I. FERTILIZERS AND COVER CROPS FOR COLORADO ORCHARDS.

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III. PEAR BLIGHT.

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I. FERTILIZERS AND COVER CROPS FOR COLORADO ORCHARDS.

FERTILIZERS AND COVER CROPS FOR COLORADO ORCHARDS.

Introduction.

The problem of orchard fertility is of vital interest to the Colorado fruit grower. An extended survey of the fruit growing regions of the state indicates that many orchards are suffering from lack of soil fertility and poor soil conditions. This condition has been especially noticeable the last few years and is apparently becoming worse. Various methods have been suggested to remedy the situation and it is to be hoped that some of these may prove of value. However, before attempting a detailed discussion of the value of fertilizers and cover crops, a few introductory remarks are necessary.

A brief discussion of the amount of plant-food removed from the soil by an acre of bearing apple trees will lend some light on the problem. The actual amount of the three main elements has been approximated chemically by determining the average composition of the wood, leaves, and fruit and by applying these figures to what might be considered good annual yields of fruit. The annual weights are based upon a yearly production of one hundred pounds of wood, leaves and fourteen bushels of apples per mature tree. A comparison of total food draft to a twenty-five bushel crop of wheat brings out the fact that an acre of apples removes more nitrogen and potash and only slightly less phosphoric acid.

The following table (1), indicates the relative plant draft:

THE RELATIVE PLANT-FOOD DRAFT OF WHEAT AND APPLES.

(In pounds per acre annually.)

	Wheat Grain	Wheat Total	Wood	Leaves	Fruit	APPLE TOTAL
	lb.	lb.	lb.	lv	lb.	lb
Annual Weights	1500	4200	3500	3500	24,500	31,500
Nitrogen (N)	30.0	43.7	11.3	25.6	16.2	53.1
phos. Acid (P_2O_5)	10.0	15.8	3.3	5.6	6.4	15.3
Potash (K_2O)	9.8	26.8	6.6	15.9	41.5	64.0
Lime (CaO)	0.84	8.0	29.1	29.5	3.0	61.6
Magnesia (MgO)	3.0	6.1	4.4	8.9	3.4	16.7
Iron (FeO)	----	----	0.5	1.5	0.8	2.8

It is interesting to note the relatively large amount of nitrogen, potash, and lime which is removed by the apples and the comparatively small amount of iron taken up. On the other hand, the wood requires relatively small amounts of the important elements, accounting for the fact that young orchards seldom respond to fertilizer applications, although they may respond to manures or mulches. This is apparently due to moisture conservation rather than any direct increase in fertility

Long, (2), has prepared an estimate of the total amount of fertility lost per acre annually in a clean cultivated orchard. He is careful to point out that the estimate is only approximate and subject to many criticisms, but it serves to illustrate the fact that there is a drain on the soil. The average annual loss approximates 200 pounds of nitrogen, 20 pounds of phosphorus, and 75 pounds of potassium. These figures are equivalent to 1275 pounds of nitrate of soda, 285 pounds of 16% super-phosphate, and 190 pounds of sulfate of potash. This estimate includes the amount of food lost through the removal of apples and the loss by drainage and leaching.

Large quantities of water are required in building the tissues of orchard trees. The soil water solution contains the elements of plant food in such limited quantities that a great deal of wateris taken into the plant which later passes off through the stomata. It has been estimated that it requires from 240,000 to 400,000 pounds of water to aid in the production of 1,000 pounds of dry matter. Thus it can be readily seen that water plays a very important part in orchard management and may easily become the limiting factor.

The plant-food elements can be restored to the soil in different ways. The oldest method is that of growing cover crops and turning them under. The ancient agriculturists recognized the importance of turning under various cultivated and wild plants. Another method of applying plant food has been to utilize the nutrient organic and mineral compounds of nitrogen, phosphorus, and potassium, as well as other elements. Still another method has been to favor the action of useful bacteria by applying manures of animal origin. The last general method of increasing the fertility of the soil has been to convert toxic substances into harmless compounds that favor plant growth. Sodium carbonate, or "black alkali" as it has been called, has been converted into the harmless sodium sulfate by applying calcium sulfate, or "gypsum", in sufficiently large quantities. These, in brief, are the principal methods in vogue today of increasing or making available plant food and practically all experimental orchard work has been confined to research problems along these lines.

The applications of chemical fertilizers have benefitted many orchards greatly. The primary function of commercial fertilizers is to add plant-food elements to the soil in an form usually more readily available than those already present or to replace those foods largely or totally absent. The commercial fertilizers are generally applied to the soil in the form of soluble inorganic salts or combined with other substances in the form of organic material. The value of the fertilizers, to a large extent, depends upon the form of combination.

Nitrogen is the most expensive and important constituent of manures on account of the fact that it is likely to be absent from soils. Nitrogenous compounds break down easily, both in the organic and inorganic forms, although the degree of unstableness varies greatly with the different compounds. The free nitrogen passes off as a gas.

The form in which nitrogen is utilized for food by plants varies somewhat. It has been found by experiments, (3), that leguminous and certain non-leguminous plants can utilize atmospheric nitrogen directly. Kellner and Kelley, (4), found that rice plants could use ammonia nitrogen. The latest general opinion (5), seems to be that practically all of the higher plants derive more benefit from the absorption of nitrogen in the form of nitrates. While the date is by no means complete or conclusive in regard to the form of nitrogen most beneficial to plants, the relative benefit has been established for several of the compounds.

The common commercial fertilizers of nitrogenous composition have been divided into two classes, namely, the organic and inorganic forms. The organic forms are characterized by their stability and lack of immediate availability as compared with inorganic fertilizers. The common organic fertilizers include dried blood, stable manure, cottonseed meal, guano, tankage, linseed meal, leather meal, fish meal, wool and hair waste as well as other unimportant residues. The inorganic forms include sodium nitrate, ammonium sulfate, cyanamid, calcium nitrate, and a few other forms of relatively poor nitrogenous composition.

Sodium nitrate is quickly available for plant food purposes, as it breaks down quickly. Calcium nitrate decomposes more slowly, but is relatively more quickly available than ammonium sulfate and cyanamid. Ammonium sulfate, however, containes from 60 to 80 pounds more of nitrogen to the ton than does sodium nitrate, so it is valuable from that standpoint. The organic compounds decompose very slowly as compared with the inorganic forms.

The percentage of availability of nitrogen has been accurately determined in the following fertilizers:

	Wagner & Dosch	Johnson & Others	Voorhies & Lipman
Nitrate of soda	100	100	100
Ammonium sulfate	90		70
Dried blood	70	73	64
Bone meal	60	17	
Stable manure	45		53
Tankage		49	
Horn and hoof meal	70	68	
Linseed meal		69	
Cottonseed meal		65	
Castor pomace		65	
Wool waste	30		
Leather meal	20		
Dry ground fish		64	

Phosphorus is generally present in fertilizers in combination with lime, iron, and alumina. The organic and inorganic forms are found, as in the case of nitrogenous fertilizers. The organic phosphates decompose more rapidly than untreated mineral phosphates and, in general, it can be said that treated phosphates decompose more rapidly than untreated phosphates. Bone tankage and bone phosphate are the chief organic phosphorus fertilizers, the phosphorus being present as tricalcium phosphate. The inorganic phosphates vary in their phorphorus containing percentages, but, as in the case of the organic forms, the tricalcium phosphate is the chief fertilizing compound. The inorganic phosphates are generally treated with sulfuric acid to render the phosphorus more available and after that treatment are known -- to the trade as "super-phosphates."

The percentage of available phosphoric acid in some of the more common phosphates varies considerably. The following list is representative of some common phosphorus fertilizers:

Bone phosphate	22%
Bone tankage	7-9%
Canadian apatite	40%
Coprolites	25%
Florida phosphate	18-30%
Tennessee phosphate	30-35%
Basic slag	variable

Potassium containing fertilizers are largely found in Germany. The famous Strassfurt salts contain potassium in the form of chloride or sulfate. The sulfate form is considered preferable on account of the injurious effect of the chloride upon certain crops, notably tobacco, sugar beets and potatoes. The commercial "Kainit" mineral contains the chloride form of potassium as well as small quantities of sodium chloride and magnesium sulfate. High grade potassium should average at least 50% potash in both the sulfate and chloride forms. Wood ashes contain potassium in varying amounts.

Farm manures are of value to the orchardist and should be used extensively. Manures have two functions to perform, namely, to act as direct fertilizers and also as indirect fertilizers. A mixed manure ordinarily contains on an average 0.50% nitrogen, 0.25% phosphoric acid, and 0.60% potash. Manure applied at the rate of ten tons to the acre will furnish the equivalent of 300 pounds sodium nitrate, 60 pounds acid phosphate, and 125 pounds of potassium chloride. Farm manure, however, is an unbalanced fertilizer containing the elements in the proportion of a 10-2-12 ratio, indicating a too high available nitrogen and a too low available phosphoric acid content. Soils that are markedly low in available nitrogen respond vigorously to manure applications. The actual fertilizing value of farm manure varies greatly, although it is generally held that the following represents the true scale of value in the common farm manures: poultry, sheep, horse, cow, and swine manure.

The indirect value of farm manure is well known. Manure, as it decomposes, produces organic acids and humus matter. Manuze increases the absorptive capacity of the soil, thus increasing the moisture holding capacity. It promote granulation in clay soils and in sand soils acts as a binding agent. It also increases the aeration of the soil and promotes better drainage. The decay of manure, as mentioned before, is accompanied by the liberation of organic acids, particularly carbonic acid, which dissolves the mineral plant foods and renders them more available. Activity of the soil organisms is greatly stimulated and the processes of nitrification, ammonification, and nitrogen fixation become appreciably greater.

