latest work on "Fertilizers" says: "It is a matter of common observation that in the production of stone-fruits, particularly, lime is an important constituent. Its functions seem to be to strengthen the stems and woody portion of the tree, to shorten the period of growth, and hasten the time of ripening." The chemical composition of some of our tree fruits especially shows that they are great users of lime. Wickson in his "California Fruits" gives the following analysis of the amount of various plant foods found in 1000 pounds of fresh fruit.

Fresh fruit	Total ash	Potash	Lime	Phosphoric acid	Nitrogen
	lbs.	lbs.	lbs.	lbs.	lbs.
Apples	2.64	1.40	.11	.33	1.05
Cherries	4.82	2.77	.20	.72	2.29
Peaches	5.30	3.94	.14	.85	1.20
Pears	2.50	1.34	.19	.34	.90
Prunes (French)	4.86	3.10	.22	.68	1.82
Plums	5.36	3.41*	.25*	.75*	1.81
Walnuts (including hulls)	12.98	8.18	1.55	1.47	

* Estimated

Wilkinson in his book, "The Apple," gives several tables of great interest. The following table is obtained from a combination of the results of many investigations.

	Dry substance	Nitrogen	Phosphoric acid	Potash	Lime	Magnesia	Iron	Total ash
	%	%	%	%	%	%	%	%
Wood	52.3	.63	.20	.37	1.60	.24	.030	3.35
Leaves	34.5	2.15	.45	1.35	2.48	.75	.125	8.70
Fruit	15.4	4.30	.17	1.11	.08	.09	.020	2.35

By using the above table and the following average weights of the various parts of the tree, just how much of the component parts of the tree are nitrogen, phosphorus, potash, etc., can be easily ascertained.

	Green weight	Dry weight
	lbs.	lbs.
Average wood and roots per tree	108	57
Average leaves per tree	111	43
Average fruit per tree	700	105

From the above figures the following table of pounds per acre of the different constituents is obtained. For convenience in figuring, the basis of weight has been made a yearly production in round figures, of 100 pounds each of wood and leaves and 700 pounds of fruit, counting 35 trees to the acre.

	Wood	Leaves	Fruit	Total
	lbs.	lbs.	lbs.	lbs.
Annual weights	3500	3500	24500	31500
Nitrogen	11.3	35.6	16.2	53.1
Phosphoric acid	3.6	5.3	6.4	15.3
Potash	6.6	15.9	41.5	64.0
Lime	29.1	29.5	3.0	61.6
Magnesia	4.4	8.9	3.4	16.7
Iron	.5	1.5	.8	2.8

It is evident that important amounts of plant food are annually removed from the soil by an apple orchard, and that unless adequate returns are made, such plant food will become a limiting factor in any vigorous and productive orchard.

In our research work in Corvallis, when we make examinations of buds and twigs of fruit trees, we find present a large quantity of lime in the form of calcium oxalate crystals, indicating that the plants are using large quantities of lime. From these evidences one might immediately conclude that it would be very desirable to add lime to our orchards, but such a conclusion might be erroneous and lead to very extravagant expenditures which might bring us no returns. We should first determine whether or not our soils have sufficient quantities of lime to meet these demands. Chemists find that the analyses which have been made of most of our fruit sections of Oregon show a great abundance of lime which should meet the general demands of the fruit trees. For example, Professor H. V. Tartar, formerly chemist at the Oregon Agricultural College Experiment Station, reports that the soils of the Willamette Valley contain from 1 to 2 percent lime. This happens to be in the form of lime silicate. Our trees evidently use it in this form as it is the only available source. To correct certain soil conditions such as soil acidity, a lime carbonate would be more desirable. It is doubtful, however, as will be shown a little later, whether the application of calcium carbonate would be of value under our conditions.

It will be of value briefly to review the literature and experiences of experts on the use of lime for fruit production. Certain acid-loving horticultural plants do not seem to thrive in lime soils, and application of lime to such plants, instead of benefiting them in any way, actually decreases the yields. The cranberry, some forms of the blueberry, the onion, the strawberry, and the blackberry all come in this group. In his recent book on Strawberries, Dr. S. W. Fletcher says: "The wild strawberry plant thrives in acid soils. Many cultivators have observed that the domestic varieties are somewhat impatient of lime." He continues by saying: "It is evident that lime should be used sparingly if at all unless needed to secure a maximum growth of legumes in the rotation." Dr. L. H. Bailey in his "Principles of Fruit Growing" states that the blackberry is at home on very acid soils, that blackcaps may occasionally be helped by light liming, that the cuthbert raspberry is appreciably helped by liming on quite acid soils, that the gooseberry and currant are greatly benefited by liming. Mr. F. W. Card in his book "Bush Fruits" states that the blackberry is not particularly sensitive to soil acidity. Lime is therefore seldom essential to best results. From all indications here in Oregon, our small fruits, especially the cane fruits such as raspberries and blackberries, are more influenced by nitrogen than by anything else, and respond to large quantities of organic matter. Our evergreen blackberry thrives the best in mountain soils thoroughly supplied with decaying organic matter and moisture.

Let us next consider the apple. Lime has generally failed greatly to influence apple trees in respect to either yields or vigor, although in some cases it may have had some value in overcoming soil acidity. Bailey in his "Principles of Fruit Growing," quoting the extensive work done in Pennsylvania with apples, quotes Stewart as saying: "Lime also has failed in most cases although it may have had some value in aiding growth. In addition it may have had some indirect value in facilitating the growth of leguminous intercrops." The same book quotes Wheeler, of Rhode Island, saying that "apple trees, as a rule, respond to liming rather better than pear trees; nevertheless, on very acid soils there are several good reasons for liming even pear trees. An occasional application of magnesian lime may be desirable, but if used, it should be alternated with applications of purer lime." Sometimes it is felt that subsoils very rich in marl, a form of lime, are not conducive to fruit production, especially some varieties of apples. Paddock in his book "Fruit Growing in Arid Regions" says that these soils are found frequently through the irrigated districts through the Pacific Coast and Rocky Mountains; that as a rule roots do not penetrate these soils; that trees growing on such soils are often unhealthy, being affected with functional trouble such as tuft blight, or rosette; and that much of the fruit is undersized. It would not be fair, however, to conclude that these conditions are due to marl subsoils entirely; they may be the result of a too thin top soil. Most American horticulturists who have experimented with tree fruits have not obtained increases in yields or material changes in the vigor of the trees.

Gourly in his "Studies in Fruit Bud Formation" says: "Apparently there is an increase in the formation of nitrates where lime has been applied to the soil."

Mr. P. J. Carmody in the Journal of the Department of Agriculture of Victoria, says: "On soils rich in lime the wood is matured earlier and the fruit buds are more stocky and robust than is the case with trees grown on soils deficient in lime. It is generally recognized that the trees are not so manageable or so prolific in bearing in soils where lime is deficient. Though lime plays an important part in the apple and pear tree, it is in the stone fruits that its value is most apparent. It is a familiar fact that in soils rich in lime stone fruits set their crops well and are not so prone to cast off their fruit at the period of 'stoning' as is otherwise the case. Where trees are making extensive wood growth with abundant foliage there is but little doubt that the application of lime at the rate of seven to eight cwt. to the acre would be of pronounced benefit."

Paterson and Scott in enumerating the various ways in which lime is of benefit to soils state that "lime greatly hastens the production of nitrates; it has a good effect in liberating potash and phosphoric acid, especially where the latter is combined with iron or alumina."

Hodsoll says: "First we must mention that lime is in itself a plant food, calcium being one of the essentials of plant life. It is, however, very seldom that a soil is encountered that does not contain a sufficient supply for the very small needs of most plants, and it is chiefly what may be called the indirect action on plant nutrition that is of value in horticulture."

Stewart says in his recent bulletin, "The Fertilization of Apple Orchards,"* that "neither phosphorus nor lime when used alone has shown any important influence on the yield or growth in apples. Lime may often have some indirect value, however, through its favorable influence on leguminous cover or intercrops, and possibly as a supplement of fertilizer applications. In the latter relation its chief effect has been on growth. Phosphorus is also generally valuable in connection with leguminous crops."

In Oregon we have conducted extensive experiments in both the Hood River and the Willamette valleys, and up to the present time have received no benefits from the application of lime to apple orchards.

Stone fruits are supposed to need lime more than the pomaceous fruits like the pear and the apple. Voorhees and Carmody have already been quoted on this question. Bailey in "Principles of Fruit Growing" quotes Wheeler as follows: "Wheeler says that peach trees are less in need of lime than apple trees, yet liming is nevertheless often desirable even for its indirect benefits." Most authorities seem to think that the plum, the prune, and the cherry need more liming than do peaches and apples. The feeling is that cherries especially use much lime. Our work with stone fruits, however, especially with prunes in the Willamette Valley, has up to the present given no benefits to the tree itself from the use of lime.

To a man deciding to use lime, the question comes, How shall I use it? It should be used conservatively and in a truly experimental way. Pick out a block of trees in your orchard which are typical as regards vigor, soil conditions, exposures, etc. Use one-half or one acre of trees and put on from one to two tons to the acre applying it broadcast. By checking this block over a period of several years with the rest of the orchard, you can easily determine whether or not the lime is of any benefit. Though it should not be said that lime will be of no benefit to the orchardist of Oregon, the indications at present are that one will

* Pennsylvania Exp. Sta. Bul. 153. May, 1918.

expect benefit only in exceptional cases and that growers are not justified in paying from $6.00 to $16.00 a ton for lime to be applied generally in our orchards.

The great mass of information neither recommends nor condemns the use of lime in fruit production. American horticulturists from the Atlantic to the Pacific who have experimented extensively with lime for fruit trees have not obtained striking results, and in making their recommendations for the application of fertilizer do not include lime. The indications are that the application of lime in Oregon orchards will not as a rule pay and that communities interested in this question should experiment in typical orchards before buying large quantities. If the returns are satisfactory then buy lime, otherwise not. A close study of American orcharding shows that nitrogen is the great determining factor and is the one needing the study of our orchardists much more than does the lime question.

We hope, during this next year, to make thorough complete fertilizer and lime tests on various soil types in this State. Such experiments will be conducted with apples, prunes, and various other fruits. It was planned to conduct this work earlier, but owing to war conditions it has been practically impossible to obtain some of the necessary ingredients. For those who do not care to wait until such trials have been completed and who wish to experiment on their own initiative, the following experiments are suggested. Choose a very typical area of the orchard; have at least a dozen trees for each plot; choose high-grade, quickly available salts, and apply them at least a month before the trees bloom; vary the amount from 5 to 10 pounds per tree according to the size of the tree. For ordinary bearing apple trees 5 pounds should be sufficient, but for extremely large trees as much as 10 pounds might be desirable.

Plot 1. Five to ten pounds of nitrate of soda or sulfate of ammonia.

Plot 2. Five to ten pounds of sulfate of potash.

Plot 3. Five to ten pounds of superphosphate.

Plot 4. Five to ten pounds each of nitrate of soda and sulfate of potash.

Plot 5. Five to ten pounds each of nitrate of soda and superphosphate.

Plot 6. Five to ten pounds each of nitrate of soda, superphosphate, and potash.

Plot 7. From one to two tons ground limestone to the acre.

If response comes from any of these combinations, a man will easily know what to buy to put on his orchard and if he desires he can put on available salts more slowly.

NITROGEN FOR FRUIT PRODUCTION

Results from the use of nitrate of soda in our experiments have been startling in the rapidity with which it has influenced the trees. The reports of the Hood River Branch Experiment Station and Southern Oregon Branch Experiment Station (Rogue River Valley) in 1913 give the results of this work, and the present bulletin gives the results of the last two years' work at Hood River and Rogue River from the use of nitrogen fertilizers such as nitrate of soda and sulfate of ammonia. The results speak for themselves. The trees have been very quickly reinvigorated, the foliage becoming thick, green, and luxuriant, the wood growth satisfactory, the bloom increased, percentage of set greatly increased, the fruit becoming larger, of finer quality, the trees giving a much larger yield, and the fruit on the whole being of good color and unless an excessively large amount of nitrate is used of good commercial color. Functional troubles such as fruit pit, apple rosette, and little leaf have practically disappeared; in fact, the addition of nitrogen has been sufficient seemingly to restore the trees to normal vigor. It might be well to add at this point that at no time at this experiment station have we recommended the use of nitrate or any other chemical fertilizer to take the place of organic matter. We are recommending that nitrate be applied because it restores the tree very rapidly, but that organic matter should also be added by using cover crops under non-irrigated conditions and alfalfa or clover if the orchards are in bearing under irrigated conditions, supplementing the use of organic matter from time to time by adding a little nitrate or other nitrogenous fertilizers whenever the trees seemingly need more food than they are receiving. As far as the methods of adding nitrogen are concerned, under normal conditions if the nitrate is used at least a month before the trees bloom, which is the correct time for applying, it can be applied broadcast and harrowed in, or allowed to dissolve with irrigation water or rains. If one is orcharding under dry conditions it might be well to spray the nitrate on the ground or to add it to the lime and sulfur and spray it on the tree. Under such conditions a pound of nitrate should be added for each gallon of spray, and from 5 to 10 gallons of spray given to a tree. This will work very nicely indeed in the dry portions where the rainfall is scant or where it is not practicable to give early irrigation water to dissolve the nitrate. We must emphasize the fact that it is desirable to put the nitrate on before the trees bloom and to have conditions such as will dissolve it if one would get really rapid response and hopes to get crop results the year the nitrate is applied. In connection with the use of nitrate of soda in reinvigorating our fruit trees attention is called to the relation which our pollination question bears to the use of nitrates.