The growing of cover crops is another method of supplying plant food needs. At the present time, green manuring is considered a part of every well established system of soil management. The effects of turning under green crops are both direct and indirect, as in the case of farm manures. Certain plant foods are also added to the soil, for instance, carbon, hydrogen, and oxygen, which come largely from the air. If the plant is a legume, nitrogen is added from the air also. The mineral constituents of the crop come from the soil originally and are only returned but they are in a much more intimate union with the organic material and are more available for plant food.

Cover crops function in taking up exceedingly soluble plant food and preventing it from being lost in the drainage water. Soil nitrates are easily lost unless taken up by the soluble plant foods. Green manures tend to carry plant food up from the subsoil and deposit it within the root zone. As in the case of farm manures, green manures stimulate bacterial action on account of the added organic matter and its consequent decomposition Green manures modify the absorptive power of the soil, promote aeration, drainage, and granulation---four important facts in determining the final growth and productivity of orchard trees.

The amount of nitrogen added to the soil by a leguminous crop is considerable. Hopkins, (6), estimates that alfalfa adds approximately 50 pounds of nitrogen to the soil per ton, red clover 40 pounds, and soybeans 53 pounds. The figures are open to criticism but give some idea of the amount of nitrogen actually added to the soil. The average cover crop produces between five and ten tons of green material, so that the amount of nitrogen actually added willprobably vary between two hundred and five hundred pounds of nitrogen per acre. In regard to the amount of nitrogen fixed from the air, Hopkins estimates that, in a normal inoculated legume, about one third of the nitrogen comes from the soil and two thirds comes from the air.

The crops generally grown for cover crops are classed as legumes and non-legumes. A list of the more common cover crops include:

Legumes: Annual	Legumes: Biennial	Non-legumes
Cowpeas	Red Clover	Rye
Soybeans	White clover	Oats
Peanut	Alsike clover	Mustard
Vetch	Alfalfa	Mangels
Canada field pea	Sweet clover	Rape
Velvet bean		Buckwheat
Crimson clover		Millet
Hairy vetch		

Orchardists should usually choose a leguminous cover crop on account of the nitrogen that might be added to the soil. However, it is often so difficult to get a stand of legumes that the orchardists are forced to utilize such non-leguminous crops as rye, oats, or millet. Among the most common legumes in use today are red clover, alfalfa, soybeans, cowpeas, and hairy vetch, all of which have been tested at different experiment stations.

Among the non-legumes, rye, oats, rape, and buckwheat have been used extensively. These crops make a succulent, rapid growth and have proved of value in one year rotations, in addition to being hardy and adapted to poor soils. Thus, it can be seen that green manure crops of this class have a place in orchard management.

The chemical composition, (7), of leguminous and non-leguminous plants is illustrated by an analysis. The much higher percentage of nitrogen is noticeable, indicating the great manurial value from that standpoint.

Alfalfa

Carbon	43.517
Hydrogen	5.868
Nitrogen	2.405
Sulfur	0.342
Chlorin	0.819
Phosphorus	0.162
Potassium	2.665
Sodium	0.374
Calcium	1.239
Magnesium	0.286
Oxygen (Plus remaining ash	42.323
	100.000

Timothy Hay

Carbon	44.241
Hydrogen	5.832
Nitrogen	0.892
Sulfur	0.104
Ash	9.370
Oxygen (Approx.)	39.045
Chlorin	0.506
	100.000

The analyses, while not respresentative of the true composition of the two classes of green manures, give an idea of the differing composition. The alfalfa contains more nitrogen, phosphorus, and potassium than the timothy hay, in fact three times as much nitrogen and larger amounts of phosphorus and potassium. The ash constituent of timothy hay contains a large portion of sulfur and chlorin, as well as phosphoric acid and potassium oxide, indicating that the main different is the nitrogen content of the respective crops.

Cover crops should be turned under when the succulent vegetative growth is the greatest. In this case, a large quantity of water is carried into the soil and the draft on the soil moisture is much less. The succulence encourages rapid and comparatively complete decomposition with the formation of desirable end products. If there be a heavy rain soon after the crop is turned under, the decomposition proceeds at an even more rapid rate. The recommendations for growing and turning under cover crops for Colorado conditions will be discussed at length later.

The rate at which cover crops decompose in the soil under favorable conditions has been determined. Merkle, (8), measured the rate of decomposition of a large number of crops in a series of experiments, arriving at several valuable conclusions. He found in regard to the rapidity of decay that the following points were brought out:

1. Plants with the highest percentage of nitrogen decompose with the greatest rapidity.
2. Legumes are usually decomposed in three months, while non-legumes require a longer period of time.
3. Plants decompose at a rate proportionate to the amount of nitrogen present.
4. Relative rapidity of decomposition:

    1. Alfalfa
    2. Red clover
    3. Soybeans
    4. Sugar beets
    5. Rape
    6. Oats
    7. Barley
    8. Buckwheat
    9. Weeds

5. The influence of commercial fertilizers on the rate of decomposition of cover crops:

    A. Increase rate of decomposition:

        1. Nitrate of soda
        2. Basic slag

    B. No apparent effect:

        1. Ammonium sulfate
        2. Acid phosphate
        3. Raw bone
        4. Sulfate of potash

    C. Actually decrease rate of decomposition

        1. Kainit
        2. Muriate of potash

A Digest of Fertilizer and Cover Crop Experiments.

A brief discussion of the work carried on by the various experiment stations engaged in orchard fertilizer and cover crop experiments will convey an adequate idea of the present status of the work. The data is extremely variable and few conclusions of value can be drawn from the conflicting mass of information.

New Hampshire.

New Hampshire station, (9), has been carrying on fertilizer and cultural experiments in an old Baldwin orchard for ten years. The data shows that trees growing in sod have not yielded sufficient fruit to justify keeping the orchard. Annual tillage increased the yield nearly 100% and also increased the growth and general vigor of the trees. However, clean cultivation could not be continued indefinitely, because the trees were not making the growth at the end of ten years that they were at the end of five years. Tillage, with crimson clover sowed at the rate of 30 pounds per acre, as a cover crop gave the best results. The fertilized plots, plus cultivation and cover crops, failed to respond in yield of fruit and did not respond in growth until the nihth year. Different combinations of complete fertilizers were used and the only combination that responded was the one richest in potash in the following proportion:

Nitrate of soda	2	pounds	per	tree
Sulfate of potash	10	"	"	"
Acid phosphate	$8\frac{1}{2}$	"	"	"

Lime had no effect on the yield of fruit.

New York

Three experiments, (10), have been carried on at the Geneva station relative to the effects of phosphorus, nitrogen, and potassium on bearing trees. The results have varied so much and have been so incönclusive that little information can be obtained. The addition of 50 pounds of nitrate of soda per acre has caused no increase in fruitfulness. The addition of 340 pounds of acid phosphate per acre has given no appreciable increase in yield and the addition of 196 pounds of muriate of potash per acre likewise has given no increase in yield. The annual application of 11,300 pounds of stable manure has not increased the yield over the check plot. However, as the experiments have continued, the phosphorus and potassium plots have taken a lower rank.

Heavy applications of nitrogen in complete fertilizers have not increase growth or productiveness.

Pennsylvania

Experiments, (11), were conducted on six bearing orchards in various parts of the state for a period of ten years. In the two orahards most responsive to fertilizers, nitrogen produced or caused the greatest growth and productiveness. Nitrogen from commercial sources and stable manure caused the greatest response. Usually phosphorus or potassium applied with nitrogen gave greater response than nitrogen, although on three orchard plots, potassium failed to give response. However, in three orchards, potassium materially increased the average size of the fruit at a cost of forty cents a bushel. No difference was observed between the chloride and sulfate forms of potassium.

The time of applying the fertilizers was found of importance, especially with the nitrogenous fertilizers. Nitrate of soda, applied as the buds were beginning to open, increased the crop of the current season. The later applications were not evident until the succeeding year. Trees in need of fertilization were recommended the treatment of 500 pounds of a 6-8-6 complete fertilizer to the acre.

It was found that the color of red apples could not be improved by fertilization. Color is dependent upon sunlight, maturity, and other factors, rather than upon fertilizers. It was found that nitrogenous fertilizers and manures had a retarding effect upon red color, but this was due to the retarding effect upon the maturity of the fruit.

West Virginia.

Four experiments, (12), were conducted on trees of various ages and under different conditions. All were given clean cultivation and cover crops of cowpeas during the length of the experiments. The results were somewhat conflicting but indicated that the average orchard would not make a profitable response to the application of nitrogenous fertilizers. No response was noted from applications of phosphorus and potassium, the West Virginia soils seeming to be rich in these plant foods. The commercial fertilizers were found to be of chief value as a tonic or restorative for starved and devitalized trees.

Nitrogen was found more beneficial if applied just as the buds were breaking. Phosphorus and potassium had no effect upon the color of fruit, although nitrogen delayed the maturity and, consequently, inhibited color development to some degree. It was recommended that yellowish, or sickly looking trees, be treated with nitrate of soda, 2 to 5 pounds per tree, to restore vogor. It was also suggested that fertilization would be of little value to the orchard unless accompanied by improved cultural, spraying, and pruning practices. Indications pointed to the fact also that the value of phosphorus was solely in its effect upon cover crops and sod coverings and that potassium was of no value whatever.

Ohio.

The Ohio experiments, (13), were conducted on bearing trees in sod that were in very poor condition as a result of continued neglect. Results obtained were conclusive and highly gratifying. The soil was relatively poor, thin, and compact, indicating low fertility or unavailability of plant food. Nitrogen gave a quick response, whether combined with sod mulch or clean cultivation with cover crop. Grass mulch culture plus 5 pounds of nitrate of soda per tree was more profitable than tillage plus cover crop. The application of a 5-5-2½% chemical fertilizer was beneficial in stimulating growth and yield of trees and also in stimulating growth and yield of trees and also in stimulating growth of soil grasses. It was recommended to apply fertilizer over the entire area of ground rather than in circles under the tree, as this method increased the growth of soil grasses over 1,600 pounds per acre.

Nitrogen was the only plant food that gave material response. Phosphorus was beneficial in stimulating growth of soil vegetation. A straw mulch materially increased the moisture holding capacity of the soil and was recommended for the Ohio orchard soil. It was found that the mineral forms of nitrogen, phosphorus, and potassium were much more satisfactory than the organic forms on account of the quick availability. Pruning, spraying, and proper cultural methods were also recommended.

The latest report of the station, (14), recommended that the best soil management program include the grass mulch accompanied by an annual application of nitrate of soda and acid phosphate at the rate of 5 pounds per tree. This soil treatment was much better than the clean cultivation or cover crop system of treatment.

Oregon.

The Oregon experiments, (15), were conducted with the intention of studying the effect of fertilizers upon devitalized trees in the Hood River valley. Nitrogen was found the limiting factor and orchards treated with 5 pounds nitrate of soda per tree were exceptionally responsive, in fact gave more response than was reported from any other experiment station. Phosphorus and potassium gave no response and were not recommended for commercial use. Attention was called to the fact that not more than 7½ pounds of nitrate of soda should be applied to each tree because larger applications reduced the quality of the fruit.

Data indicated that alfalfa as a permanent shade crop was more beneficial than red clover plowed under, although the author was careful to emphasize the point that the experiment had not been conducted long enough to study the cumulative effect of either cultural treatment.

It was found best to apply the nitrate of soda just before the blossoms opened or slightly earlier.

Indiana.

The Indiana station, (16), experimented with orchard cover crops for four years. Cover crops were accompanied by clean cultivation, the cover crops occupying the ground from the time cultivation ceased in the summer until it was resumed the following spring.

Plots of oats, rape, Canada field peas, soybeans, cowpeas, crimson clover, winter vetch, millet buckwheat, rye and weeds were used for the work. Results for that section of Indiana indicated that rye was the best cover crop because it produced the greatest growth of vegetation rich in nitrogen. Rye was followed in importance by vetch, millet, and buckwheat. Soybeans, crimson clover, and weeds ranked low in vegetative growth.

Indirect results were noted by Indiana. If the cover crop winter-killed, the dead covering acted as a moisture-conserving mulch in the spring, but if the crop started growth in the spring, a depletion of moisture was apt to occur. Cover crops protected the soil from extremes of temperature and prevented deep freezing.

Montana.

The Montana station, (17), conducted an experiment in the Bitter Root valley to determine the relative value of cover crops. The experiment was continued for eight years and some very definite information obtained. Careful cost accounts were kept and it was found that, from the standpoint of plant food added to the soil as well as economy, that the following rotations were best in the order named:

1. Clover two years with one crop removed for hay and the second one turned under.
2. Clover two years with no growth removed.
3. Clover two years with all growth removed and plowed under in the fall.
4. Peas grown two years with all growth plowed under.
5. Peas grown two years plus manure and all plowed under.

Maine.

The Maine station, (18), conducted experiments for several years on some mature Ben Davis trees. An average annual application of 1000 pounds of a 5-8-7 complete fertilizer was made for four consecutive years. The data indicates a slight increase in yield for the nitrogen plots but no increase for the phosphorus or potassium plots. No growth response was noted.

Miscellaneous Experiments.

Massachusetts, New Jersey, Iowa and other stations have conducted minor experiments but have reported no data of value. Several of the stations, however, contemplate starting a series of experiments and it is to be hoped that information of value will be forthcoming in the future.

The mass of conflicting data at hand renders the task of generalizing very difficult. Interesting results of one set of experiments have been more than offset by another experiment and that seems to be the situation throughout the entire field of orchard fertilization. Alderman, (19), has summed up the situation very well when he has said that only four points have remained consistently uncontended. Those four points have been:

1. There are apparently a great many orchards growing upon a wide variety of soils that will not respond economically to any form of commercial fertilizer or manure.
2. Orchards are much more likely to respond favorably if they are given sod mulch treatment than if kept under cultivation. The experiments of Pennsylvania and Ohio confirm that statement.
3. Orchards under starvation conditions usually give a ready response to fertilization when other treatments (culture, pruning, spraying, etc.) remain unaltered. This point is

illustrated by the work of West Virginia, Ohio, and Oregon.

4. Nitrogen in a readily available form seems to be the only element of plant food that is uniformly a factor in the favorable response--when such is secured.

Colorado Fertilizer and Cover Crop Practices.

Colorado orchard soils are generally rich in the mineral plant foods and little fear has been entertained in exhausting the native plant food elements. A bearing orchard, as previously mentioned, removes a great deal of plant food annually and it is only reasonable to presume that lack of fertility will be a serious factor in years to come. Many orchardists are having nutritional troubles of their own now, due partly to depletion of soil fertility and partly to uncongenial soil conditions as a result of continued clean cultivation.

The orchard soils of Colorado are extremely variable and streaked and no particular type can be considered representative of the orchard regions of the state. A composite soil analysis of the Haynes orchard at Grand Junction will indicate the approximate composition of the soils of that region and be as representative as can be expected. The analysis was made in 1912 before the orchard developed the serious nitrate trouble that killed it a few years later. As seen in the analysis, the total nitrogen content is somewhat below the customary amount for orchard soils of the state. Samples of soil were taken at different depth, analyzed, and the average of the analysès taken as a composite of the field.

Haynes Orchard Analysis.

Sand	72.430
Silicon dioxide	7.755
Silicon trioxide	0.155
Carbon dioxide	3.566
Chlorine	0.019
Phosphoric acid	0.166
Potash	0.761
Sodium oxide	0.461
Calcium oxide	3.510
Magnesium oxide	1.680
Ferric oxide	3.075
Aluminium oxide	2.921
Manganese dioxide	0.115
Water	1.211
Ignition	1.876
Sum	99.661
Oxygen equal chlorine	0.004
Total	99.657
Total nitrogen	0.0553
Humus	0.4060
Humus nitrogen	0.0255
Humus ash	0.7880

The application of chemical fertilizers to Colorado orchards has generally been considered unprofitable, except on very shallow soil. On the deep alluvial valley soils, characteristic of the Western

Slope, little benefit has been noticed in the application of chemical fertilizers. However, it has been found profitable to apply them in connection with the turning under of cover crops. The effect of chemical fertilizers upon potatoes was studied for four years and little or no benefit was derived from the applications in that period of time.

The bulk of the orchards in the state have been given clean cultivation throughout the entire year. Under this system of cultivation, the organic matter burned out quickly and the soil became hard and lifeless and the plant-food relatively unavailable. It is a well-known fact that organic matter decays much more rapidly in semi-arid regions than in humid regions and orchards in this state substantiate the fact very conclusively.

The advantages of cover crops have been mentioned briefly before. The greatest value of cover crops to orchards in Colorado has been the prevention of the rapid burning out of organic matter. However, cover crops prevent the soil from puddling; shade the surface soil; protect the trunk and limbs from the burning effect of the reflection of the sun's rays from the soil; conserve soil moisture; prevent excessive freezing; catch and hold leaching nitrates; render plant food more available through the liberation of organic acids; prevent nitre poisoning, and add nitrogen, if leguminous. These facts, alone, are sufficient recommendation for the wider use of cover crops.

Cover crops are assuming more importance in the East. The seed is sowed in the late summer or fall and enough growth takes place to protect the ground during the winter. The crop is plowed under the following April or May, thus permitting clean cultivation during the summer season. This method has been found to conserve moisture during the critical summer period.

Colorado orchards demand a cover crop in the summer far more than in the winter, so the practice of growing summer cover crops has become common. Practically all of the orchards are irrigated and water can be supplied to the trees and cover crop as needed without fear of the cover crop robbing the trees of moisture.

Red clover is recommended as the best cover crop for Colorado orchards. It is a biennial legume, well adapted to orchard conditions. It grows well in the semi-shaded mature orchards and also in the young orchards. About 20 pounds of seed is planted to the acre and little difficulty has been experienced in getting it to grow.

The red clover is generally planted in May on ground that has been well worked with a plow or disc to a depth of six to ten inches. The seed is broadcasted over the entire orchard rather than around the trees. The clover is allowed to stand for two summers before being finally plowed under and during the second summer it has been customary to remove a cutting of hay. The crop should be turned under in the fall and clean cultivation employed the following summer.

Sweet clover is coming into prominence quite rapidly. It is a biennial legume and is treated in the same manner as red clover with the exception that it is frequently cut during the first and second summer to prevent the clover stems from becoming coarse and hard. The hay is not used for feeding purposes, but is left in the orchard to decay.

Alfalfa has been a favorite cover crop with orchardists in the past. The average grower, however, has been apt to make a hay field out of his orchard, leaving the alfalfa for several years and removing two or three cuttings each summer. This practice soon depletes the soil feterility and is as bad, if not worse, than growing no cover crop. If alfalfa is used as a cover crop, it should be turned under at the end of three years and in the meantime only one cutting of hay removed yearly.

Winter vetch has been used to a small extent as a cover crop. It is not recommended, or is Canada field peas. Cowpeas have also been used, but the season has been found so short that growers seldom find it advisable to grow them. Cowpeas are quite easily injured by over-watering.