For thirteen years the Oregon Agricultural College Experiment Station has been investigating the pollination of fruits. We determined first the fertility or sterility of the varieties, then the mutual affinity between our leading varieties of fruits, and in this way were able to discover what seemed to be the best pollinators for our leading commercial varieties of fruits. These investigations revealed the great necessity of pollinators for most varieties of fruit, especially such fruits as the Spitzenberg and Winesap apples and the Comice pear. These investigations determined later that not only were the Royal Ann, Lambert, and Bing cherries sterile, but they would not interpollinate each other, thus revealing why so many of our commercial cherry orchards were failures. As a result most of the orchards planted to the varieties named have now had grafted into them a sufficient number of scions of good pollinators so that we may expect heavy crops in the future. In our investigations we were interested in determining the cause of sterility, in order to find out whether the orchardist could in any way change or modify that condition through orchard practices. The early investigations did not throw much light on this subject so we next took up a study of the structures which might be involved, and this study resulted in the bulletin on "Gross Morphology of the Apple." Our fertilizer experiments at Hood River seemed to throw some light on the pollination question, as the percentage of blooms that set fruit was greatly increased by the use of nitrate. Our results with nitrate fertilizers on apples led us to believe that nitrate was speedily playing a much greater role than the mere addition of so much nitrogen would mean to the tree and that the use of nitrate fertilizers on plants needed a much closer study than had heretofore been given. Finally, Dr. E. J. Kraus, of the Oregon Agricultural College Experiment Station, and Mr. H. R. Kraybill, of the Pennsylvania Station, started investigations at the University of Chicago where Dr. Kraus was on leave of absence for two years conducting research study. Their results have been published in the bulletin, entitled "Vegetation and Reproduction with Special Reference to the Tomato."* This is one of those rare publications which are really epoch-making because they reveal certain fundamental truths that enable us to interpret our general agricultural results. The title is misleading, as far as the average fruit grower or farmer of Oregon is concerned. While the investigational work dealt to a certain extent with tomatoes and is of distinct interest to scientists and to vegetable gardeners, it is, nevertheless, of greater value and interest to fruit growers and general farmers because it enables them to interpret their results and know why they may be obtaining good or poor crops. The study is very gratifying to the department of Horticulture because it shows that the general recommendations we have been making at this experiment station concerning the pruning, tillage, and use of fertilizers on fruit trees, have been sound; the bulletin gives the scientific reasons why such recommendations are sound. For example, we have been recommending that with orchards from six to ten years of age which are rather vigorous, a system of light tillage or even no tillage at all, and in some cases even a crop of grain accompanied by light pruning, chiefly thinning, would aid particularly in encouraging fruitfulness on the part of the tree. If we continued in the heavy cutting back, intensive tillage, and stimulation which seemingly were very advisable during the first few years of the orchard's life, we would not obtain fruit, but would simply obtain vegetative growth with very little fruit. The bulletin deals with the relation of nitrates and moisture to carbohydrates (such substances as starch and sugar) within the plant itself and the responses apparently correlated therewith. Such relationships are four, and are as follows:

"1. Though there be present an abundance of moisture and mineral nutrients, including nitrates, yet without sufficient available carbohydrate supply, vegetation is weakened and the plants are non-fruitful.

"2. An abundance of moisture and mineral nutrients, especially nitrates, coupled with an available carbohydrate supply, makes for increased vegetation, barrenness, and sterility.

---

* Vegetation and Reproduction with Special Reference to the Tomato, by E. J. Kraus and H. R. Krayhill. Oreg. Agr. Col. Exp. Sta. Bul. 149. January, 1918.

"3. A relative decrease of nitrates in proportion to the carbohydrates makes for an accumulation of the latter; and also for fruitfulness, fertility, and lessened vegetation.

"4. A further reduction of nitrates without inhibiting a possible increase of carbohydrates, makes for a suppression both of vegetation and fruitfulness.

"This analysis is not intended, in any way, to convey the idea that only these compounds—carbohydrates, nitrates, and moisture—are concerned in vegetation and fruitfulness, but that the study in hand is principally concerned with them and the response resulting from an alteration of their relative proportions within the plant. It would be extremely difficult also to draw rigid lines between any particular class and the one next to it, since they intergrade insensibly one into another and yet, generally speaking, are recognizably distinct."

In the plant or tree we have, coming up from the ground, the moisture and mineral nutrients, including the nitrates. On the other hand we have the leaves of the tree manufacturing from certain gases taken from the air and the materials which they obtained from the roots, the carbohydrates, that is, sugar and starches. Practically every condition a plant or tree may be in can be interpreted according to the relationship of the moisture and nitrates on the one hand to the carbohydrates on the other hand. With certain relationships we may get no vigor in the tree and no fruit. Other relationships produce both vigor of tree and fruit while in others we obtain plenty of vigor, but no fruit.

Let us see how these four statements pertain to the tomato plants.

The first group, where we have an abundance of moisture and nitrates but a small amount of carbohydrates, may be illustrated by plants which are well fertilized, but strongly defoliated, heavily shaded, or severely cut back or pruned. The growth of such plants is tender, weak, or spindling. and not productive of blossoms or fruit.

The second group, where we still have an abundance of moisture and much nitrate fertilizer, suggests a great deal of vegetative growth. The carbohydrate or sugar and starch present in the leaves is utilized almost entirely for wood or vegetative growth, and we get no tomatoes. Such plants generally have thick, large, green leaves, and are characterized by being very vigorous, healthy, and thrifty.

In the case of the third group, we begin to reduce the amount of nitrate fertilizer placed on the tomatoes, providing an increase of sugar and starch proportionately, and immediately the plants begin to become fruitful, blossom heavily, and set well.

In the fourth group we cease using much nitrate, using in fact little or none, and the carbohydrates or sugars and starches accumulate in the plant and the proportion between them and nitrate is much in their favor. We find that while the plants may bloom under such conditions and have many blossoms, yet they fail to set and their vitality becomes weakened.

Let us see how these four statements pertain to our apple trees for example. The first group, where we have an abundance of moisture and mineral nutrients, but low available carbohydrate supply, we can illustrate by several common cases; for instance, if we entirely dehorn a tree, leaving nothing but a stub, we have removed practically all of the sugar and starch from the tree, yet have an abundance of moisture and nutrients coming up from the ground. The tree cannot utilize this material, however, because it has not enough stored food in the wood; neither has it the foliage to utilize food. As a result, the tree often dies or makes an extremely feeble growth. Another good example is where we practice excessive summer pruning, removing large quantities of wood and leaves, or practice frequent pinching; such a practice dwarfs, may devitalize, reduce to too low an amount the carbohydrates and the foliage necessary to manufacture more. In the case of the second group, with an abundance of moisture and nitrates and with an available carbohydrate supply, we get greatly increased wood growth, but practically no fruit. This is best illustrated in a case of young trees, say from one to five or six years of age, growing in rich moist soils and pruned rather heavily during the dormant seasons. Here we get a great deal of vegetative growth—all our orchard practices encourage it; but we get very little fruit. The third group we can illustrate well by trees, say from nine to fifteen years of age, which are of very fair vigor and are producing heavy crops of fruit. Here we get a certain balance between nitrates and sugars and starches, neither one greatly predominating and both correlating nicely and producing both wood growth and fruit. The fourth class we can illustrate by many of our older apple trees in the Pacific Northwest situated on light soils. The trees possess a large number of spurs, but make very little wood growth and appear greatly devitalized. Though they may be packed with sugar and starch, yet there is not enough nitrate to utilize it. Consequently, we do not get vegetative growth, neither do we get much fruit; the few blossoms set very poorly. It is with this class of trees that the application of a little nitrate works wonders, because the restoration of a small amount of nitrogen again results in a balance between the nitrogen on the one hand and the carbohydrates on the other; the tree begins to make vegetative growth and begins to set fruit again.

Let us briefly apply these four principles to the life of an average tree. The first five years of the tree's growth is the formative period, when we are building up the framework of the tree. Intensive tillage will aid in conserving moisture in the ground and encouraging the production of nitrates available to the tree. Pruning generally consists of heading in the top in order to force out laterals, and in doing this we are restricting somewhat the carbohydrates, but unless over severe not to such an extent that the tree does not possess enough of them for growth. The result is that our tree is all wood. If we carry out this same practice until the tree is six to ten years of age we get nothing but wood, a result too many of us have experienced; but if we begin to reduce or cease the tillage, or even perhaps put in a grain crop, or do very little pruning, what is done being mainly a thinning, there is a relative increase in the carbohydrates and a decrease in nitrates. The tree passes from the second stage into the third and soon comes into heavy bearing. The trees may now grow along beautifully for four, five, or six years, produce heavy crops, make pretty good growth; we are very much satisfied. But soon the growth begins to be less, the leaves become thin and yellow, the trees while blooming set very poorly. Our trees have evidently entered into a decline. What has happened? We have allowed them to slip into the condition of the fourth group. The nitrates and moisture have not relatively increased or kept pace with the area capable of manufacturing sugars and starches, and because of lack of utilization they accumulate as such. Our trees may be packed with sugar and starch, yet are virtually starving to death if they have not enough nitrate to utilize this sugar and starch. Adding nitrate of soda, 3 to 5 pounds per tree, in March as we have done at Hood River and Rogue River in many of these devitalized trees, immediately causes a transformation and brings the trees back to the third condition, namely, plenty of vegetative growth and abundance of fruit. Why? Simply because the addition of nitrate restored the balance in the tree. Often by pruning trees such as we have mentioned some of the sugar and starch are removed, and in that way a fruiting balance between the sugar, starch, and nitrate, has been restored. That is why a general pruning, well distributed over the bearing tree, a pruning that is not too severe, will help to keep up the balance between the nitrates and sugar and starch.

We can say, then, that the great problem in our orcharding is so to control the moisture and nitrates on the one hand and the sugar and starch or carbohydrates on the other hand, as to permit us so to mould our trees as to secure any results we may desire; that pruning, tillage, fertilization, irrigation, all affect the correlation between these two classes of food; that if we allow a great disproportion of nitrate on the one hand or carbohydrates or sugar and starches, on the other hand, we must not expect much fruit or proper vigor in our trees. As far as our bearing trees are concerned, we must try to keep a fair balance between those two. While these experiments have been conducted on apples and tomatoes, other investigators have been conducting experiments on wheat and other grains with exactly the same results, indicating that these fundamental principles which were brought out by investigations with apples and tomatoes may hold true with practically all agricultural plants. The results published in Bulletin 149, therefore, apply to general agriculture; the bulletin has opened up for us a great field for further investigation. Undoubtedly we can better interpret many abnormal conditions of trees by a better understanding of the relationship between nitrates and carbohydrates, and it is not too much to expect that many of the so-called functional troubles of our trees may be due to a large extent to wrong relationships in the tree between such elements. We can look forward to further investigations likely to be of great value to agriculture.

GENERAL RECOMMENDATIONS

Before deciding on using fertilizers one should analyze local conditions very carefully, and it would be well from time to time to consult the Experiment Station concerning the advisability of using the various fertilizers. In general, under normal conditions, orchards from one to five years of age in Oregon do not need any fertilizer. If good stock has been chosen and proper methods of pruning, tillage, and spraying are followed, trees should make a sufficient growth. If trees have not made sufficient growth due to unwise inter-cropping, lack of care, etc., light applications of fertilizer might be very beneficial, such as a few handfuls of nitrate applied broadcast in the early spring or if preferred some sulfate of ammonia or well rotted manure. If the soil is in poor physical condition and devoid of humus a cover crop is found to be of advantage. It is wise in young orchards to have the intercrop consist of a hoed or cultivated crop rather than a hay or grain crop. Even with trees from six to ten years of age fertilizers should not be necessary; in fact, if they are used indiscriminately they may encourage wood growth at the expense of fruit. It is only where trees are much under-sized or stunted and show indications of being badly run down that it would pay to use fertilizers at this stage. If the trees show that they are in such a condition, an application of some nitrogenous fertilizer or manure would be highly desirable. One should, however, constantly be on guard not to over-invigorate such trees. When trees come into heavy bearing and show signs of going into a decline one should at once apply fertilizers. It is under such conditions that nitrate can check such decline and keep the trees in a normal condition. An early application of this fertilizer will put the trees back into normal condition very quickly, but one should supplement the treatment by use of crops which add humus and organic matter to the ground. Under non-irrigated conditions, by the latter part of August or early part of September crops of vetch, cowhorn turnips, rape, or similar crops should be added. The leguminous crops like vetch will be superior if the trees are badly run down. Under irrigated conditions with these older trees it is advisable to plant the orchard to clovers or alfalfa and irrigate it very thoroughly. We caution growers who first attempt this, however, that it is necessary to irrigate earlier than formerly and also to irrigate very thoroughly indeed, because the clover or alfalfa growing with the trees requires more water than would the trees alone. In some cases the growing of the clover or alfalfa will be sufficient to add enough nitrogen to keep the trees in shape; in many cases it is not sufficient and an occasional application of a nitrogenous fertilizer applied early in the spring would be highly desirable. It may be that where the alfalfa or clover is growing that other fertilizers will be found to be of advantage; for example, superphosphate, or in soils that are not acid a hundred pounds of sulfur to the acre, may be very beneficial under such conditions. Addition of lime, while of doubtful value to the orchard under normal conditions, might be of benefit to clover or alfalfa which is being grown along with the trees. If it is desired to attempt the complete fertilizer test we suggest following directions previously given. In no case should the grower spend money for fertilizers that are already mixed and of which he knows very little, because even though such fertilizers might be beneficial the grower would be at a loss to know what element or elements in such fertilizers were beneficial to his orchard. Since this question is being made one of the major studies at the Oregon Agricultural College Experiment Station and not only will be taken up at the sub-stations such as the Southern Oregon Branch Experiment Station and the Hood River Branch Experiment Station, but also will be studied in respect to soil types in other valleys such as the Umpqua, Willamette, etc., it would be wise for growers to keep in touch with these experiments and to obtain advice and recommendations. The Experiment Station may be in position to give them the benefit of developments that we have not yet had opportunity to publish.

NITROGEN FERTILIZERS FOR FRUIT TREES IN THE ROGUE RIVER VALLEY

By

F. C. REIMER

INTRODUCTION

All plants require ten elements for their proper growth. Seven of these are derived directly from the soils.* Soil analyses show that four of these seven elements—potassium, calcium, magnesium, and iron—occur in great abundance in the soils of the Rogue River Valley. The three elements which often occur in limited quantity in our soils are nitrogen, sulfur, and in some soils phosphorus. The element sulfur is used in such limited quantities by fruit trees that even the small amount in our soils, with that derived from the rainfall and the lime-sulfur sprays, is ample for these plants. Apple, pear, and peach trees use only one-fourth as much phosphorus as they do nitrogen, and in many of our soils this element occurs in sufficient quantity at the present time to supply the needs of our common fruit trees.

Analysis shows that the nitrogen content of many of our soils is too low. The growth and general condition of the trees in some orchards is indicative of a need for more nitrogen. This element is easily lost from the soil and needs frequent replenishing.

FERTILIZER EXPERIMENTS

Fertilizer experiments with fruit trees have been conducted by the Southern Oregon Branch Experiment Station in the Rogue River Valley during the past seven years. Since the Experiment Station during this period has had no land and no trees suitable for fertilizer experiments, it has carried on this work in the various orchards of the valley. Owing to change of ownership of the orchards in some cases, lack of proper cooperation in others, and the destruction of several crops by frost, most of these cooperative experiments have given results of little value. In many instances it became necessary to discontinue the experiment before any results of value could be obtained. Such experiments will not be reported in this bulletin. A number of the experiments, however, have already given results of sufficient interest to justify a report.

Fertilizer Experiments with Winter Nelis Pears

In the spring of 1917 a fertilizer experiment was started in the old Winter Nelis block of the Burrill orchards. The trees were planted in 1888, had always made a good growth and borne good crops, and had reached a large size. The soil in this orchard is designated as Medford gravelly clay loam. While this soil contains a considerable amount of gravel, it contains such a high percentage of clay that it must be classed as a very heavy soil, and it must be plowed and cultivated at the proper time to keep it in good tilth. It retains moisture remarkably well, but when not irrigated becomes quite dry and very hard during the latter

* The legumes can obtain nitrogen from the air in the soil.

part of the summer. Until 1915 this orchard was not irrigated. Since that time it has received a moderate amount of irrigation during May and June, and in some years during early July.

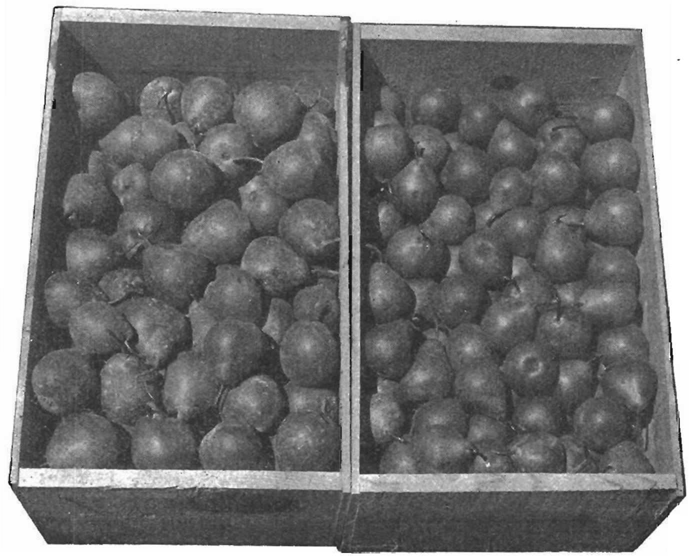


Fig. 1. WINTER NELIS PEARS, BURRILL ORCHARD, 1918
Typical fruit from trees fertilized with 10 pounds of nitrate of soda (1), and from check trees (2).

The following table gives the composition of this soil. This is expressed in pounds of plant food per acre; that is, the amount in the surface soil to a depth of one foot, or 3,500,000 pounds; and in a layer of subsoil one foot thick, or 4,000,000 pounds.

	Potassium	Nitrogen	Magnesium	Calcium	Phosphorus	Sulfur	Organic matter
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Surface	58000	6195	85050	36750	2415	1330	250250
Subsoil	52400	2440	100800	57600	3400	1000	184800

The analysis of the surface soil shows an abundance of all the elements with the exception of phosphorus. The subsoil contains a sufficient amount of all the elements with the exception of nitrogen.

At the beginning of the experiment the trees were in a healthy condition, making a good annual growth, and producing fair crops of fruit. The fruit, however, was undersized.

The first year the trees in the check row produced slightly more than 12 boxes per tree, while the trees treated with 10 pounds of nitrate of lime produced slightly more than 15 boxes per tree, or an increase of almost exactly 3 boxes per tree. The trees treated with 10 pounds of nitrate of soda per tree produced 15.45 boxes per tree or practically 3⅓ boxes per tree more than the check plots. The three rows which received 5 pounds of nitrate of soda per tree showed considerable variation. The lowest yield produced by these rows, however, is nearly 3 boxes more per tree than on the check row; and one row produced nearly 5 boxes more per tree than the check row. With trees of this age it is difficult to select a large number of trees which are absolutely uniform, especially where blight has not attacked all the trees to the same extent. The results, none the less, are striking, and indicate great benefit from the nitrogenous fertilizers.

TABLE I. TREATMENT AND RESULTS WITH WINTER NELIS PEARS

Plot	Treatment 1917*	Yield in boxes per tree 1917	Treatment 1918*	Yield in boxes per tree 1918
1	Check	12.13	Check	15.00
2	Nitrate of lime 10 lbs. per tree	15.12	Nitrate of lime 10 lbs. per tree	18.84
3	Nitrate of soda 10 lbs. per tree	15.45	Nitrate of soda 10 lbs. per tree	18.37
4	Nitrate of soda 5 lbs. per tree	16.53	Nitrate of soda 5 lbs. per tree Superphosphate 5 lbs. per tree	16.63
5	Nitrate of soda 5 lbs. per tree	17.03	Nitrate of soda 5 lbs. per tree	17.72
6	Nitrate of soda 5 lbs. per tree	15.06	Sulfate of ammonia 5 lbs. per tree	18.23

* The fertilizer was applied April 7, 1917 and March 22, 1918.

It will be noted that the trees which received only 5 pounds of nitrate of soda produced, with one exception, more fruit than the trees receiving 10 pounds of nitrate of soda and those receiving 10 pounds of nitrate of lime. The difference, however, is not as great as it is between the three rows which each received five pounds of nitrate of soda per tree, indicating probably a difference in the trees to begin with rather than any injury resulting from the larger application of the nitrate. This is especially evident when the results of the second season are studied.

During the second season the experiment was altered on two of the rows which received five pounds of nitrate of soda the first year. One of these rows received 5 pounds of superphosphate in addition to the nitrate of soda, and the other row received 5 pounds of sulfate of ammonia instead of the nitrate of soda.

The results during the second year are interesting. All of the plots produced more than during the previous year. The plot which received ten pounds of nitrate of lime produced nearly four boxes more than the check plot, while the one which received the ten pounds of nitrate of soda produced about three and one-third more than the check plot. The plot which received the 5 pounds of nitrate of soda produced 2.72 boxes more per tree than the check plot, while the plot which received both 5 pounds of nitrate of soda and 5 pounds of superphosphate produced only 1.63 boxes more per tree than the check plot. It is quite remarkable that the nitrate of soda alone should produce over a box more per tree than the nitrate of soda and the superphosphate combined. Judging from the analysis of this soil, especially the subsoil, and from these results, applications of phosphorus are not needed by these trees at this time

It is difficult to believe that the superphosphate when applied in addition to the nitrate of soda is responsible for the decreased yield. The treatment will be continued and special attention will be given to this question.

The 10 pounds of nitrate of soda and nitrate of lime during the second year produced a considerable increase in yield over the amount produced the previous year; while the plot receiving only 5 pounds of nitrate of soda made a comparatively small gain the second year.

The plot which received 5 pounds of sulfate of ammonia produced a notable increase in yield, almost equalling the yield produced by the 10 pounds of nitrate of soda. The increase in the yield of this plot over its yield the previous year is actually greater than the increased yield produced by the 10 pounds of nitrate of soda.

The 5 pounds of sulfate of ammonia contains as much nitrogen as 6½ pounds of nitrate of soda.

From these results it would seem that on this soil and for this variety the sulfate of ammonia may be equal and perhaps superior in value to the nitrate of soda.

The treatments will be continued, and future results noted with much interest. It is well known from many fertilizer experiments conducted elsewhere that the cumulative results of the various fertilizers are of great importance, and final conclusions regarding the comparative value of two fertilizers cannot be drawn from two years work.

While the increased yields of the fertilized trees are notable, the increased size of the fruit was even greater. Most of the fruit from the unfertilized trees packed 225 pears to the box, while most of that from the fertilized trees packed 175 to the box. All of those familiar with the marketing of Winter Nelis pears will readily appreciate the far greater value of the larger fruit from the fertilized trees.

Before the war the cost of nitrate of soda was 3 cents a pound. It is now about 5 cents a pound. Even at this high price, however, the largest application of nitrate of soda amounted to only 50 cents a tree. Considering the increased yields and the greater value of the larger fruit, it is evident that the use of the expensive fertilizer proved highly profitable.

While the cost of sulfate of ammonia per ton is greater than that of nitrate of soda, the cost per pound of nitrogen is practically the same in both fertilizers.

The fertilized trees have been more vigorous than the check trees, making much greater annual growth, and have produced much darker and larger foliage.

Fertilizer Experiments with Spitzenburg Apple

These experiments have been conducted on Mr. R. C. Washburn's ranch in the Table Rock district.

The soil on which these experiments were conducted is locally known as pumice. In the soil survey made by the Bureau of Soils it is designated as Bellavista fine sandy loam, and is described as follows: "The Bellavista fine sandy loam consists of six feet or more of a light gray to light brown fine sandy loam, carrying small to large quantities or rounded and water-worn fragments of pumice and fine-grained basaltic rock. The structure and texture of this soil are uniform throughout its entire depth. This type owes its formation to material derived from pumice, volcanic ash, and massive basaltic rocks, transported and deposited by the Rogue River at an earlier stage, with admixture of some later alluvial material derived by erosion of the basaltic slopes of the Upper Table Rock."

The following table gives the composition of this soil as analyzed by the chemist at the Oregon Agricultural College Experiment Station. The composition is expressed in pounds of plant food per acre; that is, the amount in the surface soil to a depth of one foot, or 3,500,000 pounds; and in a layer of subsoil one foot thick, or 4,000,000 pounds.

	Potassium	Nitrogen	Calcium	Magnesium	Phosphorus	Sulfur	Organic matter
Surface	35000	1470	79100	17500	3220	1400	98000
Subsoil	46800	920	73600	22400	3440	1280	114400

The analysis shows that this soil contains an abundance of potassium, calcium, and magnesium, and a fair amount of phosphorus and sulfur; and that it is low in nitrogen and in organic matter. The subsoil is especially low in nitrogen.

The trees were sixteen years old when the experiment was started. During earlier years the trees had made a good growth and had produced good crops of highly colored and highly flavored fruit. About five years before the beginning of the experiment these trees began to decline in vigor and productiveness, and at the beginning of the experiment the trees were making a very poor growth; the branches possessed a peculiar reddish color and were producing poor crops. Clean cultivation had been practiced for many years, and the orchard had been properly irrigated. During later years winter cover crops had been planted, but these had not proved successful.

Two separate experiments have been conducted, one of which was started in the spring of 1916 and the other in the spring of 1917.

First Experiment on Spitzenburg Apple. The following table shows the fertilizers applied and the yields produced in the first experiment with Spitzenburg apples. The fertilizer was applied Feb. 7, 1916.

TABLE II. TREATMENT AND RESULTS WITH SPITZENBERG APPLES

Plot	Treatment 1917	Yield in boxes per tree 1916	1917
1	Nitrate of soda 10 lbs. per tree	7.1	21.9
2	Check	1.6	4.1
3	Superphosphate 10 lbs. per tree	.57	2.5
4	Muriate of potash 8 lbs. per tree	2.33	4.3

An effort was made to select trees which were reasonably uniform. It was impossible, however, to get strict uniformity in size and vigor in as many trees as this and have them all in one block. The trees which received the muriate of potash were in slightly better condition than the others at the beginning of the experiment.

The increases in yield produced by the nitrate of soda are really phenomenal. The first season the increase over the check plots amounted to 343 percent, and the second year to 434 percent. The exceptionally low yield of all but the nitrate plot the first year was due to a very heavy frost during the blooming season, which destroyed most of the weak blossoms. The blossoms on the trees fertilized with the nitrate of soda were seemingly much more resistant and a smaller percentage of them were destroyed. In addition to the much greater number of apples on the nitrate plot, the individual apples were very much larger than those on the other plots.

The color of the fruit on the nitrate plot was not as dark red as that on the other plots. To improve this condition the fruit was left on these trees a week longer than on the check trees. While the color never did attain the dark red of the fruit on the other trees it was very good and was placed in the first grade. The fruit on these nitrate trees also was more tender and juicy, and of better quality than that on the other trees.

While the plot fertilized with superphosphate produced less than the check plot this should not necessarily be attributed to any injurious effect of the fertilizer. The smaller yield of the superphosphate plot is probably due to a slight difference in the trees at the beginning of the experiment. This is especially evident when the results obtained from the second experiment in this same orchard are considered.

The first season the trees fertilized with the muriate of potash produced 45 percent more than the check plots, while the second season there was very little difference. Since this soil naturally contains an abundance of potash, and since there was very little difference in the yield the second season, the larger yield the first season was probably due to a difference in the trees at the beginning of the experiment.

The effect of the nitrate of soda on the trees was remarkable. These trees made a new-shoot growth of from two to three feet, while the trees on the other plots made a puny growth of from five to ten inches. The leaves on the nitrate plot were very large, and possessed a rich, dark-green color, while those on the other plots were small and yellowish-green in color. The effect on the color of the bark was very evident. The color of the bark of the branches of the check, phosphorus, and potash plots was a pale, reddish, sickly hue, while that on the nitrate plots assumed a normal, lusty, grayish-green color.

Second Experiment on Spitzenburg Apple. This experiment was conducted in the same orchard, and on the same kind of soil as the former experiment. The first application of fertilizer was made March 7, 1917, and the second March 9, 1918.

In this experiment all of the fertilizers containing nitrogen again produced large increases in yield. The 5 pounds of sulfate of ammonia produced an increase of 345 percent, while the 5 pounds of nitrate of soda produced an increase of 471 percent. The amount of sulfate of ammonia applied contained more nitrogen than the nitrate of soda, but it is not so readily available, and did not produce as good results the first season on this soil.

The largest yield was obtained from a combination of 5 pounds of nitrate of soda and 5 pounds of superphosphate. This is quite surprising since this soil contains a fair amount of phosphorus, especially in the subsoil. It will also be noted that the application of 5 pounds of superphosphate alone produced an increase in yield. Considering the fact that this experiment was conducted near the first experiment, and on soil which appears to be identical, these results with superphosphate cannot be considered conclusive, especially as they represent only one season.

Table III shows the fertilizers applied and the yields.

TABLE III. TREATMENT AND RESULTS WITH SPITZENBERG APPLE

Plot	Treatment 1917, 1918	Yield in boxes per tree 1917	1918
1	Sulfate of ammonia 5 lbs. per tree	5.93	No fruit
2	Nitrate of soda 5 lbs. per tree	7.60	No fruit
3	Nitrate of soda 5 lbs. Superphosphate 5 lbs.	8.73	No fruit
4	Check	1.33	No fruit
5	Nitrate of soda 2½ lbs. per tree	3.29	No fruit
6	Superphosphate 5 lbs. per tree	2.51	No fruit
7	Dried blood 6½ lbs. per tree	3.25	No fruit

Nitrate of soda at the rate of 2½ pounds per tree produced an increase of 147 percent over the check plot. While this is a considerable increase the application was not sufficient to produce maximum yields. In fact it is probable that 10 pounds of nitrate per tree the first year would have produced better results than the 5 pounds, which was the largest amount applied.