Non-leguminous cover crops can be grown successfully in the state. Rye, oats, and rape are among the more common crops of this class. These crops mature in one year and provide a means of a short rotation. They are treated, in general, the same as legumes, with the exception that no hay is removed, all being turned under. These crops obviously add little nitrogen, but function chiefly in adding an enormous amount of organic matter.

Greenhouse Experiments with Cover Crops.

The object of the cover crop experiments conducted in the greenhouse was to determine the relative value of some of the more common cover crops upon the growth and behaviour of geraniums and tomatoes. Conditions were somewhat different than in the field, but it was hoped to study the influence of the cover crops, making due allowance for the differences.

Geraniums and tomatoes were chosen for the experiments on account of their ease of handling under greenhouse conditions and their growth response to various degrees of soil fertility. The length of time in which to perform the experiments also precluded the possibility of using any but the rapid growing plants and that was another reason why geraniums and tomatoes were selected.

The soil chosen for the first experiment was typical garden soil of this locality. It had been planted to lettuce the preceding summer and only a fair crop harvested, indicating that it was neither excessively rich in plant food nor in good condition. The soil was a rather heavy red clay loam and quite compact.

Several legumes and non-legumes were selected for the test. The legumes chosen were well cured, mature samples of alfalfa, red clover, sweet clover, and soybeans. The non-legumes were wheat, barley, apple leaves, weeds, dry lettuce, and green lettuce. Thus it can be seen that a wide variety of plants were selected, some of which are in common use today and some are not. These samples were ground up very finely in a coffee grinder in order to have the material in just as fine a state as possible, thereby favoring the rapidity of decomposition. The ground-up samples were even finer than alfalfa meal.

Care was taken to incorporate the material separately and thoroughly in the soil in amount proportionate to the amount of each cover crop plowed under in the orchard. The writer was unable to find data dealing with the approximate amount of vegetative growth produced by each cover crop, so upon the suggestion of Dr. E. P. Sandsten, State Horticulturist, and Prof. Alvin Kezer, Agronomist of the College, the following amounts were chosen:

Alfalfa	2.9	tons	per	acre	dry	hay
Red clover	2.5	"	"	"	"	"
Sweet clover	2.5	"	"	"	"	"
Soybeans	2.0	"	"	"	"	"
Wheat straw	1.5	"	"	"	"	"
Barley straw	1.5	"	"	"	"	"
Apple leaves	1.0	"	"	"	(Approx.)	
Green lettuce	5.0	"	"	"	"	
Weeds	0.5	"	"	"	dry material	

The moisture content was considered to average about ten percent in all except the green lettuce crops, and in that crop, it averaged ninety percent.

The weeds selected for the experiment were common garden and orchard weeds. Pigweed, (Amyranthus retroflexus), Folsola, and Kochia vestita, S. Wats., were the ones selected.

The moisture content of the soil was found to average 8.9%. After determining the moisture content of the garden, individual portions of soil were weighed out, due allowance being made for the moisture content, and the ground up material mixed with the soil in the proportions stated in the preceding page. The soil was stirred vigorously for five minutes, in order to get the samples well distributed.

The remainder of the experiment was simple. The soil was put into four-inch greenhouse pots, three pots of each cover crop being used for the tomatoes and geraniums. Small tomato plants were then transplanted directly into the pots and geranium plants were also transplanted. Data was taken of the plants while they were being transplanted. The plants were put in an especially warm place in the greenhouse and were allowed to grow for three months. The comparative effects of the cover crops were noted at the end of that time.

Results of the Garden Soil Experiment.

The observations were based on facts considered indicative of the general response to the cover crops. Readings were taken with the following points in mind: height, leaf diameter, number of leaves, number of subordinate stems, blossoming time, weight, and development of root system. The probable error was very large, as only three plants in each class were used, and no general recommendations could be given concerning the best cover crop to grow.

Weight.

The green weight of the tomatoes and geraniums was considered the most important single factor in determining the relative response to the cover crops. The weight represents the total response to the various degrees of fertility. The plants were carefully removed from the soil and the roots washed in order to remove the adhering soil particles. The moisture was removed with cheesecloth and the plant allowed to stand for fifteen minutes so that the remaining moisture might largely evaporate before the plant was weighed. In treating the plants in the above manner, it was hoped to

GENERAL SUMMARY OF RESULTS FOR TOMATOES.

Plot	Cover Crop	Height	Leaf Diameter	Number of Leaves	Number of Stems	Blossoming Time	Weight	Root System	Gain over Check in Height	Gain over Check in Weight
0	Check	14.33	7.12"	10	1	April 10th.	59gr.	10" Fair		
1	Alfalfa	12.33	7.33	11.66	1.66	---	60.66	12" Long	-2"	+1.66
2	Red Clover	13.3 3	7.33	12.33	---	---	59	12" Long	-1	0
3	Sweet Clover	13.83	6.92	12.33	---	---	49.66	13" Weak	-0.5	-9.34
4	Soybeans	16.33	8.75	11.66	3.0	---	84.33	12" Compact	+2.0	+25.33
5	Wheat	14.83	7.83	11.33	---	April 8th	66.66	12" Medium	+0.5	+7.76
6	Barley	19	7.5	12.33	---	April 1st	61.33	11" Fair	+4.66	-2.33
7	Apple Leaves	17.16	7.97	11.66	0.66	April 5th	76	12" Long	+2.83	+17
8	Weeds	18.33	7.25	12.33	---	---	59.33	10" Weak	+4	+0.33
9	Green Lettuce	17.85	9.30	13.33	---	---	90.3 3	15" Compact	+3.52	+31.33
10	Dry Lettuce	17.75	8.69	12.33	----	April 10th	72	12" Good	+3.42	+13.

GENERAL SUMMARY OF RESULTS FOR GERANIUMS.

6

Plot	Cover Crop	Height	Leaf Diameter	Number of Leaves	Number of Stems	Blossoming Time	Weight	Root System	Gain over Check in Height	Gain over Check in Weight
0	Check	2.0	2.45	13	1.33	April 10th	29.33g	12" Fair		
1	Alfalfa	2.66	3.31	9	---	---	32 gr	13" Fair	+0.66	+2.67g
2	Red Clover	1.83	2.90	9.33	1	April 15th	26	12" Poor	-0.17	-3.33
3	Sweet Clover	1.95	2.81	9	1	---	26.33	12" Poor	-0.05	-3.0
4	Soybeans	1.66	2.80	10	---	----	30.33	12" Compact	+0.34	+1.0
5	Wheat	1.83	2.88	9.33	1.66	April 11th	28.0	11" Fair	-0.17	-1.33
6	Barley	1.66	3.04	8.33	1.33	April 5th	28.33	12" Medium	-0.34	-1.0
7	Apple Leaves	1.16	2.97	9.33	1.33	---	31.33	12.33 Compact	-0.84	+2.0
8	Weeds	2.0	2.97	9.33	1.0	April 10th	18.0	10" Poor	--	-11.33
9	Green Lettuce	2.33	2.95	9.0	1.0	---	29.33	12" Fair	+0.33	0
10	Dry Lettuce	2.33	2.68	11.0	1.33	---	30.16	12" Good	+0.33	+0.83

avoid error as much as possible.

The tomatoes responded very definitely. All of the cover crops with the exception of sweet clover weighed more than the check, the sweet clover falling nearly ten grams below it. Green lettuce made the greatest gain, as would be expected on account of the large amount of water present and the consequent solvent effect of the organic acids liberated in the decomposition of the green lettuce upon the unavailable plant-foods in the soil. However, the other crops were relatively dry, containing about ten percent moisture and of these soybeans made the greatest response. Apple leaves followed soybeans and dry lettuce came next in rank. The noticeable fact was that alfalfa, red clover, and sweet clover were at the bottom of the list being exceeded by wheat and barley and only on a par with the weed plot and check plot.

The geranium weights varied considerably. Alfalfa headed the list and weeds were at the bottom. Apple leaves, soybeans, and dry lettuce followed in the order names, while green lettuce and the check plot tied for fifth place. Only five of the plots weighed more than the check, indicating that the geraniums did not respond as quickly as the tomatoes. The sweet clover, red clover, barley, and wheat failed to make as great a growth as the check plot.

WEIGHT TABLES.

Tomatoes.

Plot	Cover Crop	Weight	Gain or Loss over Check
9	Green Lettuce	90.33 gr.	+31.33 gr.
4	Soybeans	84.33	+25.33
7	Apple leaves	76.00	+17.00
10	Dry Lettuce	72.00	+13.00
5	Wheat	66.66	+7.66
6	Barley	61.33	+2.33
1	Alfalfa	60.66	+1.66
8	Weeds	59.33	+0.33
0	Check	59.00	----
2	Red Clover	59.00	----
3	Sweet Clover	49.66	-9.34

Plot	Cover Crop	Weight	Gain or Loss over Check
1	Alfalfa	32.0 gr.	+2.65 gr.
7	Apple Leaves	31.33	+2.00
4	Soybeans	30.33	+1.00
10	Dry Lettuce	29.33	----
0	Check	29.33	----
9	Green Lettuce	29.33	----
6	Barley	28.33	-1.00
5	Wheat	28.00	-1.33
3	Sweet Clover	26.33	-3.00
2	Red Clover	26.00	-3.33
8	Weeds	18.00	-11.33

Height.

The height factor is of importance to tomatoes but of less importance to geraniums, because geraniums are naturally short stemmed plants. The results are of benefit in interpreting the general effect of cover crops, although the data is somewhat conflicting. The height, in every case, was considered to be the distance from the first root to the tip of the main growing stem, rather than from the surface of the ground to the tip of the stem.