The application of 6½ pounds of dried blood supplied as much nitrogen as the 5 pounds of nitrate of soda. While the dried blood produced an increase in yield of 144 percent, it produced less than half the amount of fruit produced by an equal amount of nitrogen in the form of nitrate of soda. In fact, the 2½ pounds of nitrate of soda per tree produced slightly more fruit than twice that amount of nitrogen in the form of dried blood. It appears probable from these results that all of the nitrogen in the dried blood does not become available the first season, and will not give as quick results as the same amount of nitrogen in nitrate of soda. On the other hand, the form in which nitrogen exists in a fertilizer may be an important factor.

The trees fertilized with the larger amounts of these nitrogenous fertilizers were so much more vigorous, and the foliage was so much denser and darker-colored, that these trees could be distinguished from the check trees for a distance of half a mile.

Effect of Nitrate of Soda on Winesap Apple

Another experiment was conducted to determine the value of nitrate of soda on old Winesap apples on the same soil and ranch as that on which the two previous experiments were conducted. Table IV gives the results.

TABLE IV. EFFECT OF NITRATE OF SODA ON WINESAP APPLES

Plot	Treatment	Yield in boxes per tree 1917	1918
1	Nitrate of soda 10 lbs. per tree	7	5.83
2	Nitrate of soda 5 lbs. per tree	6	7.50
3	Check	7	3.66
4	Check	9	1.80

The trees in the two rows which received the nitrate of soda were slightly smaller than those in the two check rows. The first year the nitrate of soda had no noticeable effect on the fruit. In fact the check trees actually produced more. But this was probably due to the fact that the trees in the check plots were larger. The second year, however, the two fertilized plots produced on an average 143 percent more than the check trees. In fact, the difference is even greater than this, since check row 3 received some benefit from the nitrate applied to the adjacent row, as could be observed in the darker foliage and larger and better fruit on the side of these trees next to the nitrate trees.

At the beginning of the experiment these Winesap trees were making very little annual growth and the foliage was small. While they were producing moderate crops, the fruit was small and a large percentage of it dropped from the trees before picking time. This continued to be the case with the check trees, but showed a decided improvement in the fertilized trees the second year. These trees made a good new growth, and the leaves were much larger and darker-colored, the fruit larger, and very little of it dropped before picking time.

Effect of Nitrate of Soda on Yellow Newtown Apples

In another portion of this orchard on pumice soil five Yellow Newtown apple trees were treated as indicated in Table V.

TABLE V. EFFECT OF NITRATE OF SODA ON YELLOW NEWTOWN APPLES

Plot	Treatment 1917	Treatment 1918	Yield in boxes per tree 1917	1918
1	Nitrate of soda 5 lbs. per tree	Nitrate of soda 10 lbs. per tree	No fruit	13.75
2	Check	Check	No fruit	11.25

The fertilizer was applied March 12, 1917, and March 9, 1918. The trees at the beginning of the experiment were making a moderate growth and were bearing fair crops every other year. Even with an abundance of water it was difficult to get the fruit to size properly. Furthermore, these trees had received heavy applications of stable manure during previous years, and had improved considerably from this treatment, although the stable manure appeared to be very slow in its action, and the trees remained considerably below normal even after this treatment. While the stable manure is very valuable and every particle produced on the farm should be conserved and used, its action is very slow in producing the necessary improvement. For this reason, even where an abundance of manure is applied much better results will be obtained the first two or three years if the trees are also fertilized with some quickly available nitrogenous fertilizer.

In this test the difference in yield amounts to 2½ boxes per tree in favor of the fertilized trees. This, however, does not represent the total gain. The fruit from these fertilized trees was much larger than that from the unfertilized trees and therefore more valuable per box. Furthermore, these trees made a much better growth, possessed darker and healthier foliage, and undoubtedly are in much better condition to produce larger crops in the future. Since these trees were in a weak condition at the beginning of the experiment it is probable that the value of the fertilizer will become even more apparent in future years. It is probable that the fertilized trees will bear more regularly than the unfertilized trees on this soil.

From these results and those obtained elsewhere in this valley the writer has reached the conclusion that the Yellow Newtown does not respond to the use of fertilizers as readily as does the Spitzenburg apple.

The increases in the yield of fruit on the fertilized plots in all of these tests have been so large with all of these varieties, however, that even with the present high cost of nitrogenous fertilizers their use has proved very profitable.

Fertilizer Experiment With Peaches

Only one fertilizer experiment has been conducted with peaches, and this owing to frosts some years, lack of uniformity in the trees, and failure to get the yields for one year, has not been very satisfactory. The value of nitrate of soda in this orchard has been so evident, however, that the meagre results obtained are worth reporting.

The experiment was conducted on Mr. A. C. Joy's ranch, one mile southeast of Ashland, in the leading peach district of the county. The trees are all Muirs and were eighteen years old when the experiment was started. This has been one of the leading peach orchards in the valley, and in the past has produced splendid crops of excellent fruit. During the three years previous to the experiment the trees were beginning to decline in vigor, and during dry seasons it was difficult to get fruit of desirable size.

The soil is a coarse granite, and is classed as Barron coarse sand by the U. S. Bureau of Soils. The following table gives the chemical composition of this soil expressed in pounds of plant food per acre; that is, the amount in the surface soil to a depth of one foot, or 3,500,000 pounds, and in a layer of subsoil one foot thick, or 4,000,000 pounds.

	Potassium	Nitrogen	Calcium	Magnesium	Phosphorus	Sulfur	Organic matter
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Surface	65100	1820	77000	17850	2695	980	52150
Subsoil	105200	600	61600	29200	3560	600	82400

This soil contains an abundance of potassium, calcium, and magnesium, a small amount of phosphorus in the surface soil and a fair amount in the subsoil. The nitrogen and sulfur content is very low, especially in the subsoil. The amount of organic matter is very small.

TABLE VI. TREATMENT AND RESULTS WITH PEACHES

Plot	Treatment 1915	Yield in boxes per tree 1915	1916	1917	1918
1	Nitrate of soda 3 lbs. per tree	48.5	36.0	40% increase	No fruit
2	Superphosphate 3 lbs. per tree	45.7	8.5	No increase	No fruit
3	Sulfate of potash 3 lbs. per tree	52.0	8.0	No increase	No fruit
4	Nitrate of soda 1½ lbs. Sulfate of potash 1½ lbs.	53.5	8.5	No increase	No fruit
5	Check	52.6	9.0		No fruit
6	Nitrate of soda 1½ lbs. Superphosphate 1½ lbs.	69.0	7.0	No increase	No fruit
7	Superphosphate 1½ lbs. Sulfate of potash 1½ lbs.	30.0	9.0	No increase	No fruit
8	Nitrate of soda 1 lb. Superphosphate 1 lb. Sulfate of potash 1 lb.	60.0	9.5	No increase	No fruit
9	Check	41.0	7.5		No fruit

The fertilizer was applied on Feb. 17, 1915, Feb. 15, 1916, March 14, 1917, and March 23, 1918. The application during 1915 and 1916 was the same. In 1917 the amount was cut down to 1 pound of each fertilizer per tree, due to the excessive growth produced by the nitrate of soda during the two previous seasons. In 1918 this was again increased to 2 pounds per tree. During 1917 and 1918 no potash was applied as none was available.

The yields produced on the various plots during 1915 are so inconsistent that they probably are of little or no value. For example, in the two check plots there is a difference of more than 11 boxes. Taking this fact into consideration, especially when compared with the results of the following years, the 1915 results are probably of no value owing to too great variation in the trees.

The value of the nitrate of soda in improving the vigor of the trees was very clearly demonstrated in 1915. All of the trees receiving this material made a much better growth, and possessed darker green foliage than the other trees. This increased vigor was so great where the trees received the 3 pounds of nitrate of soda, and the foliage so heavy that the fruit was considerably greener and ripened a week later than on the check plots.

The value of the increased vigor is clearly demonstrated in the results of 1916. During the blooming season a heavy frost occurred which destroyed most of the fruit. The trees which had received the three pounds of nitrate of soda were in such vigorous condition that they withstood the frost much better. This plot produced four times as much fruit as the other plots. The fruit was larger, and the trees in very much better condition than those on the other plots.

During the picking season of 1917 the writer was in the Orient and hence no record was obtained of the yield of each plot. The crop during this year was a heavy one and the fruit of good quality. The owner of this orchard and Mr. A. C. McCormick, of the Southern Oregon Branch Experiment Station, examined these trees carefully and estimated that plot 1 produced from 35 to 40 percent more fruit than the check plots. The plots which had received superphosphate and potash either separately or in combination showed no superiority over the check plots. The plots which in 1917 had received an application of only 1 pound of nitrate of soda in combination with phosphorus and potash showed very little improvement over the check plots.

Owing to heavy frost during the blooming season of 1918 there was very little fruit on any of the trees.

While this experiment cannot be considered a very satisfactory one, it is, nevertheless, very evident that nitrogen is the chief need of peach trees on this soil, and that it is profitable to supply it in the form of nitrate of soda. The owner of the orchard in which this experiment is being conducted has been so impressed with the value of the nitrate of soda on these trees that he fertilized his entire orchard with this material in the spring of 1919.

The results obtained from nitrate of soda in this orchard are in harmony with the chemical analysis of this soil.

This experiment is being continued and it is hoped that more conclusive results will be obtained in the future, especially regarding the value of phosphorus and potash when used in conjunction with nitrogen.

SUMMARY

From the results obtained thus far it is very evident that the chief element needed in some of our orchards is nitrogen. It is still a question whether it will prove profitable to use phosphorus in addition to nitrogen in some of these orchards. In fact, it is very probable that it will not prove profitable to use phosphorus at the present time in most of these orchards.

Preliminary tests conducted on some of the very heavy soils in the valley, which usually show a fair amount of nitrogen in the soil, indicate that on most of them commercial fertilizers for fruit trees will not prove profitable at the present time.

Owing to the numerous soil types in this county, and the fact that often several soil types are found on one ranch, the question whether or not fertilizers are needed is a purely local one. This must be determined experimentally for each soil type, and probably for every ranch. A careful study should be made of the bulletin on the Soils of Jackson county,* recently published, which gives the chemical composition of all the leading soil types of this county. In this it will be found that a number of our soil types are very low in nitrogen, and these will probably respond to the use of nitrogenous fertilizers.

Wherever fruit trees are not giving entirely satisfactory results it will be an excellent plan to apply nitrate of soda, nitrate of lime, or sulfate of ammonia to at least ten typical trees in the orchard to determine whether nitrogen is needed. To get results as quickly as possible it is suggested that in such an experiment an application of 10 pounds be made to each tree in the case of old apple and pear trees, and 3 pounds to each tree in the case of large peach trees.

* The Soils of Jackson County, by H. V. Tartar and F. C. Reimer. Oreg. Agr. Col. Exp. Sta. Bul. 164. January, 1920.

RECENT EXPERIMENTS WITH NITRATE OF SODA IN BEARING ORCHARDS IN HOOD RIVER VALLEY

By

GORDON G. BROWN

This report deals very largely with experiments with nitrate of soda in Hood River Valley for the years 1917 and 1918. The experiments conducted previous to these dates have already been reported in reports of the Hood River Branch Experiment Station. For the benefit of new readers, however, brief reference is made to conditions of orchards which prompted the investigation and some of the early results of our first experiments.

When investigational work was started in the several orchards referred to, conditions prevailing were typical of a large number of orchards. Clean cultivation was for many years the established practice. Irrigation was withheld. The result was, that the humus content of the soil became very low; this was also true of available nitrogen. As may be surmised, the physical condition of the soil underwent a marked change. It puddled or baked easily, lacked water-holding capacity, and on hillsides was subject to erosion. Under these abnormal conditions trees failed to make a satisfactory growth. Fruit spurs lacked vigor and a high percentage of blossoms failed to set their fruits. Fruit was of deep color but small. Yields were abnormally small.

Experimental work with nitrate of soda very quickly indicated that nitrogen was the limiting factor. When nitrate of soda was applied at the rate of 5 or 6 pounds per tree in early spring, trees took on renewed vigor. Terminal growth was good. Fruit spurs became vigorous and a high percentage of the blossoms retained their fruits until maturity. Large, green, vigorous foliage resulted, as contrasted with the small, yellow, weak foliage on unfertilized trees. There was a marked increase in size of fruit on fertilized trees. With Spitzenbergs, however, repeated applications of nitrate of soda tended somewhat to decrease the deep red color.

When two or three successive, annual applications of nitrate had been made, several problems came up for future study. It appeared that excessive use of this fertilizer could easily be made. There was evidence to support the view that by so doing, deep color in Spitzenbergs might be unduly sacrificed and possibly keeping quality impaired. There appeared to be a danger, moreover, that trees might be thrown "out of balance," in that the tree's energies would be diverted into excessive wood-growth instead of a properly proportioned fruit production.

Meanwhile, in the experimental orchards referred to, shade crops such as clover or alfalfa were introduced. The former was grown largely for turning under, in order quickly to restore humus, while alfalfa was seeded with the view of keeping it in the orchard for many years. These two soil practices were, therefore, essentially distinct. Both practices had to be studied as regards how they influenced tree growth and fruit production.

The continued use of nitrate had to be studied, moreover, in connection with these additional soil factors. Where such crops are employed, is it necessary to use any artificial fertilizer, and, if so, when, and in what amounts? The problem was further complicated in that it had to be studied with reference to two or more varieties, Spitzenbergs and Newtowns, each representing different growing and producing habits.

The reader is urged to keep in mind that results were studied on one soil type, "Hood silt," and may not apply in all respects to the several other types in the same valley on which apples are grown. Generally speaking, experiments with nitrate of soda on bearing apple trees in different parts of the State indicate that nitrogen is lacking on the lighter soils and that the use of a nitrogenous fertilizer such as nitrate of soda has been justified. We are interested to know the following: Can nitrate of soda insure large and regular crops of good quality? May the tendency of these varieties to produce a large crop one year and a much smaller one the next be influenced, and to what extent? These are but a few of the more important factors on which information is desired.

SOIL MANAGEMENT IN ORCHARDS 1 AND 2

To facilitate study, orchards will be designated by number. Table VII indicates the basis of fertilizer tests in orchards 1 and 2. Notice that orchard 1 includes both Newtowns and Spitzenbergs. For both varieties, similar fertilizer tests were made. Five and two-tenths pounds of nitrate of soda per tree were applied in 1914 and 1915. It will be noticed further that for each variety there are three plots, each of which received similar amounts of nitrate during each of the years mentioned. This was due to the fact that the methods of application differed. The fertilizer was applied broadcast on one plot; on another, it was sprayed on the ground in liquid form; on another, it was sprayed on the tree and ground.

Orchard 2 refers to Spitzenbergs. Here, also, the methods of application for 1914 and 1915 differed as in the case of orchard 1. Six and seven-tenths pounds of nitrate per tree were applied each year. In both orchards one plot was left unfertilized and will be referred to as the check.

Orchard 1 was seeded to clover in the spring of 1914. In 1915 hogs and young cattle were allowed to pasture on this crop during a major portion of the growing season. In the spring of 1916 this crop was plowed under and clean cultivation practiced during early summer. In 1917 alfalfa was seeded and a fair stand obtained.

Orchard 2 was seeded to a mixture of alfalfa and clover in 1914. After the first season alfalfa predominated. A fair stand was obtained. One or two cuttings of hay were removed annually since 1915. The stand of alfalfa has been thoroughly disked each spring, principally to control weeds. Irrigation has been a regular feature in both orchards since 1914.

Having brought both varieties in each orchard to a highly productive state by the use of early-spring applications of nitrate, in two consecutive years, at the rate of 5.2 and 6.7 pounds per tree, additional fertilizer was withheld during 1916 and 1917. By so doing the aim was to determine whether the changed response in these trees induced largely by the use of nitrate of soda was temporary in character, and if not, how long such influence lasted. Furthermore, it was hoped to secure data bearing upon

TABLE VII. FIVE-YEAR SUMMARY, YIELDS AND VIGOR OF GROWTH, ORCHARDS 1 AND 2

Spitzenbergs

Orchard No.	Plot No.	Nitrate per tree 1914	1915	1916	1917	1918	Yields per tree (loose boxes) 1914	1915	1916	1917	1918	Avg.	Terminal Growth Annual average 1914	1915	1916	1917	1918	Avg.
		lbs.	lbs.	lbs.	lbs.	lbs.							in.	in.	in.	in.	in.	
1	1	5.2	5.2	....	....	3.0	4.1	8.1	13.0	18.7	5.7	9.93	12.8	18.0	20.1	13.3	17.6	16.30
	2	5.2	5.2	....	....	3.0*	.2	6.0	9.6	18.6	2.6	7.40	10.8	17.0	16.1	14.0	13.2	14.20
	3			Check—none			.2	.3	8.8	15.3	1.10	5.10	7.5	6.4	19.9	18.1	13.2	13.00
	4	5.2	5.2	....	....	....	.1	8.5	14.8	17.3	4.0	8.90	9.25	13.6	17.1	10.6	14.6	13.07
2	2	6.7	6.7	....	....	3.0	9.8	10.1	15.7	4.5	6.66	9.38	7.8	14.0	14.7	11.1	12.5	12.03
	3	6.7	6.7	....	....	3.0*	1.6	10.0	14.8	2.8	6.8	7.21	5.8	11.0	15.4	11.2	10.6	10.30
	4			Check—none			2.1	.9	5.7	3.9	5.5	3.60	5.3	8.0	5.2	12.1	10.3	8.10
	5	6.7	6.7	....	....	....	2.3	9.9	15.5	3.3	5.0	7.20	4.5	16.2	8.4	10.7	13.5	10.60

Newtowns

Orchard No.	Plot No.	Nitrate per tree 1914	1915	1916	1917	1918	Yields per tree (loose boxes) 1914	1915	1916	1917	1918	Avg.	Terminal Growth Annual average 1914	1915	1916	1917	1918	Avg.
1	1	5.2	5.2	....	....	3.0	3.15		16.7	4.0	13.3	9.30	6.3	10.8	16.7	6.4	8.8	9.80
	2	5.2	5.2	....	....	3.0*	.56	Very light crop	9.8	12.6	4.9	6.90	6.8	8.1	8.4	10.7	7.6	8.30
	3			Check—none			1.29		13.3	12.6	9.1	9.07	4.4	3.2	8.6	9.0	8.8	6.80
	4	5.2	5.2	....	....	....	1.68		14.4	8.4	10.4	8.73	6.8	6.9	12.3	8.3	9.0	8.60

* In 1918 the equivalent of 3.0 lbs. of nitrate applied in the form of sulfate of ammonia.

the further use of nitrate, in addition to the two applications referred to, this to be considered as a supplement to the use of shade crops. Consequently, after having withheld nitrate during 1916 and 1917, three pounds per tree were applied in early March, 1918, to one of the plots formerly fertilized, in each orchard. At the same time, on another formerly fertilized plot, in each orchard, sulfate of ammonia, the equivalent of three pounds of nitrate per tree, was applied. The other, formerly fertilized plot, in each orchard, received no fertilization in 1918. No fertilizer has been applied to trees in the check in either orchard since the test started.

In orchard 1 this schedule of applications applied to both Newtowns and Spitzenbergs. The plan thus enables us to complete a five-year study in tree response; first, from the 1914, 1915, and 1918 applications; second, from the 1914 and 1915 applications; and third, from no fertilizer applications. Incidentally, a comparative study of results of nitrate of soda and sulfate of ammonia was afforded.

SOIL MANAGEMENT IN ORCHARDS 3 AND 4

Results from the use of nitrate of soda in orchards 1 and 2 were so striking by the end of the second year's work, that it was decided to study further in what amounts, and at what intervals, nitrate of soda under initial conditions, similar to those enumerated in orchards 1 and 2, might most profitably be applied. The economic aspect of the problem is apparent, since the price of this fertilizer has risen from $60.00 to $115.00 a ton during the past two years. The point of view in this regard was not that of restricting its use but rather to find out in what respect its most profitable use could be assured.

Orchards 3 and 4 were selected in the spring of 1916 and tests made bearing upon these points. These orchards were twelve and thirteen years of age, respectively, when the tests were started. Trees in both orchards had been very unproductive for a number of years, being influenced by similar soil practices to those which induced lack of vigor and low production in orchards 1 and 2; namely, prolonged clean tillage and lack of irrigation.

When experiments in orchards 3 and 4 were started in 1916, four plots were laid off in each case. Each plot refers to both Newtowns and Spitzenbergs. Plot 1 in each orchard received 7.3 pounds nitrate per tree in early March; plot 2, 5 pounds; plot 3 (check), no fertilizer; and plot 4, 3 pounds.

In the spring of 1917, when second applications were made, each fertilized plot was equally divided, one-half receiving a second application equal in amount to that of the previous year. On the other half of each plot, fertilization was withheld until the spring of 1918. At this time, however, on that portion of each plot receiving nitrate of soda in 1917, fertilization was withheld. No fertilizer was applied to trees in the check during this three-year period.

Experiments in orchards 3 and 4, covering a three-year period, represent therefore, in addition to the unfertilized checks, two consecutive annual applications of nitrate at the rate of 7.3, 5.0, and 3.0 pounds per tree, followed by no application in 1918, as contrasted with similar amounts applied in the springs of 1916 and 1918, but with no fertilizer during the intervening year. In both orchards fair stands of clover were obtained from 1916 seeding, and two crops have been removed a season during each year, 1917 and 1918. Irrigation has been regular since 1916. Table VIII clearly indicates soil practices. In addition to these tests, experiments with both varieties were also conducted in a fifth representative orchard for further study of points already raised.

YIELDS, SPITZENBERGS, ORCHARD 1

Table VII records average yields per tree in loose boxes for the several plots covering a five-year period. During the first year, yields were abnormally small in all plots. In 1915, however, all plots receiving nitrate of soda show very marked increases in yield over the check. For example, plot 4 shows an average of 8.5 loose boxes per tree and the check only .3 box.

In 1916, the year during which clover was turned under, a distinct change in the check trees was brought about. This, as well as the fertilized plots, gave good yields. In 1917, there were no marked differences in yields in any of the plots. Yields, however, were very good.

For two successive seasons following the turning under of clover the check shows an average of 8.8 and 15.3 loose boxes per tree. Trees in any of the fertilized plots also show excellent yields. Plot 4, for example, shows an average of 14.8 and 17.3 loose boxes per tree for 1916 and 1917. As far as yields are concerned, therefore, the change following the turning under of clover is more marked in the case of check trees than is true of the trees receiving nitrate in addition to the shade crop. The fact that trees receiving no nitrate of soda, but rather a shade crop of clover only, respond in increased yields so quickly, is distinctly encouraging to one who would depend upon this system of management to maintain fertility without a commercial fertilizer as a supplement.

The 1918 bloom for this variety was extremely small, as is reflected in yields. Plot 1, on which three pounds of nitrate were applied in 1918, produced 5.75 loose boxes per tree, practically double that of plot 2 on which sulfate of ammonia was applied. These figures cannot be construed to throw much light upon the relative value of nitrate of soda and sulfate of ammonia, since plot 1 had the better bloom. Viewed in the light of several years, the check, in giving an average annual yield of only 5.1 boxes per tree, shows up poorly. A five-year average shows that the plots range 1, 4, 2, and 3 (check) in relative order of higher to lower yields. This relation also holds true for total yields covering years 1917 and 1918.

YIELDS, NEWTOWNS, ORCHARD 1

A five-year summary of the same test for Newtowns is also shown in Table VII. The beneficial influence of clover when turned under, without the use of nitrate as a supplement, is very conspicuous. Three good crops have been borne from 1916 to 1918 inclusive. For these three years, the check shows an annual average of 11.6 boxes per tree. The conspicuous fact worthy of emphasis in this test is, that under these conditions trees fertilized in 1914 and 1915 with nitrate of soda do not show a higher average annual yield per tree for 1916, 1917, and 1918, than trees receiving no additional fertilization. This would seem to indicate that under some conditions, especially with orchards grown on the heavier soils, a system of management in which clover only is used may be expected to keep up soil fertility without the use of nitrate of soda or similar fertilizers.

YIELDS, SPITZENBERGS, ORCHARD 2

Turn to orchard 2, Table VII. It is to be noted that in this orchard, alfalfa has been growing since 1914. There has been a gradual physical improvement in trees in the check. Yields, however, are small. Approximately a fifty percent full bloom appeared in the plots in 1918, sufficient for a good yield, but the fruit did not "set" well. The leaf roller is also responsible for much loss in this regard.

TABLE VIII. YIELDS PER TREE AND VIGOR OF GROWTH

Plot	No.	Nitrate per tree 1916	1917	1918	Total	Yields per tree (Loose boxes) 1916	1917	1918	Average	Terminal growth 1916	1917	1918	Average
		lbs.	lbs.	lbs.	lbs.					in.	in	in.	in
				Spitzenbergs—Orchard 3									
1	A	7.3	7.3	....	14.6	18.00	9.80	10.00	12.60	11.5	14.40	15.7	13.80
	B	7.3	....	7.3	14.6	14.20	4.37	7.09	8.50	11.5	10.80	14.9	12.40
2	A	5.0	....	5.0	10.0	13.90	2.40	6.60	7.60	9.9	7.60	15.1	10.90
	B	5.0	5.0	....	10.0	13.20	5.80	10.60	9.90	9.9	13.70	11.2	11.60
3		Check—none				8.56	1.28	9.80	6.50	4.1	6.90	12.0	7.70
4	A	3.0	....	3.0	6.0	16.00	1.23	13.50	10.20	14.1	7.90	10.5	10.80
	B	3.0	3.0	....	6.0	10.40	2.99	12.00	8.40	14.1	13.90	7.43	11.80
				Newtowns—Orchard 3									
1	A	7.3	7.3	....	14.6	14.60	9.70	10.10	11.46	9.5	7.35	15.0	10.60
	B	7.3	....	7.3	14.6	13.10	7.30	6.70	8.80	9.5	5.60	10.9	8.70
2	A	5.0	....	5.0	10.0	12.80	5.80	7.20	8.60	6.2	7.30	15.0	9.50
	B	5.0	5.0	....	10.0	11.40	12.70	5.00	9.70	6.2	9.60	12.2	9.30
3		Check—none				5.30	5.70	7.30	6.10	4.5	3.80	15.2	7.80
4	A	3.0	....	3.0	6.0	12.70	4.96	14.60	10.70	6.4	3.10	8.1	5.88
	B	3.0	3.0	....	6.0	7.50	11.30	6.10	8.30	6.4	9.05	7.0	7.48
				Spitzenbergs—Orchard 4									
1	A	7.3	7.3	....	14.6	7.60	21.60	3.30	10.8	17.4	20.00	25.3	20.90
	B	7.3	....	7.3	14.6	5.40	17.30	0.00	7.5	17.4	17.30	23.6	19.40
2	A	5.0	....	5.0	10.0	3.80	14.60	0.00	6.15	20.1	14.70	20.9	18.60
	B	5.0	5.0	....	10.0	5.50	22.10	0.00	9.20	20.1	16.60	15.4	17.40
3		Check—none				1.58	7.25	2.45	3.70	4.7	7.60	14.6	8.90
4	A	3.0	....	3.0	6.0	6.25	17.60	0.00	7.95	17.7	14.10	18.3	16.70
	B	....	3.0	....	6.0	5.73	20.70	0.00	8.80	17.7	15.40	10.2	14.40
				Newtowns—Orchard 4									
1	A	7.3	7.3	....	14.6	3.30	12.70	0.00	5.38	13.4	16.80	14.0	14.90
	B	7.3	....	7.3	14.6	2.60	13.20	1.40	5.75	13.4	14.50	17.1	15.00
2	A	5.0	....	5.0	10.0	3.90	10.90	1.30	5.30	12.3	12.60	12.6	12.50
	B	5.0	5.0	....	10.0	3.80	15.90	2.80	7.50	12.3	15.30	10.9	12.80
3		Check—none				.20	7.70	7.00	4.90	3.9	5.70	11.4	7.00
4	A	3.0	....	3.0	6.0	2.70	9.10	0.00	3.90	8.9	11.90	10.8	10.50
	B	3.0	3.0	....	6.0	3.30	13.90	0.00	5.70	8.9	12.50	8.2	9.90

From the standpoint of yields, there is little to support the idea that nitrate of soda exerts direct influence beyond the second season following its application. During 1916, the largest crop was obtained, and differences in favor of nitrated trees were marked. Fertilized trees bore over 15 loose boxes and the check only 5.7 per tree.