The barley gave the greatest height in the tomato plants, although the weight factor forced it down to the seventh place. The plants were tall, spindling, and with relatively small leaves. Weeds ranked next in growth, but were near the bottom of the list in weight. Green lettuce was third in height and was followed by dry lettuce, apple leaves, soybeans, wheat, and the check plot, all of these plants being relatively strong and stocky. Sweet clover, red clover, and alfalfa were at the bottom of the list, as they were short and weak. The legumes ranked consistently low in regard to weight and height with the exception of soybeans.

The difference in height in the geraniums varied only one and one-half inches, so that the results were not so clearly defined. Alfalfa headed the list, followed by green lettuce, dry lettuce, weeds and the check plot. In this case, the legumes, as well as the wheat, barley, and apple leaves, were below the check in height. Sweet clover, red clover, and soybeans were near the middle of the table and were practically the same height.

HEIGHT TABLES

Tomatoes.

Plot	Cover Crop	Height	Gain or Loss over Check.
6	Barley	19.00"	+4.66
8	Weeds	18.33	+4.00
9	Green Lettuce	17.85	+3.50
10	Dry Lettuce	17.75	+3.42
7	Apple Leaves	17.16	+2.83
4	Soybeans	16.33	+2.00
5	Wheat	14.83	+0.50
0	Check	14.33	---
3	Sweet Clover	13.83	-0.50
2	Red Clover	13.33	-1.00
1	Alfalfa	12.33	-2.00

Geraniums.

Plot	Cover Crop	Height	Gain or loss over Check.
1	Alfalfa	2.66"	+0.66"
9	Green Lettuce	2.33	+0.33
10	Dry Lettuce	2.33	+0.33
8	Weeds	2.00	---
0	Check	2.00	---
3	Sweet Clover	1.95	-0.05
2	Red Clover	1.83	-0.17
5	Wheat	1.83	-0.17
6	Barley	1.66	-0.34
4	Soybeans	1.66	-0.34
7	Apple Leaves	1.16	-0.84

Leaf Diameter.

The leaf diameter was regarded as an important factor, as it gave some idea of the relative development of the leaf area. A close relationship exists between the leaf area and the health and vigor of a plant and for that reason it was considered advisable to note the diameter of the leaves. The average diameter of the tomato leaves was nearly twice that of the geranium leaves, due to the different shape of the leaves.

The relative rank of the leaf diameters of the tomato plots, followed the weight table very closely, indicating the close harmony between those two factors. Green lettuce excelled with an average leaf diameter of 9.30 inches, followed closely by soybeans and dry lettuce. Apple leaves, wheat, barley, alfalfa, weeds, and red clover followed at rather close intervals. Sweet clover brought up the rear, falling even below the check plot. The variation exceeded two and one half inches between the plots.

Alfalfa had the largest leaf diameter in the geranium plots. It was followed by barley, apple leaves, and weeds. Green lettuce was fifth on the list, being followed by red clover, wheat, sweet clover, dry lettuce, soybeans, and the check. Barley was sixth in the weight table, and soybeans, which was second, fell down to the tenth place. The results were more confusing in this series but in general followed the weight series quite closely. The total variation in geranium leaves was less than one inch.

LEAF DIAMETER TABLES.

Tomatoes.

Plot	Cover Crop	Leaf Diameter	Gain or Loss over Check.
9	Green Lettuce	9.30"	+2.18
4	Soybeans	8.75	+1.68
10	Dry Lettuce	8.69	+1.57
7	Apple Leaves	7.97	+0.85
5	Wheat	7.835	+0.715
6	Barley	7.5	+0.38
1.	Alfalfa	7.33	+0.21
8	Weeds	7.25	+0.13
2	Red Clover	7.16	+0.04
0	Check	7.12	---
3	Sweet Clover	6.92	-0.22

LEAF DIAMETER TABLES

Geraniums.

Plot	Cover Crop	Leaf Diameter	Gain or Loss over Check.
1	Alfalfa	3.31"	+0.86
6	Barley	3.04	+0.59
7	Apple leaves	2.97	+0.52
8	Weeds	2.97	+0.52
9	Green Lettuce	2.95	+0.50
2	Red Clover	2.90	+0.45
5	Wheat	2.88	+0.43
3	Sweet Clover	2.81	+0.36
10	Dry Lettuce	2.68	+0.13
4	Soybeans	2.80	+0.35
0	Check	2.45	---

Development of the Root System

The relative development of the roots was regarded as significant of the response to the different dover drops. The length, compactness, and number of the roots varied greatly in the different plant. In the poorer plants, compactness of roots was lacking, while in the stronger plants a great many fibrous roots were present.

The green lettuce roots excelled in the tomato plot, leading with compact roots averaging fifteen inches in length. Soybeans were second with length less, but compactness practically the same as the green lettuce. Apple leaves were third with compactness decidedly less. Dry lettuce, wheat, barley, alfalfa, and weeds ranked above the checkplot, but sweet clover was below with roots of about the same length but less compact.

The geranium plots were fairly uniform in the root development. Alfalfa lead the list with a root length of thirteen inches and compact, closely woven roots. Apple leaves came next with somewhat less length but equal compactness. Soybeans were third with roots of good length but less compactness. Dry lettuce was fourth with roots still shorter and less compact. The check plot was fifth and was followed by green lettuce, barley, wheat, sweet clover, red clover, and weeds.

ROOT DEVELOPMENT TABLES.

Tomatoes.

Plot	Cover Crop	Length of Root	Compactness of Root
9	Green Lettuce	15"	Excellent
4	Soybeans	12	Excellent but short
7	Apple Leaves	12	Very good
10	Dry Lettuce	12	Fair
5	Wheat	12	Medium
6	Barley	11	Poor
1	Alfalfa	12	Poor
8	Weeds	10	Very Poor
0	Check	10	Poor
3	Sweet Clover	12	Poor
2	Red Clover	12	Poor

ROOT DEVELOPMENT TABLES.

Geraniums.

Plot	Cover Crop	Length of Root	Compactness of Root
1	Alfalfa	13"	Excellent
7	Apple Leaves	12.33	Excellent
4	Soybeans	12.33	Very good
10	Dry Lettuce	12.33	Fair
0	Check	12.00	Fair
9	Green Manure	12.00	Fair
6	Barley	12.00	Medium
5	Wheat	12.00	Poor
3	Sweet Clover	12.00	Poor
2	Red Clover	11.00	Very poor
8	Weeds	10.00	Very poor

Minor Factors.

The number of leaves on each plant varied only slightly in either the tomatoes or geraniums. The number of leaves varied from thirteen in the green lettuce tomato plot to ten in the check plot. Practically all of the plots averaged twelve leaves with the result that little information could be obtained from this factor. The number of leaves, in general, varied directly with the leaf diameters and and weights. There seemd to be a tendency in the geranium plots for the poorer plants to produce a larger number of leaves with a smaller leaf diameter.

The blossoming time was considered important only in its relation to the degree of maturity. A plant usually sends out blossoms as it nears maturity, indicating that the reproductive cycle is at hand and that the full vegetative stature has been reached, whereas a plant that is still growing vigorously produces few flowers. The inference would be that the tomatoes or geraniums that had produced no flowers would grow for some time.

The period of blossoming in the tomato plots varied from April 1st to April 10th. The barley plots produced flowers that blossomed the first of April, as did the weed plots. The apple leaves plots blossomed on April 5th and the check plot on April 8th. Dry lettuce blossomed on April 10th. Green lettuce, soybeans, alfalfa, red clover, and sweet clover produced no blossoms during the experiment.

The blossoming period of the geraniums followed that of the tomatoes closely. Barley produced flowers on the fifth of April, weeds on the tenth of April, wheat on the eleventh, and red clover on the fifteenth of April. Green lettuce, alfalfa, apple leaves, soybeans, dry lettuce, and sweet clover produced no flowers.

Pure Sand Experiment.

An additional experiment was conducted with the cover crops which were grown in pure sand rather than garden soil. Pure silica sand is 99.6% pure and carries little plant-food and on that account the exact degree of influence of the cover crops upon plants grown in it can be determined. There was no way to determine the influence of the plant-food removed from the garden soil upon the tomatoes and geraniums, so it was thought advisable to conduct a similar experiment under conditions of better control.

The pure sand experiment was performed in the same manner as the garden soil experiment. Finely ground samples of alfalfa, red clover, sweet clover, soybeans, wheat, barley, apple leaves, weeds green lettuce, and dry lettuce were separately and thoroughly mixed in pure sand. The amount of material incorporated in the sand was proportionate to the average amounts of the cover crops plowed under in the field. The tomato and geranium plants were potted in the sand pots and given care and attention for twelve weeks. Readings were taken at the end of that period.

The few tomato plants that survived were in very poor conditions. The cover crops evidently did not decompose rapidly enough to furnish plant-food with the result that over two-thirds of the tomatoes died. The three classes of tomato plants that survived made a fairly vigorous growth, although to not such an extent as the corresponding garden soil plants. This point, alone suggested that the garden soil contributed some plant-food to the growing plants.

Practically all of the geranium plants grew. The wheat and barley pots died before the experiment ended, but the other pots made considerable growth. The data obtained from the geranium plants was of much more value because so many more of the plants lived.

Pure Sand Plot of Tomatoes.

The green lettuce plots survived and made a vigorous growth of twenty-three grams. It exceeded in height, leaf diameter, and number of leaves, indicating a superiority in every respect. Wheat made a growth amounting to eleven grams and exceeded the red clover in leaf diameter, but not in number of leaves, Red clover was third and last with a growth of six grams. The plants had a healthy green color.

PURE SAND TABLE

Tomatoes.