In spite of a good bloom in 1917 the marked difference in yields between fertilized trees and those in the check does not exist. The crop was small. A comparison between yields from the check in 1918 and plot 5, which had no fertilization in 1918, still further indicates this important fact. Plots 2 and 3, which were fertilized in 1918, show slight gains over the check in point of yields but reveal no practical differences as between nitrate and sulfate of ammonia. Yields were disappointing and indicated strongly that Spitzenbergs of average vigor, in the presence of well established alfalfa, appear to be limited in their ability to respond to additional applications of nitrate of soda in a manner comparable to that experienced by the same trees a few years before, when their vitality was low and clean tillage was employed.

YIELDS, SPITZENBERGS, ORCHARD 5

Additional observations concerning the use of nitrate of soda when applied to trees of moderate vigor, were made in orchard 5. In this case, thirteen-year-old Spitzenbergs were studied in an orchard where alfalfa had been growing for four years. The trees had borne several average crops of good quality just previous to the starting of this experiment. In early March, 1917, to each of these trees, a three-pound application of nitrate of soda was made. Another block of similar trees was left unfertilized as a check. Briefly, yields were as follows: Fertilized trees in 1917 showed an average of 11.3 boxes each, as compared with only 6.4 for the check, a difference of 4.9 boxes per tree. Neither block was fertilized in 1918. Note results. The previously fertilized trees yielded only 6.4 boxes each as compared to 9.4 for the check, thus leaving a yearly margin of only .9 box per tree in favor of the nitrated trees. Here, again, as in orchard 2, trees of moderate vigor, growing in well established alfalfa, appear to be less easily influenced in yields by small applications of nitrate of soda than was true of trees of subnormal vigor where clean cultivation was employed. The above facts throw light on how long the influence of nitrate applied to bearing trees under shade-crop conditions may be expected to last.

YIELDS, NEWTOWNS, ORCHARD 5

Where trees show a tendency to bear heavy crops one year and light the next, the problem of knowing whether to apply nitrate of soda during the spring of the heavy- or the light-yielding year or during both years is important. With this point in mind, in 1917 two blocks of sixteen-year-old Newtowns of more than average size were chosen for a test. Alfalfa, of average vigor, had been growing between the trees during three seasons. During 1917 scarcely any bloom appeared. Yields averaged less than 1½ boxes per tree for that season. Trees in both blocks made a good growth for several years previous to the test, but were beginning to show decreased vigor, following several heavy crops.

In early March a three-pound application of nitrate of soda was made to trees in block 1 in 1917 and again in 1918. Block 2 received no fertilizer in 1917, but 3 pounds in 1918. Yields for 1918 were: block 1, 18.6 loose boxes per tree; block 2, 19.0 boxes. The fruit from trees thus receiving but the one application of nitrate the same season as the heavy crop was fully as large as that from trees receiving a similar application in addition during the previous "off" year. The data of course, cover results for two seasons only, and do not throw light upon all of the points raised; but as far as this orchard is concerned, the more economical use of nitrate is made when it is applied during the spring of the year when heavy crops are expected.

YIELDS IN ORCHARDS 3 AND 4

Turn again to Table VIII. First, notice when, and in what amounts, nitrate was applied. Since both orchards were given identical fertilizer treatment it seems best to deal with results in both cases together. With Spitzenbergs in both orchards in 1916 the plot receiving the heavy application (7.3 pounds) gave highest yields, although a heavy bloom occurred in orchard 3 and a light one in orchard 4. Again, in 1917 trees in plot 1 (a) representing two consecutive, annual, 7.3-pound applications stand first in point of yields.

Owing to the fact that the bloom in orchard 4 was almost negative in 1918 except in the check, it will be fairer to compare yields on a three-year average. On this basis, plot 1 (a) excels, showing an average of 12.6 loose boxes per tree for orchard 3, and 10.85 boxes for orchard 4. It should be kept in mind that no fertilizer was applied in 1918. The notable feature in this study is the bearing habits of trees. Orchard 3 at the end of the third season's test shows two good crops interspersed with a light one in 1917. It is encouraging to note that this tendency to heavy and light bearing was largely overcome in plot 1 (a). Trees show an average of 18.06 boxes per tree for 1916, 9.8 for 1917, and 10.0

TABLE IX. PARTIAL SUMMARY OF TABLE VIII SHOWING RANKING ORDER OF PLOTS AS BASED ON AVERAGE YIELDS FOR THREE-YEAR PERIOD

Yield order	Spitzenbergs Orchard 3	Spitzenbergs Orchard 4	Newtowns Orchard 3	Newtowns Orchard 4	Nitrate of soda applied 1918	1917	1916	Total
					lbs.	lbs.	lbs.	lbs.
First	1(a)	1(a)	1(a)	1(a)	7.3	7.3	....	14.6
Second	4(a)	4(a)	4(a)	4(a)	3.0	....	3.0	6.0
Third	2(b)	2(b)	2(b)	2(b)	5.0	5.0	....	10.0
	1(b)	1(b)	1(b)	1(b)	7.3	....	7.3	14.6
	4(b)	4(b)	4(b)	....	3.0	3.0	....	6.0
Fourth				2(a)	5.0	....	5.0	10.0
		2(a)	2(a)		5.0	....	5.0	10.0
Fifth				4(b)	3.0	3.0	....	6.0
				4(b)	3.0	3.0	....	6.0
	2(a)				5.0	....	5.0	10.0
				3	No fertilizer			
Sixth	3	3	3		No fertilizer			

for 1918. In orchard 4, however, trees receiving similar fertilizer treatment, although averaging better than those in any other plot, are given to wide fluctuations in yields.

Table IX supplements Table VIII in graphically indicating the relative order of average yields per tree for the different plots, covering a three-year period, for both varieties, in orchards 3 and 4. Where plots differ in average yield for a three-year period by less than 1 box per tree they are given equal rating. The conspicuous fact is, that either variety when given 7.3 pounds of nitrate of soda per tree for two consecutive years shows larger average yields than smaller applications made at similar times, or than two equally large applications put on with a two-year interval, during which no nitrate was applied. The reader is again reminded, that these results were brought about with trees extremely low in vitality and production when the test started and that clover, which grew in both orchards during the three-year period, was not plowed under as was true in orchard 1.

RELATION OF SOIL CULTURE TO VIGOR OF TREE GROWTH

The relative vigor shown by trees studied in these tests has been measured in respect to the character and extent of terminal growth. This latter method has proved very satisfactory. The plan has been to measure a large number of growths, from which averages are derived. For a study of this factor, see Tables VII and VIII.

First, notice Spitzenbergs in Table VII, orchard 1. We are interested mainly in growth during the past three years. Since 1916, when clover was turned under, terminal growth in the check has been very vigorous, and practically equal to that of the other plots. Differences in growth in trees to which applications of nitrate of soda and sulfate of ammonia were made are slight.

In orchard 2, trees in all plots show moderate vigor, regardless of treatment given. During the past three years those in the check plot show greatly increased vigor compared with that of former years. During 1917 and 1918 growth has been practically equivalent to that of trees in plots formerly fertilized with nitrate of soda and indeed to that made by plots 2 and 3 which had nitrate of soda and sulfate of ammonia in addition to previous fertilization. It has already been suggested that trees of moderate vigor in the presence of well established alfalfa are less liable to striking changes in yields than trees of less vigor under clean cultural methods. This appears to be true also as far as vigor is concerned. That trees in poor physical condition have gradually improved in this respect where alfalfa is used as a shade crop without the use of nitrate of soda is a point with which we are greatly concerned.

In orchards 3 and 4, growth on all fertilized plots during the three years was good. Trees in plots receiving two consecutive, heavy, annual applications of nitrate of soda made slightly better averages than those receiving smaller amounts, but differences are slight. Trees in the checks, of course, have not given as good averages as the fertilized trees. The unfertilized trees, however, have improved materially in physical condition under the influence of irrigation and clover not yet plowed under.

Fig. 2. VIGOROUS SPITZENBERGS ORCHARD 3, PLOT 1 (A)
Nitrate has rapidly restored this plot to vigor. Clover has not yet been turned under.

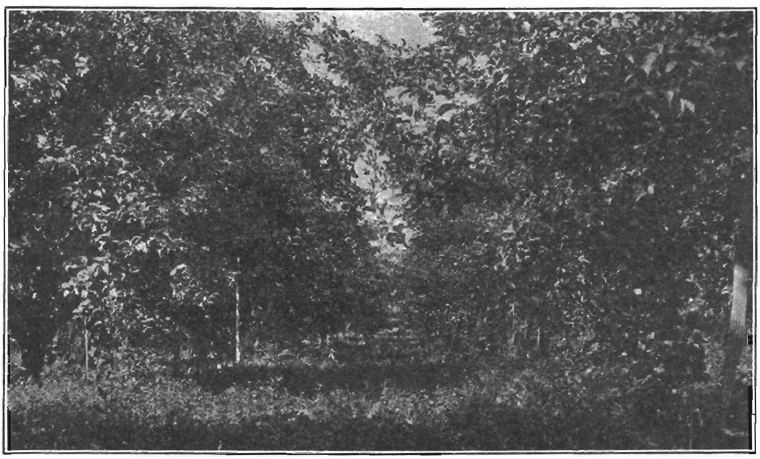


Fig. 3. VIGOROUS NEWTOWNS ORCHARD 1, PLOT 3 (CHECK)
Result of clover as a green manure crop without the use of nitrate.

RELATION OF SOIL CULTURE TO BLOOM

That Newtowns and Spitzenbergs are given to fluctuations or variations in yields from year to year has been pointed out. This factor of course is reflected in the amount of bloom appearing from year to year. It would be desirable, if it were possible, to control these factors in such a way as to cause trees to blossom and yield more uniformly year after year. If such were the case, labor and expense would be saved in thinning, spraying, etc., and average yields per tree would probably be higher and quality improved.

What are the factors associated with such fluctuations? Is this a natural tendency which cannot be controlled, or may orchard practices be so correlated as to overcome this undesirable feature? Obviously, these questions must be studied from the standpoint of pruning, irrigation, thinning, cultivation, shade crops, etc. Control measures, if possible, probably will not be brought about through any one of these important agencies alone, but rather, when they are in harmony. The present discussion, however, must deal with the problem largely from the standpoint of shade crops and fertilizers.

Can nitrate influence the tree in this respect? With this question in mind, we have kept individual tree records during the past three years in all plots reported in these experiments. Yields per tree, terminal growth, blossoming habits, and percentages of fruit set were noted. For comparison, the amount of full bloom exhibited by each tree in each plot has been classified roughly for each year on a percentage basis, as follows: 100 percent, 50 percent, 20 percent, 5 percent, and 0 percent. Table X shows the average degree of full bloom covering a three-year period for plots in orchards 1, 2, and 3. Notice data for Spitzenbergs in orchard 2. First, notice whether the average amount of bloom for three years is materially different. The data show 69 percent for the three plots receiving fertilizer and 68 percent for the check. While these figures of course are only approximate, they do not show that nitrate of soda as a

TABLE X. PERCENTAGE OF FULL BLOOM SHOWN BY YEARS 1916-1918 INCLUSIVE

Spitzenbergs—Orchard 3												
		Nitrate per tree			Average percentage of full-bloom					Average variation in percentage of full-bloom		
										Maxi-mum	Mini-mum	
Plot No.		1916	1917	1918	1916	1917	1918	Aver-age	Mode	Aver-age	Aver-age	Aver. age
		lbs.	lbs.	lbs.	%	%	%	%	%	%	%	%
1	A	7.3	7.3	....	91	91	50	77	80	58	17	37
	B	7.3	....	7.3	85	66	54	69	80	56	18	37
Average		....	....	....	88	78	52	73	....	57	17	37
2	A	5.0	....	5.0	100	48	61	69	80	62	41	51
	B	5.0	5.0	....	85	50	85	66	60	70	50	60
Average		....	....	....	97	49	73	67	....	66	45	55
4	A	3.0	....	3.0	84	58	80	74	70	62	58	60
	B	3.0	3.0	....	76	50	70	65	60	79	73	76
Average		....	....	....	80	54	75	69	....	70	65	68
3 (Check) None					90	34	76	64	60	81	66	77
Spitzenbergs—Orchard 1												
1, 2, 4 See Table VII					63	99	16.0	59	50	80	37	59
3 (Check) None					30	91	12.5	66	60	79	61	70
Spitzenbergs—Orchard 2												
2, 3, 5 See Table VII					94	67	45	69	60	66	21.4	43
4 (Check) None					100	54	58	68	70	82	40.0	61

supplement to the practice of turning under clover as green manure was able to exert any marked influence favoring greater total bloom. In orchard 1 the fertilized plots show 59 percent average bloom for three years, compared with 66 percent for the check. Here again differences in favor of trees receiving nitrate of soda are not great enough to warrant any other conclusion than that already drawn. In other words, Spitzenbergs of moderate vigor, growing under such soil conditions as pointed out in orchards 1 and 2, do not appear to be greatly influenced in total average bloom exhibited for a three-year period. It is possible that such studies conducted over a longer period might show different results.

Table X indicates similar observations made with this variety in orchard 3. Where heavy applications of nitrate were made, especially during two consecutive years, the total average bloom is increased. For example plot 1 (A) shows a three-year average bloom of 77 percent, as compared with 64 percent for the check. Even under these conditions, that is, with trees badly run down and in need of nitrogen, the total average bloom appearing over a three-year period does not differ in a striking way between fertilized and non-fertilized trees.

The data to which reference has just been made relate to the average degree of bloom exhibited during a three-year period. It will be readily understood that these figures do not point out what the individual tree performance was, but rather that for an entire plot. Table X bears more directly upon this additional question. The average maximum and average minimum fluctuation or variation in amount of bloom exhibited by Spitzenberg trees for a three-year period in orchards 1, 2, and 3 are also indicated.

In order to make this point clearer, let us assume that we are studying two trees, each of which exhibits widely different blooming habits. The following example is purely hypothetical, and figures used are to make comparisons easier. We will assume that tree number 1 gives a full (100 percent) bloom one year, no bloom (0 percent) the next, and one-half bloom (50 percent) the following year. The maximum fluctuation in degree of bloom is, therefore, 100 percent and the minimum 50 percent. Incidentally, the average bloom for three years is 50 percent. Tree number 2 may exhibit altogether different blooming habits. It may exhibit a 50 percent full bloom one year, 50 percent the next, and 50 percent the following year. Its average is, therefore, 50 percent full bloom for three years, or the same as tree 1. In this case, however, there are no variations or fluctuations in bloom, there being the same amount appearing each year.

Observations on this basis have disclosed that on an average trees on all plots are given to wide fluctuations in amount of bloom exhibited from year to year, or at least during one of the three years during which a study was made. Considering all Spitzenberg plots in orchards 1, 2, and 3, it will be noted that maximum variations as high as 82 percent are recorded as a general average. The fertilized plots in orchard 2 appear to be subject to less fluctuation than the check. In orchard 1, however, there appears to be no appreciable difference.

Heavy applications of nitrate of soda in orchard 3, on the other hand, appear to have prevented to a considerable extent this undesirable tendency. Plots 1 (A) and 1 (B) show a respective maximum variation of 58 percent and 56 percent, as compared with 81 percent for the check.

It has been assumed that 0 percent variation or fluctuation in the blooming habit was the ideal around which we would have trees perform. Keeping this in mind, it has been found that heavily fertilized Spitzenbergs in plot 1, although showing a maximum variation of 58 percent, show a minimum variation of 17 and 18 percent, whereas trees in the check have never shown less than 66 percent. In other words, although heavily fertilized trees have varied as much as 58 percent, they have approached within 17 and 18 percent of the assumed ideal, whereas the check trees have never come nearer than 66 percent. Table X likewise points out striking differences in orchards 1 and 2. In both cases, fertilized trees show much smaller percentages of minimum variation than do those in the checks.

RELATION OF BLOOM TO YIELDS

The effectiveness with which a tree is able to make full use of the amount of its bloom is an interesting study. We judge this efficiency in many ways, the most important of which is that from the standpoint of yields. The point in which we are interested is, How many packed boxes will we get? How do the different plots compare in this respect? Average yields and degree of bloom per tree covering a three-year period have been summarized in Tables VII, VIII, and X. Table XI has been constructed to bring out graphically a more definite relation. The aim is to show the productive ability of different plots when reduced to one uniform basis, namely, 100 percent or full bloom. The reason for this may not be readily apparent. To explain, let us assume that we have two trees, each of which produces 10 boxes of fruit; one tree, however, had only a 50 percent full bloom, and the other, 100 percent. It is evident, therefore, that the former is twice as effective in making full use of its bloom as the other tree, and that when studied on a uniform, 100 percent full bloom basis its productive capacity is 20 boxes as compared with 10 boxes for the other tree. This is not to suggest that such wide differences in bloom may result in equal quantities of fruit, but more clearly to illustrate the point. The reader may object to the reasoning on the ground that greater thinning is often done on trees showing heavy bloom than on trees showing light bloom. The reply is that the trees were either not thinned at all or were thinned to one fruit to a spur, without spacing, which would make the treatment uniform throughout.

One who studies Table XI will note readily that results are strikingly consistent for both Newtowns and Spitzenbergs in orchard 3. Plots representing 1916 and 1917 applications of 7.3, 5.0, and 3.0 pounds of nitrate of soda per tree show 16.4, 15.0, and 13.0 loose boxes per tree for Spitzenbergs, as compared to 12.4, 11.0, and 13.7 boxes for plots representing similar amounts of nitrate of soda applied in the springs of 1916 and 1918. Trees in the check average poorest in this respect, averaging only 10.2 boxes per tree. Results for Newtowns for these same tests are on the whole quite similar to those for Spitzenbergs.

TABLE XI. RELATION OF BLOOM TO YIELDS

ORCHARD	PLOT	AVERAGE PERCENT OF FULL BLOOM FOR THREE YEAR TERM	YIELDS PER TREE IN LOOSE BOXES: ACTUAL YIELD	YIELDS PER TREE IN LOOSE BOXES: YIELD BASED ON 100% BLOOM	SCALE SHOWING EQUIVALENT YIELD PER TREE BASED ON 100 PERCENT BLOOM (1–20)
		SPITZENBERGS			
3	1 A	77.0	12.62	16.4	
	2 B	66.0	9.9	15.0	
	4 B	65.0	84.4	13.0	
	1 B	69.0	85.5	12.4	
	2 A	69.0	7.6	11.0	
	4 A	74.0	10.24	13.7	
CHECK		64.0	65.4	10.2	
1	1-2-4	59.0	11.6	19.6	
CHECK		66.0	8.4	12.6	
2	2-3-5	69.0	83.4	12.1	
CHECK		68.0	50.0	7.3	
		NEWTOWNS			
3	1 A	73.0	11.46	15.5	
	2 B	65.0	97.4	15.0	
	4 B	50.0	8.3	16.6	
	1 B	68.0	88.5	13.0	
	2 A	65.0	86.1	13.2	
	4 A	72.0	10.7	14.9	
CHECK		50.0	6.1	12.2	

PERCENTAGES OF BLOSSOMS SETTING FRUIT AS RELATED TO VIGOR OF TREE GROWTH

Table XII indicates the terminal growth made by trees in the different experiments referred to and the percentages of blossoms setting fruits after the "June drop." Where one or more apples to a flower cluster are retained, the spur is credited with 100 percent fruit set. A study of the table does not show a definite, clear-cut, correlation between vigor of terminal growth and percentage of fruit set. For example, in some cases it has been found that 18.0, 82.6, and 19.1 percent set are associated with trees in different plots, whereas differences of less than two inches terminal growth exist between trees in these same plots. Where terminal growths of less than 7.9 inches are recorded, the percentage of fruit set as a rule is smaller than on trees making higher average growths.

In Table XII the percentages of fruit set before July 25 have been arranged in progressive order, beginning with 86.2 percent and ranging to 9.0 percent for Spitzenbergs on the one hand, and from 8.8 percent to 50.1 percent for Newtowns on the other. In making such an arrangement it was hoped that those factors associated with higher or lower percentages might thus be grouped. Obviously, the question of yields is an important one. What influence does the amount of previous crops have on the percentage of blossoms setting fruits on the following year? The figures presented seem to show that on an average the natural tendency is to alternate bearing, although there are a good many apparent exceptions to this rule. Since exceptions do not occur by chance, however, but rather in accordance with definite fundamental laws governing plant growth, it seems clear that on many of the plots where alternate bearing is conspicuous, some influence has been omitted in management which causes such wide differences in response in blossoming and fruit production. To find all of the factors involved a wider study than the mere use of shade crops and commercial fertilizers will probably have to be made.

INFLUENCE OF SOIL CULTURE ON PERCENTAGE OF FRUIT SET

The discussion regarding percentages of blossoms setting fruit has thus far concerned itself with relation to yields. Let us now study this factor as related to soil culture. Nitrate of soda, as will be recalled, has been applied at the rate of 3, 4, 5, or 7.3 pounds per tree. In Table XII symbols representing modes of soil culture employed are used to facilitate study. In this case C indicates clean cultivation; Cl, clover; N, nitrate of soda; A, alfalfa; and V, vetch. These symbols appear in three columns in each of which soil culture for one entire season is indicated. The symbols represent, therefore, soil culture for three seasons. They should be read downward in progressive order, the last symbol indicating soil culture the same year that percentages of fruit set are given.

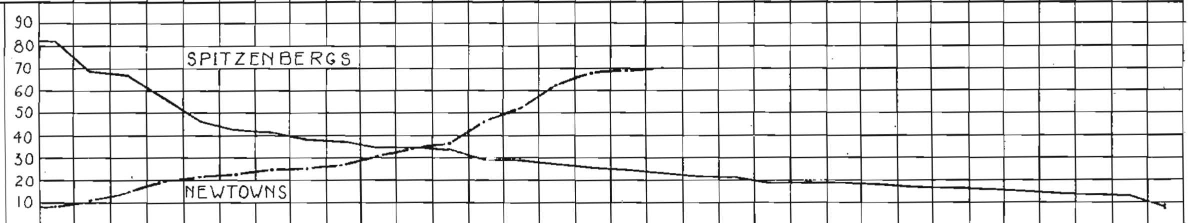
The 32 cases cited for Spitzenbergs in Table XII represent 13 different soil treatments when considered on a three-year basis. Several of these differ but slightly, however. Several plots received no fertilizer. Some, during at least one or two of the three years indicated, depended upon clover or alfalfa sod, or the former turned under as green manure, for organic matter. With each different general treatment given the

TABLE XII. RELATION OF FRUIT SET TO YIELDS, VIGOR OF GROWTH, AND SOIL CULTURE

SPITZENBERGS

ORCHARD NUMBER	2	2	2	1	4	1	1	4	4	2	4	4	1	2	4	6	1	4	3	6	2	1	3	3	1	3	3	3	3	2	2	1
PLOT NUMBER	3	2	5	4	1B	2	1	4B	1A	4	2B	2A	1	3	3	1	3	4A	3	2	2	2	4B	1A	4	1B	2B	2A	4A	5	4	3
YEAR	15	15	15	15	17	15	15	17	17	15	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	15
SOIL CULTURE LAST THREE YEARS	C	C	C	C	C	C	C	C	C	C	C	C	CLN	CLN	C	CL	CL	C	C	CL	CLN	CLN	C	C	CLN	C	C	C	C	CLN	—	C
	CLN	CLN	CLN	CLN	CLN	CLN	CLN	CLN	CLN	CL	CLN	CLN	C	SOD	CL	CN	C	CLN	CL	C	SOD	C	CLN	CLN	C	CLN	CLN	CLN	CLN	SOD	—	CL
	CLN	CLN	CLN	CLN	CL	CLN	CLN	CLN	CLN	CL	CLN	CL	A	SOD	CL	A	A	CL	CL	A	SOD	A	CLN	CLN	A	CL	CLN	CL	CL	SOD	—	CL
YIELDS LOOSE BOXES PREVIOUS YEAR	1.9	9.8	2.3	.1	5.4	.2	4.1	5.7	7.6	2.1	5.5	3.8	13.0	15.5	1.5	—	8.8	6.2	8.5	—	15.6	9.6	10.4	18.0	14.8	14.2	13.2	13.9	16.0	14.9	5.7	4.1
YIELDS LOOSE BOXES SAME YEAR	10.0	10.9	10.9	8.5	17.3	6.0	8.1	20.7	21.6	.9	22.1	14.6	18.7	2.8	7.2	—	15.3	17.6	1.2	—	4.5	18.6	2.9	9.8	17.3	4.3	5.8	2.4	1.2	3.2	3.9	8.1
GROWTH INCHES	11.0	14.8	16.2	13.6	20.5	17.0	18.0	15.4	17.3	8.0	16.6	14.7	13.3	11.2	7.6	—	18.5	14.1	6.8	—	11.1	14.0	13.9	10.8	10.6	14.5	13.7	7.6	7.9	10.7	12.1	6.4
PERCENT SET	82.6	69.6	68.0	58.0	47.8	43	42	39	38.5	35.5	35.0	34	29.6	29.1	28.7	26.7	25.3	23.5	21.0	20.2	19.1	19.1	18.7	18.0	17.6	17.1	16.1	15.0	14.7	14.4	12.8	9.0

SCALE SHOWING PERCENTAGE OF FRUIT SET



NEWTOWNS

PERCENT SET	8.8	9.5	14.9	19.9	20.5	22.7	24.2	25.1	27.3	30	34.6	35.8	36.9	41.1	42.2	47.6	48.5	50.1
GROWTH INCHES	7.3	7.3	9.6	12.6	3.1	3.8	10.7	8.3	15.3	6.4	12.5	5.6	11.9	9.0	5.7	9.0	14.5	16.8
YIELDS LOOSE BOXES PREVIOUS YEAR	13.3	12.8	11.4	3.9	12.7	5.3	9.8	14.4	3.8	4.0	3.3	14.6	2.7	13.3	.2	3.3	2.6	3.3
YIELDS LOOSE BOXES SAME YEAR	7.3	5.8	12.7	10.9	4.9	5.7	12.5	8.4	15.9	16.7	13.9	9.6	9.18	12.5	7.7	13.9	13.2	12.7
SOIL CULTURE LAST THREE YEARS	C	C	C	C	C	C	CLN	CLN	C	CLN	C	C	C	CL	C	C	C	C
	CLN	CLN	CLN	CLN	CLN	CL	C	C	CLN	C	CLN	CLN	CLN	C	CL	CLN	CLN	CLN
	CL	CL	CLN	CL	CL	CL	A	A	CLN	A	CLN	CL	CL	A	CL	CLN	CL	CLN
ORCHARD NUMBER	3	3	3	4	3	3	1	1	4	1	4	3	4	1	4	3	4	4
PLOT NUMBER	1B	2A	2B	2A	4A	3	2	4	2B	1	4B	1B	4A	3	3	4B	1B	1A
YEAR	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17

SOD—SODIUM
C—CLEAN CULTIVATED
CL—CLOVER
N—NITRATE OF SODA
A—ALFALFA.
V—VETCH

percentages of fruit set have been studied and averages made. It is scarcely feasible in this discussion to attempt to indicate average percentages set for each of these thirteen different tests. A simpler and more readable method, covering a majority of the tests, is to study results upon the basis of when nitrate was applied.

First, notice percentages of fruit set associated with trees to which nitrate of soda was applied the season previous to that in which percentages were taken. Application of 3 pounds shows an average of 19.0 percent set; 5 pounds, 25.2 percent; and 7.3 pounds, 32.4 percent set. Allowing equal weight to each of the three percentages given, we have a general average of 25.5 percent set. Note in passing that the heavier applications gave higher percentages set than the lighter applications.

Second, notice percentages of fruit set associated with trees to which nitrate of soda was applied not only the previous season, as in the above instance, but also during the spring of the same year in which percentages set were taken. Three-pound applications show 29.0 percent set; 5 pounds, 38.8 percent; 7.3 pounds, 55.4 percent set. In this instance also higher percentages set are associated with trees on which the heavier applications were made. Again, allowing equal weight to each of the three percentages, we have a total average of 41.0 percent set. Obviously, then, we have a superiority of 15.5 percent set (the difference between 25.5 percent and 41.0 percent set) in favor of trees to which the two applications of nitrate of soda were made.

Newtowns were similarly studied in the work represented by Table XII. In this instance fewer examples are available. Results on the average are quite similar to those indicated for Spitzenbergs. Highest percentages of fruit set are found associated with trees fertilized with nitrate of soda at least twice, once during the same year as percentages of fruit set are taken and once during the previous year. Likewise, as was true with Spitzenbergs, heavier applications of nitrate gave higher percentages of fruit set than lighter applications.

The data given in Table XII regarding percentages set were taken almost exclusively during 1917. They refer largely to orchards 3 and 4, where trees were badly devitalized and capable for the time being of using large amounts of nitrogen.

Percentages of fruit set in orchards 1 and 2, following the initial application of nitrate in 1914 and 1915, were large. The facts are consistent with similar studies in orchards 3 and 4, where soil requirements were similar. During the past two years, however, in the first two orchards, the general tendency has been that blossoms set a smaller percentage of their fruits than during previous years when the need of nitrogen was more acute. This fact is reflected in two small yields for Spitzenbergs in 1917 and 1918 in orchard 2 and for 1918 in orchard 1.