Plot	Cover Crop	Leaf Diameter	Number of Leaves	Weight	Height
1	Alfalfa	Dead	---	---	---
2	Red Clover	5.0"	7	6.0 gr	5"
3	Sweet Clover	Dead	---	---	---
4	Soybeans	Dead	---	---	---
5	Wheat	7.0"	5	11.00	7"
6	Barley	Dead	---	---	---
7	Apple Leaves	Dead	----	---	---
8	Weeds	Dead	---	---	---
9	Green Lettuce	8.0"	7	23.00	12"
10	Dry Lettuce	Dead	---	---	---
0	Check	Dead	---	---	---

Pure Sand plot of Geraniums.

The geranium plants responded very well. Green lettuce, alfalfa, soybeans, dry lettuce, and apple leaves gave the greatest response, while red clover and sweet clover were down in the list. Green lettuce made the greatest growth, however, with alfalfa a close second in weight, height, and leaf diameter. Soybeans were third, dry lettuce fourth and apple leaves fifth in general response.

Geraniums.

Plot	Cover Crop	Leaf Diameter	Number of Leaves	Weight	Height
1	Alfalfa	2.37"	7.5	20 gr.	2.5"
2	Red Clover	1.75	6.0	8	1.0
3	Sweet Clover	1.75	4.0	9	2.0
4	Soybeans	2.50	7.0	18.5	2.12
5	Wheat	Dead	---	----	----
6.	Barley	Dead	---	----	----
7	Apple Leaves	2.00	6.0	12.5	1.0
8	Weeds	2.00	3.0	6.0	2.0
9	Green Lettuce	3.03	7.0	21.25	2.25
10	Dry Lettuce	2.40	10.5	17.00	2.50
0	Check	Dead	---	----	----

Conclusions.

The contradictory and inconclusive nature of the evidence renders generalization very difficult and hazardous until further experiments have been performed. A few of the points that have been brought our in the work with cover crops are:

1. Alfalfa gave the greatest consistent growth response of the legumes.
2. Soybeans were clearly second in order of response of the legumes.
3. Red clover and sweet clover were of minor importance throughout the experiment, averaging less response than wheat and barley of the non-leguminous plants.
4. Green lettuce produced the outstanding plants of the non-leguminous cover crops.
5. Green lettuce made as great a growth response as alfalfa and exceeded soybeans.
6. Apple leaves ranked next to green lettuce and were followed in importance by dry lettuce.
7. Wheat and barley were outstanding in no particular, giving only medium responses.
8. The influence of weeds upon plant growth was relatively small, as the weed plots were at the bottom of the list in both the geranium and

tomato plots.

9. The pure sand experiment substantiated the results obtained from the garden soil experiment to a large degree.

10. No recommendation can be given as to the best cover crop for Colorado orchards on the basis of this experiment.

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II. THE UTILIZATION OF CARBON BY PLANTS.

THE EFFECT OF CARBON DIOXIDE UPON THE GROWTH AND BEHAVIOR OF COLEUS AND LETTUCE.

Plant physiologists generally believe that land plants cannot grow unless they can obtain carbon dioxide from the air. The German botanist, Moll, was the first man to demonstrate that land plants diewhen placed in an atmosphere free of carbon dioxide. Experiments conducted since the time of Moll have invariably confirmed his results, so that practically all of the leaders in the field of plant physiology uphold his belief.

The influence of the absorption of carbon dioxide from the soil upon plant growth has not been determined. Experimental work along that line has been very contradictory and little information of value can be obtained by reading the literature on the subject. However, some of the experiments indicate that, in case carbon dioxide is taken in through the roots, the amount absorbed is not sufficient to maintian plant growth.

The recent work of a German engineer has clearly demonstrated the fact that plantsrespond very quickly to applications of carbon dioxide made by enriching the atmosphere. This fact has been known for many years and de Saussure, over one hundred years ago, proved that plants made an increasing vegetative growth until the concentration of carbon dioxide gas was about eight per cemt. However, it remained for Reidel to prove that plants under field conditions could be made to grow to a noticeable degree.

Reidel worked with barley, potatoes, turnips, sugar beets, tomatoes, spinach, and various flowers grown under greenhouse conditions and outside conditions. The carbon dioxide gas was obtained from a nearby blast furnace and was piped to the greenhouses and the open fields. The gas was applied to the plants in various strengths, but as the experiments progressed, Reidel discovered that a five percent stream of gas gave best results. De Saussure recommended eight percent whereas Reidel recommended only a five percent mixture of carbon dioxide.

The data obtained by Reidel was conclusive. The growth response varied from a minimum of fifteen percent in root and fruit crops to as high as 200 percent in other crops. In practically all cases, the gain was at least seventy percent over the check plots. He also found that the average crop increase in the plots given carbon dioxide fertilization and ordinary fertilization was eighty-two percent, indicating a much greater growth increase from the carbon dioxide than from the ordinary inorganic and organic fertilizers.

Coleus Experiment.

Two experiments were conducted in the greenhouse, one with the common ornamental coleus plant and the other with lettuce. The experiment with the coleus was to study the behavior of the plant when grown in an atmosphere free of carbon dioxide but which was supplied with carbon dioxide through the roots. The experiment with lettuce was to determine the growth response of the plant when grown in an atmosphere enriched with carbon dioxide. Thus, the experiments were closely allied.

The apparatus in which the coleus plant was grown was devised to control conditions as much as possible. The carbon dioxide was removed from one bell jar by passing the air through three flasks of a forty percent solution of sodium hydroxide and also through a solution of barium hydroxide. The carbon dioxide was removed from the air by the sodium hyrdoxide in the form of sodium carbonate, a soluble compound, while the remaining carbon dioxide was removed by the barium hydiroxide as the insoluble, white precipitate known as barium carbonate. The air was then introduced into one bell jar. The other bell jar was connected up in a similar manner, although no attempt was made to remove the carbon dioxide from the air.

Two coleus plants were selected for the experiment. The four inch pot of one coleus plant was completely coated with forty degree paraffine in order to prevent the carbon dioxide in the soil from passing into the atmosphere in the bell jar as well as prevent the carbon dioxide given off in the process of respiration from entering the soil. The plant was grown in an atmosphere free of carbon dioxide. A thistle tube was extended from the rubber stopper in the bell jar to the soil so that water could be added to the soil without disturbing the apparatus.

The other coleus plant pot was not paraffined although a thistle tube was extended to the soil. Ground plate glass was used as a base for the bell jars which were firmly glued to theglass by applying a thin coating of sticking wax, composed of vaseline, paraffine, and rubber, to the ground basic rim of the bell jars.

A small beaker of calcium chloride was put into each bell jar for the purpose of absorbing moisture given off by the plants. A beaker of a strong solution of sodium hydroxide was put into the carbon dioxide free bell jar to absorb the carbon dioxide given off during the respiration process.

The apparatus was connected up with rubber tubing and attached to a filter pump. The filter pump provided for a good circulation of air in the bell jars during the ten days of the experiment. Care was taken to reduce rapidity of circulation as much as possible to simulate natural conditions.

The coleus plant in the carbon dioxide free atmosphere was watered daily with distilled water through which carbon dioxide gas had been bubbled for thirty minutes. In this manner an abundance of carbon dioxide was assured the roots, although the exact amount was not determined. The normal air plant was watered with distilled water daily.

Results of the Coleus Experiment.

The data obtained at the end of the experiment was rather conclusive. The plants were subjected to the test for starch immediately after being removed from the bell jars.

The common test for starch is to apply a few drops of a ten percent solution of tincture of iodine to the leaves, that have been gently boiled in alcohol to remove the chlorophy ll or green coloring matter. The starch turns a bright blue or purplish color if present in large quantities but a dark brown color is present in rather limited amounts.

The plants reacted to the iodine test at the beginning of the experiment. However, the coleus plant grown in an atmosphere free of carbon dioxide did not give the dark blue color, so pronounced at the beginning of the experiment. The color was a very weak,brown hue, indicating that a slight formation of starch might have taken place, but not a normal production. Several leaves were tested from various parts of the plant and a small portion of the green stem likewise tested.

The coleus plant grown in a normal atmosphere responded to the iodine test. The leaves turned a dark, blue to purple color and the stem reacted also. The difference in color as compared with the other coleus plant was noticeable and well defined. Judging from this experiment, the roots may absorb carbon dioxide, but certainly not to the same degree or extent as the leaves.

Lettuce Experiment.

A later experiment was conducted with lettuce in the greenhouse to not only study the effects of an absence of carbon dioxide but also the effects of an increased amount of the gas upon plant growth. Lettuceis a tender,short lived quick maturing vegetable that is sensitive to changes of any kind. The weak vegetative growth is an indication of the weakness of the plant and the lack of ability to withstand unfavorable conditions.

Eight potted lettuce plants about three weeks old were selected for the experiment. The plants were about the same size and were uniform in nearly every respect. The four following combinations were made and two plants selected for each plot:

1. Check plot.

   The plants were grown in common garden soil to which only distilled water was added.

2. Plot No. 2.

   The plants were grown in common garden soil to which distilled water containing carbon dioxide was added.

3. Plot No.3.

   Plants in common garden soil were grown in bell jars in carbon dioxide free air.

4. Plot No.4.

   Plants in common garden soil were grown in bell jars in atmosphere enriched with approximately five percent of carbon dioxide gas.

The two pots of check plants were given care and attention throughout the experiment. They were watered daily with distilled water but were not disturbed in any respect.

The lettuce plants in the second plot were given daily applications of water enriched with carbon dioxide. The carbon dioxide was bubbled through water for thirty minutes. However, in other respects the firsttwo plots were treated alike.

The lettuce plants in the third plot were placed in an atmosphere free of carbon dioxide. The apparatus was assembled in exactly the same manner as described for the coleus plant. Carbon dioxide was removed from the air by passing the air through a strong solution of sodium hydroxide and a solution of barium hydroxide before entering the bell jar chamber. Circulation of air was provided by the filter pump and all other details were treated as previously mentioned, with the exception that the water applied to the soil contained no carbon dioxide.

The two lettuce plants in the fourth plot were subjected to favorable growing conditions. The atmospheric carbon dioxide, in stead of being removed, was enriched with more of the gas. The amount of carbon dioxide was estimated to be about five percent by volume, although the concentration varied somewhat on account of the apparatus. The gas was forced into the bell jars twice a day after the stale air had been fairly well removed. In this method, the percentage of carbon dioxide varied as the plants used it and decreased the amount of carbon dioxide in the bell jar chamber. The gas was evolved by treating calcium carbonate with dilute hydrochloric acid.

Results of the Lettuce Experiment.

The beneficial effects of carbon dioxide were apparent. The two plants growing in an atmosphere enriched with carbon dioxide were superior in every respect. They were larger, more stocky, more vigorous and had more leaves. A comparison can be had by looking at the pictures.

The check plot made a fair growth. The plants were strong, well colored, and vigorous. The average longitudinal diameter was three inches, slightly less than in the other plots, but nevertheless, comparable with the other plants.

The second plot made a good growth response on account of the presence of carbon dioxide in the water, presumably. There were more leaves and their average diameter was somewhat greater than in the check plot. The leaves were stocky, well colored and apparently in the best of health.

The lettuce plants in the third plot were grown in an atmosphere free of carbon dioxide and were unable to survive the experiment. The leaves became noticeably weak and pale green in color at the end of seven days. At the end of fourteen days a large portion of the green chlorophyll had disappeared and the plants had assumed a very pale, sickly, green color, rather spotted and rough. The plants died on the seventeenth day of the experiment, wilting and apparently dying from lack of food, as the soil was moist and in good condition. The picture shows the emaciated and starved appearance of the leaves very well.

The lettuce plants in the fourth plot were the most vigorous and healthy of all of the plots. The increased growth was apparent in ten days and became more noticeable as the experiment was contined. The plants were exceptionally strong and stocky and the leaves were very crisp, indicating a rapid, succulentgrowth. The number of leaves averaged ten while the longitudinal diameter was over four and one-half inches. The bright greencolor of the leaves testified to the healthy condition of the plants. While, the superiority could not be estimated in terms of percent, the advantage was apparent.

STATISTICAL TABLES.

February 24,1922.

	Plot 1	Plot 2	Plot 3	Plot 4
Number of Leaves	6	6	6	5
Longitudinal Diameter Leaves	3"	3"	$3\frac{1}{2}$"	$3\frac{1}{4}$"
Appearance	Healthy	Healthy	Healthy	Healthy

March 24,1922.

	Plot 1	Plot 2	Plot 3	Plot 4
Number of Leaves	8	9	7	10
Longitudinal Diameter Leaves	4"	4 1/3"	3 6/7"	4 3/5"
Appearance	Healthy and Vigorous	Very Healthy and Vigorous	Spindly. Died on Mar.13,1922	Stocky and Very Vigorous.

Summary.

The following points have been emphasized in the carbon dioxide experiments with coleus and lettuce plants:

1. That the coleus plant grown in an atmosphere free of carbon dioxide could not manufacture starch to any extent, although carbon dioxide was added to the soil.
2. That the coleus plant grown in a normal atmosphere manufactured starch in sufficient quantity to react to the iodine test.
3. That lettuce plants watered with distilled water in which carbon dioxide gas was present made a material growth response when compared to a check plot.
4. That lettuce plants grown in an atmosphere enriched with carbon dioxide to the extent of five percent made the greatest growth response.
5. That lettuce plants grown in an atmosphere free of carbon dioxide died in seventeen days.
6. That coleus and lettuce plants seem to be very sensitive to the presence or absence of carbon dioxide.

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Plot I

Plot II

Plot III

Plot IV

III. PEAR BLIGHT.

THE PROBLEM OF PEAR BLIGHT CONTROL IN THE ROGUE RIVER VALLEY

The first recorded account of pear blight was published in "The Transactions of the Massachusetts Society for the Promotion of Agriculture" by William Denning in 1794. Mr. Denning noticed that this disease attacked apples, pears and quinces in the highland region of the Hudson River, New York. Subsequently, other men reported its presence on Long Island, in New Jersey and near Philadelphia in Pennsylvania. As the fruit region spread westward, the disease kept apace and the blight appeared in Ohio, Indiana, Michigan and Illinois in the early thirties.

Pear blight has done a great deal of damage in the eastern part of the United States during the last century. The regions of New York, Michigan, Florida, Georgia and many other eastern states has suffered seriously, in fact, commercial pear growing has largely ceased to exist in these affected regions. Bartlett pears were once commonly grown in the east, but these have given away to the hybrid varieties, namely LeConte and Kieffer, which seem to be somewhat more resistant to the ravages of the pear blight.

Apples have proved an easy prey to pear blight, although not to such an extent as pears. The characteristic injury, however has been to the blossoms and tender twigs, rather than to the large branches. The varieties that have been most seriously injured have been the Ben Davis, Spitzenberg, Yellow Transparent, Alexander, Wealthy and the Red Astraken.

The middle western states, comprising Illinois, Iowa, Nebraska and Kansas hawe paid toll to the ravages of pear blight. The loss has amounted to many thousands of dollars in this area and has materially reduced the profits as well as the yield, but not to such an extent as in the eastern states.

Pear blight has followed two well defined routes in its spread westward. The southern route, as it is called, is clearly traced across Colorado, southern Utah, and Nevada to the San Joaquin Valley of California, where it first appeared in the summer of 1900. It has gradually spread northward to the Sacramento and other small adjacent valleys until it has reached the Rogue river valley of southern Oregon.

The blight did not appear in southern Oregon until in 1907, but since then it has been a relatively serious problem, gradually assuming a more serious and alarming aspect in spite of the efforts to control it. The most serious outbreak in the history of the Rogue river valley occurred in the Spring of 1930 when climatic conditions happened to be unusually favorable to the spread of the disease. Many thousands of dollars were lost before the epidemic was brought under control late in the summer. Several large orchards were completely killed and scores of smaller orchards seriously injured.

The nothern route of the blight can be traced across Colorado, northern Utah, Idaho, eastern Oregon and Washington to British Columbia, where it appeared about 1890. The blight has slowly moved down the western part of Washington and it is only a matter of time until it is found in the Williamette and Umpqua river valleys, which are relatively free from it. The concensus of opinion seems to be that the disease will cause serious injury to the apple and pear plantings of the northwestern part of Oregon when the two infections meet.

Foreign countries have never felt the full force of the pear blight. The disease has never been found outside of the Continental North America, although many reports of its presence in other countries have been received. The term "fire blight" is commonly used in referring to many plant disorders and diseases in Australia, New Zealand, and Tasmania, and the horticultural literature of those countries abounds in references dealing with fire blight. However, the American pear blight, or fire blight, has never been positively identified, and probably will not be a problem as long as the strict quarrantine against American pear stock is maintained.

Professor T. J. Burrill of the University of Illinois, discovered the true nature of the pear blight in 1879. He discovered that the trouble is caused by a bacillus, which he called Bacillus amylovorus. By determining the specific cause of this serious disease, Professor Burrill was able to bring the disease before the spot-light of publicity, with the result that a great deal of information is to be had. Bacteriologists are familiar with its morphology and cultural characteristics as well as with its life history under field conditions, so that there is no difficulty in identifying the organism.

Pear blight attacks every tree and shrub of the pome family. It is commonly called pear blight because it has been much more disastrous upon the pear (Pyrus communis) than upon any of its numerous hosts. It is also found upon the apple, (Malus), quince, (Cydonia vulgaris), wild crabapples (Malus Coronaria), hawthorne, (Crataegus), service berry, mountain ash (Sorbus Aucuparia) and other native pomaceous fruits. It has recently been found on the plum and apricot.

Bacillus amylovorus belongs to the general class of microscopic organisms called "bacteria". Single cells of the organism are oval shaped, 1.5 to 2 microns long, and from .5 to .75 microns wide. The organism multiplies by dividing in the middle and growing to normal size in about every thiry minutes as long as conditions are favorable to the growth of the disease. They are covered with hair-like flagella which enable them to move about in the juices of the diseased parts of the plants, being single or attached, several end to end.

Gelatine plates. Growth is slow, requiring three to five days for appearance of colonies, which are of a yellowish color, sharply outlined, and globular of lenticular shape. Surface colonies slowly liquify the gelatin forming little pits.

Agar plates. Colonies are evident in two days, becoming characteristic in five days. Surface colonies are from two to three mm. in diameter, in the form of thin, white, finely granular or cloudy circular growth, with a densely defined white center. Deep colonies are somewhat larger, globose, dense opaque to yellowish color. The surface growth is coarsely granular or flocculent, whitish.

Beef bouillon. Becomes uniformly cloudy in twenty-four hours. Slightly acid. Cloudiness slightly increased in forty-eight hours, neutral to litmus. Becomes a strongly alkaline substance in twenty days. Odor not marked.

Potato bouillon. Becomes uniformly cloudy in twenty-four hours. Growth most active at surface. Slightly acid to litmus paper. After forty-eight hours liquid becomes heavily clouded and decidedly alkaline. Clears in about twenty days with abundant sediment at bottom of plates.