Finally, notice percentages of fruit set in orchard 5 for 1918. Reference was made to this experiment under Yields for Newtowns. The trees, as will be recalled, were in alfalfa for a number of years and had borne several good crops previous to the experiment. The 1917 crop was almost negligible. The percentage of fruit set in 1918 for trees receiving a three-pound application of nitrate of soda in the spring of that year is 39.0, and that for trees also receiving a similar application during the previous season, 46.2.

RELATION OF EARLY AND LATE SPRING APPLICATIONS OF NITRATE TO PERCENTAGE OF BLOSSOMS SETTING FRUIT

We are interested in knowing when to apply nitrate of soda. Since it is readily soluble in water and in a readily available form for plant use we wish to avoid making applications too early in the spring lest, especially on light soils, much valuable plant food be leached away by excessive rainfall; yet as a rule we wish to apply sufficiently early in order that plants may make full use of it as soon as growth starts.

Previous observations made by the Hood River Branch Experiment Station appeared to show that apple trees made a much better response from applications in early March than from those made as late, for example, as May. In the former case, response in tree growth and general renewed vigor was very quick, whereas in the latter, the influence of nitrate of soda was not readily apparent until nearly the end of the growing season, when growth became more vigorous. One of the most important results expected from the use of nitrate of soda is a better setting of fruit.

In 1917 an experiment was conducted so as to observe results more fully from early and late applications of nitrate. For the work, fourteen-year-old Spitzenbergs and Newtowns were chosen. Owing to lack of irrigation and to excessive tillage, the trees were badly devitalized and in need of nitrogen. Each variety was divided into five plots, each of which received 3.5 pounds nitrate per tree. Each plot represented applications two weeks apart and ranging in dates from March 6 to May 7, when first and last applications were made. Percentages of fruit set were taken July 25, after the "June drop." It will be recalled that the blossom season in 1917 was very late. Newtowns, receiving the March 6 application gave 50.1 percent set. Later applications, in order, gave the following percentages: 46.4, 42.5, (no record), and 32.2. Spitzenbergs also showed better colored foliage where receiving the earliest application, showing a 43.6 percent set. Trees receiving the later applications show 46.9, 34.1, 33.6, and 21.2 set respectively, the last figure being for trees fertilized May 7. The economic importance of early applications is in both cases quite evident also in the matter of yields. The early fertilized Newtowns yielded 7.9 and the Spitzenbergs 10.83 loose boxes per tree, as compared to only 2.28 and 1.20 boxes for the latest application.

RELATION OF SOIL CULTURE TO SIZE AND COLOR OF FRUIT

The market demands of late years have been for large fruit. Five-tier apples as a rule are not wanted. Observations made at the Hood River Branch Experiment Station show clearly that nitrate of soda, manure, shade crops, or other factors which increase the nitrogen content of soils low in this element tend to give larger fruit. This has been one of the outstanding features of the study of the influence of shade crops and nitrate of soda. Table XIII gives data for Spitzenbergs in orchards 1, 2, and 5. The problem of maintaining deep color in fruit of this variety is also of great importance. The trade wants deep color as well as good size. Table XIII also shows color of fruit obtained in orchards 1, 2, and 5, and also the relation of size to color.

TABLE XIII. RELATION OF NITRATE TO SIZE-AND-COLOR PERCENTAGES, SPITZENBERGS

Orchard 1. Clover as Green Manure, 1916

Plot	Year	Percent color			Nitrate applied					Percent size			Order
		Good	Med.	Poor	1914	1915	1916	1917	1918	Large	Med.	Small	
		%	%	%	lbs.	lbs.	lbs.	lbs.	lbs.	%	%	%	
1, 2, 4	1917	84.08	11.28	4.60	5.2	5.2	....	....	....	19.8	44.7	35.5	4
4	1918	69.0	23.5	7.50	5.2	5.2	....	....	....	15.9	59.8	24.3	3
2	1918	52.7	39.7	7.60	5.2	5.2	....	....	3.0*	31.4	59.6	9.0	1
1	1918	23.7	43.3	33.00	5.2	5.2	....	....	3.0	30.9	56.4	12.7	2
		Orchard 2. Alfalfa Sod Continuous, 1913-1918											
2, 3, 5	1917	98.3	1.6	.00	6.7	6.7	....	....	....	3.4	44.8	51.7	4
5	1918	95.7	4.1	.20	6.7	6.7	....	....	....	5.9	43.2	50.9	4
4	17-18	93.42	6.32	.25	(Check) No Fertilizer					1.7	58.19	40.1	3
3	1918	86.0	12.7	1.30	6.7	6.7	....	....	3.0*	2.9	74.2	22.9	2
2	1918	65.1	31.9	3.00	6.7	6.7	....	....	3.0	10.9	78.9	10.2	1
3	1918	86.0	12.7	1.30	6.7	6.7	....	....	3.0*	2.9	74.2	22.9	2
		Orchard 5. Alfalfa Sod, 1914-1918											
5	1918	94.6	5.4	.00	....	....	....	3.0	....	5.8	71.4	22.8	2
6	17-18	76.1	15.6	8.30	....	....	....	....	....	18.0	70.2	11.8	1
5	1917	57.9	23.4	18.70	....	....	....	3.0	....	4.0	58.4	37.6	3

Note: 75-100% red (good); 40-75% (medium); 0-40% (poor). 100 and larger per box (large); 112-138 (medium); 150 and smaller (small).

Order. Refers to higher to lower percentages of "small" fruit.

* The equivalent in sulfate of ammonia used.

Here, again, it is extremely difficult to lay down definite rules which the average grower may safely follow regarding the use of fertilizers. If only one factor were involved this would probably be possible. Where such factors, however, as pruning, thinning, irrigation, and tillage are inseparably associated with the soil fertility problem, further studies on an extensive scale and over a long period of years will probably be necessary before it will be possible to lay down very definite rules. Furthermore, until we know what chemical reactions are taking place in response to these separate practices, we shall be working upon a more or less superficial basis.

The general experience with these tests has been that where more than two consecutive, heavy applications of nitrate are made, even to trees badly in need of this fertilizer, color is often unduly sacrificed. On the other hand, sizes have tended to run large, in some cases unduly large. The sacrifice of deep color is often increased when heavy pruning, green manuring, excessive irrigation, or cultivation is likewise done simultaneously with the application of nitrate. To a certain extent this was true with Spitzenbergs in orchard 1.

Tables XIII and XIV very definitely show the relation between sizes and color for all of the tests reported upon. In many cases it is evident that color has been decreased, but a compensating feature has been larger-sized fruit and incidentally larger yields. It is therefore largely a problem for the grower to decide how much he can afford to sacrifice in the matter of color in order to obtain increased size. The economic aspect of the problem is apparent.

TABLE XIV. RELATION OF TIME APPLIED AND AMOUNT OF NITRATE TO RELATIVE SIZES AND DEGREE OF COLOR

Orchards 3 and 4, Average

Year graded	When applied 1916	1917	1918	Sizes, Spitzenbergs: 7.3 lbs. Large	Medium	Small	5.0 lbs. Large	Medium	Small	3.0 lbs. Large	Medium	Small	Average Large	Medium	Small
'16	†	..	..	9.6	32.0	58.3	12.2	26.0	61.7	10.6	35.3	54.1	10.8	31.1	58.0
'17	†	§	..	6.4	44.1	49.3	3.2	45.7	51.0	2.0	41.8	56.1	3.88	43.8	52.3
'17	†	†	..	10.2	46.5	43.1	.7	52.9	45.8	2.7	52.9	44.3	4.50	50.0	44.6
'18	†	§	†	3.1	64.4	32.5	1.3	69.2	29.5	.7	54.1	45.2	1.70	62.6	35.7
'18	†	†	§	10.3	79.2	16.7	.6	33.8	65.6	.4	38.1	61.5	3.80	50.4	45.8
Newtowns															
'16	†	§	..	1.10	32.3	66.6	.90	17.6	81.5	.20	19.5	80.3	.73	23.1	76.2
'17	†	§	..	.63	45.1	54.2	.60	56.5	42.9	.95	42.7	56.3	.73	48.1	51.1
'17	†	†	..	1.50	50.0	48.5	.2	45.7	54.1	.2	60.7	39.1	.57	52.1	47.5
'18	†	§	†	19.8	59.1	21.1	29.2	51.4	19.4	21.3	52.6	26.1	23.40	54.4	22.2
'18	†	†	§	25.5	60.2	14.3	20.9	54.1	25.0	2.6	51.2	46.2	16.30	58.5	28.5
Newtowns. Orchard 1															
'17	§	§	..	....	....	....	....	....	....	4.0	52.3	43.7	....	Check	....
'18	§	§	†	....	....	....	....	....	....	16.7	56.1	27.2	....	....	....
'18	§	†	§	....	....	....	....	....	....	13.4	73.3	13.3	....	Check	....
Newtowns, Orchard 5															
'18	§	†	§	....	....	....	....	....	....	11.5	50.0	38.5	....	....	......
'18	§	†	†	....	....	....	....	....	....	11.5	50.0	38.5	....	....	....

Year graded	When applied 1916	1917	1918	Color, Spitzenbergs: 7.3 lbs. Good	Medium	Poor	5.0 lbs. Good	Medium	Poor	3.0 lbs. Good	Medium	Poor	Average Good	Medium	Poor
'16	†	..	..	83.2	10.5	6.2	91.6	5.4	2.9	57.9	28.8	13.2	77.5	14.9	7.5
'17	†	§	..	70.5	9.6	19.7	72.6	16.0	4.2	86.9	9.5	3.4	76.6	11.7	11.6
'17	†	†	..	24.8	28.9	46.2	61.0	21.8	17.0	70.5	21.3	8.1	52.1	24.0	23.9
'18	†	§	†	78.7	19.1	2.2	78.7	19.2	2.0	96.2	3.6	.2	84.5	13.9	1.6
'18	†	†	§	80.4	18.7	.7	96.1	3.8	.1	96.9	3.1	.00	94.1	8.5	.3

† Indicates year fertilizer was applied

§ Indicates no applications made

Note different amounts of nitrate applied

Color of Fruit—

75-100 percent Red (Good)

40- 75 percent Red (Medium)

0- 40 percent Red (Poor)

Size of Fruit—

100 and larger per box (Large)

112-138 per box (Medium)

150 and smaller (Small)

In orchard 1, since clover was turned under, sizes have been large, but color has not been first-class. The further addition of nitrate in 1918 caused a still further reduction in color but increased size has not been a compensating feature. Sizes remained fairly large without this additional application, as is indicated in plots 3 and 4 for 1918. On the other hand, although color was good in orchard 2 during 1917 and 1918, sizes and yields ran small. Again, however, under these conditions of shade-crop management, the addition of nitrate of soda and sulfate of ammonia tended to reduce color materially, but gains were made in the percentage of large fruit. We would urge, therefore, moderation in the use of all orchard practices mentioned which bear upon these two important qualities in fruit.

SUMMARY

This report deals with experimental work in the use of nitrate of soda as fertilizer for bearing Spitzenberg and Newtown orchards in the Hood River Valley. The study covers a period of five years. During a part of the time sulfate of ammonia was also used for a similar purpose.

The relation of shade crops such as clover and alfalfa to the use of these fertilizers as affecting tree growth and production has also been studied.

The character of soil management in apple orchards in the Hood River Valley has undergone a marked change since the results of these experiments have become generally known. A few years ago clean tillage and lack of irrigation characterized general practice. This was later replaced by shade crops, irrigation, and the use of commercial fertilizers, principally nitrate of soda. Under the former system of management, trees were generally lacking in vigor and low in production, principally because nitrogen in the soil was greatly lacking; but under the latter system, trees were quickly reinvigorated and produced larger and better crops.

The aim in this study has been to find out what are the best kinds of shade crops and the most practical methods of handling them; also, when and in what amounts such fertilizers as nitrate of soda should be used as a supplement. Studies have been made in tree response under two distinctly different types of soil management: (1) where clover was grown, pastured, and plowed under; and (2) where alfalfa has been growing for a number of years. Results thus far from a very limited number of these appear to favor the latter system of management as far as color in Spitzenbergs is concerned, and it appears that the use of a small amount of nitrate of soda may supplement this practice whenever trees begin to lack vigor.

This report deals further with blossoming habits and percentages of fruit set where nitrate of soda and sulfate of ammonia have been used on Newtowns and Spitzenbergs, covering a wide range of conditions. Where trees are lacking in vigor because of insufficient nitrogen, fruit does not set well, and the tendency toward alternate bearing is encouraged; but when this element is furnished in sufficient quantity, either through the use of shade crops or these commercial fertilizers, the percentage of blossoms setting fruit is greatly increased and the tendency toward alternate bearing apparently retarded. On the heavier soils where green manurial crops such as clover are turned under, the necessity for

using nitrate of soda in addition, the same year, is greatly reduced or entirely eliminated, especially where the trees are making normal growth.

The use of nitrate of soda bears an important relation to both size and color of fruit. Evidence shows clearly that excessive use of nitrate of soda can easily be made in that deep color in Spitzenbergs is unduly sacrificed. Furthermore, in several cases by so doing, increased sizes and yields, where obtained, have not been compensating features to offset lowered quality caused by poorer color.

Both the Yellow Newtown and the Spitzenberg seem to be alternate bearers, and even under some of our fertilizer experiments continue to be. On the other hand, in some of our experiments we were able to get three heavy successive crops with both Spitzenbergs and Newtowns. It would appear reasonable to conclude that such a condition was due to the fact that all factors surrounding the tree contributed to such a condition; namely, that tillage, irrigation, pruning, etc., all contributed to this general result and harmonized with the fertilizer treatments. Under the condition in which we work, that is, cooperating with growers, it is not always possible to control all such practices as pruning, tillage, and cultivation. It might be, however, that by a proper control of such factors, both the Yellow Newtown and the Spitzenberg might be made to be annual bearers, for it would seem that it would only be necessary to repeat the correlations which in the past have produced three successive crops. This is a phase of the work to which we hope to give much more attention.

Acknowledgements: The author is greatly indebted to Professor C. I. Lewis for assistance in conducting work leading up to this report. Work was started in 1914 under his guidance and from time to time helpful suggestions have been given. Dr. E. J. Kraus has kindly looked over the manuscript and suggested changes. We are also greatly indebted to Messrs. Lage, Dragseth, McCully, Shelton, Stone, Radford, and others who have given practical assistance in the field.