Sugar Free Bouillon. Clear at end of twenty-four hours, with only slight sediment at bottom. Neutral to litmus paper. After several days becomes slightly cloudy and alkaline. No odor produced.

Agar slant. Growth slight the first twenty-four hours. Moderate glistening white, opalescent, but little spreading growth which is not viscid. Growth increases but little after twenty-four hours.

Glucose sugar. No gas. Growth of organism vigorous, in twenty-four hours, forming thick layer at top. Submerged colonies are granular. Little change noted except that white surface layer becomes thicker as time goes on.

Glucose bouillon. Uniformly cloudy in twenty-four hours, with abundant flocci and a weak pellicle. Acid reaction, remaining acid.

Milk. No change until the third or fourth day when things begin to thicken, becoming very thick by sixth day. Milk does not curdle, but becomes subgelatinous. In about ten days the thickened portion gradually settles leaving a clear watery liquid above. Acid at first but becomes strongly alkaline.

In discussing the migratory habits of Bacillus amylovorus, Miss Bachman said that the bacteria move almost entirely through the intercellular spaces rather rather than through the sap tubes as previously supposed. In the young stems, all parts are diseased, even the wood, but in the older shoots and branches, only the phloem region is affected. The cell walls are apparently not dissolved by the bacteria. The cells are killed primarily by the extraction of the water from them.

According to Burrill, in his study of diseased tissue, the most conspicuous change that can be observed by the aid of the microscope is the total disappearance of stored starch.

Waite found that the blight bacilli apparently live on the nitrogenous matter, sugars, and to some extent, the organic acids present in the cells. These substances occur abundantly in young growing tissues.

Stewart found that the blight bacilli are present in great numbers in the intercellular spaces and to some extent in the cells.

The complete life history of Bacillus amylovorus under field conditions is well known. It winters over, under favorable conditions, in relatively few hold over cankers in protected parts of pear trees. As the blight can stand but a brief exposure to sunlight, and is quickly killed by a period of drying, it is evident that the hold-over cankers must be in some protected part of the tree, usually on the north side of a branch. With the return of growing conditions in the spring, fermentation sets in and gummy beads of exudation appear around the edges of the cankers. These drops contain millions of the living bacteria, in an extremely active condition.

The disease is carried from hold over cankers to pear blossoms almost entirely by insects. Bees are particularly active in spreading the organism at this time of the year. The bacillus multiplies very rapidly in the nectary of the flower where it is left by the bees or other insects. From the nectary it easily enters the softer tissues of the bark and cambium, and its progress into the larger limbs is only a matter of time, in many cases. Biting and sucking insects are active agencies in the spreading of this disease, during the spring and summer, causing many infections through the succulent water sprouts which appear throughout the trees.

Symptoms.

The first symptoms of pear blight are first commonly noted in the early part of the season. About two weeks after blossoming time, the tips and blossoms of the affected parts wilt, turn brown and finally become black, indicating that death has become general in the tissues. Frequently, in severe cases, the disease will kill every blossom and twig on the tree. This form of blight is known as twig or blossom blight and is fairly common on pears although more so on apples and quinces.

The progress of the disease, under favorable conditions, is into the larger branches and trunk of the tree. This type of injury is known as "body Blight" and is by far the worst form on pears. The large branches are easily girdled as the disease progresses at a fairly rapid speed. The growth of the organism within the tissues is accompanied by a water soaked appearance and finally a blackening and shriveling, accompanied usually by a copious exudation of a dark brown color and gelatinous nature.

The activity of Bacillus amylovorus gradually lessens as the summer passes. Towards fall or under unfavorable conditions the organism ceases to spread rapidly and goes into a relatively passive stage. A sharp line of demarcation separates the dead tissue from the healthy tissue, forming the characteristic canker, with its dark brown sunken surface of bark. They are distinctly sunken, smooth, never checked or spotted with pustles except when saprophytic rot fungi gain entrance later.

Influence of weather and soil conditions.

Certain climatic conditions are favorable to the spread of pear blight. It has been observed that the disease is always more severe after spells of warm, damp, muggy weather, during pollination or later. Humidity of the atmosphere, coupled with warm days, as well as increased moisture content of the soil, causes a large amount of water to be present in the plant tissues and this condition frequently leads to serious results. Not only is damp weather liable to cause a greater susceptibility to the disease, but it also facilitates the spread of the bacteria. They cannot stand extremely dry weather, as they are easily killed by a wound drying out before they have infected the living tissue. Therefore, climatic conditions that favor the activity of the disease in the host also favor the dissemination of the bacteria.

Soil conditions determine the prevalence of pear blight to some extent. While a typical pear soil is defined as a rich, deep moist heavy soil, yet under southern Oregon conditions, a lighter type of soil has been found preferable. The prevailing type of soil best suited to pears is known as the Agate Gravelly, Loam, Deep phase. The depth of the soil ranges from two to four feet, and is of a dark red color, being underlaid by a gravelly subsoil, usually firmly cemented together. However, other soil types of a heavier nature are commonly found.

Irrigation is regularly practiced in southern Oregon, as the summer rainfall is insufficient for pear growing. It is the general practice among experienced pear growers to apply the minimum rather than the maximum or optimum amount of water, on account of the influence upon vegetative growth of the bearing trees. It is quite possible during the early part of the summer to keep the trees in a healthy growing condition without applying a great deal of water, depending upon cultivation to conserve the soil moisture. However, during the latter part of the summer, when the blighting is not so vigorous, a liberal supply of water is used to put size on the fruit. Bartlett pears are given a heavy watering about the first of August, as the fruit matures about the middle of the month, and Bosc pears, which mature about a month later, are heavily irrigated about the first of September.

Dissemination.

The chief agency in the spread of pear blight is insects. The chief offender is the aphis, of which there are several different kinds, while the click beetle, bees, ants and many kinds of flies likewise contribute. The insects become contaminated with the live bacteria while visiting the active hold over cankers in the spring, and carrying the bacteria to the nectaries of the pear blossoms. The bacteria multiply very rapidly under favorable conditions, and as insects visit the blossoms in search of honey, they carry the bacteria to other blossoms, soon infecting thousands of blossoms.

The common grain or weed thrips has recently been found to be an especially dangerous carrier of the disease. The insects are small and work into the blossoms and axils of the young growing leaves and due to their habits, cause a great many infections. Hundreds of click beetles have been found around the roots of the pear trees in the early morning. They ascend the trees during the forenoon and feed upon the blossoms and tender shoots, descending in the later afternoon. Many of the infections have resulted from the activities of these beetles.

Various sprays have been used to control the insects, but at the present time only one spray is recommended. Nicotine sulphate 1---800 part water; distillate oil emulsion 1½%, applied when the first outbreak of blight is noticed, will quite effectively control new infections. If new infections are not controlled in some manner, it is almost impossible for blight cutters to keep up with the work, whereas with a thorough application of the insecticide, infections will be prevented for a few days and the cutters can get the epidemic under control.

Sulphur is commonly put around the roots of pear trees, two or three inches below the surface to keep the click beetles and other insects away from the roots. It is applied at the rate of four pounds per tree and has been found effective when used consistently. A three or four inch band of tanglefoot is also put around the trunk of the trees to keep the crawling insects from gaining access to the tree proper.

The problem of control.

The only successful method of controlling pear blight at the present time consists in cutting out and destroying the diseased tissue as quickly as it shows up. This is a rather drastic treatment but the experiences of several years has proved it to be the only feasible way of controlling the disease. The pear trees should be looked over every week or, better yet, every three days and all of the diseased twigs, branches and cankers carefully removed. The blighted twigs and branches are usually cut off from three inches to one foot below the last visible evidence of discolored tissue, and in severe cases, as much as two feet. Experienced men can judge rather easily the extent of the infection, by noticing the typical water soaked appearance of the diseased tissues, whereas inexperienced men are apt to overlook this important point, and not cut out at a sufficient distance below the infection.

Cankers and diseased portions of the main limbs and trunk are carefully removed wherever necessary. The diseased bark is removed and great care taken to cut out enough healthy bark tissue to completely surround the canker. With the active infection on the larger limbs, it may not be possible to trim around it, and in that case, the limb, of course, is girdled. As was previously stated, the bacteria are present in only the phloem or bark tissues of the older parts of the pear trees, so that in the main branches, the bacteria are confined to the bark.

Wounds incurred in removing the blight twigs and branches should be disinfected immediately with a solution of cyanide of mercury, in order that any bacteria adhering to the open wound might be killed. The pruning shears, knife or saws that are used should also be disinfected <u>every time</u> a new wound is made, corrosive sublimate being used for the instruments. The importance and necessity of adhering to this practice cannot be overemphasized, as a great many infections may be started by disobeying the recommendation. Many other disinfectants have been tested out but none have been found as effective as cyanide of mercury and corrosive sublimate, when used in the correct proportions. The accepted strength of both cyanide of mercury and corrosive sublimate (bichloride of mercury), is 1 to 500 parts water. White tablets are preferable to the pink tablets of cyanide of mercury on account of the fact that they dissolve much more rapidly and more thoroughly. The two disinfectants are commonly put in the same container, and both chemicals applied to the wounds or instruments, thus elimining considerable work.

Experiments by Reimer of the Southern Oregon Experiment Station indicate that corrosive sublimate is a very powerful disinfectant under certain conditions. However, its value is impaired by certain conditions, as the presence of organic matter, especially albumins, causes it to form insert combinations which destroy the value of the poison. Therefore, it cannot be used on naked wounds of the pear tree with any degree of success.

Reimer has found that cyanide of mercury cannot be used with any degree of certainty as a disinfectant on metal tools. Why the cyanide should not be effective is a question, but it is supposed that a chemical compound is formed with the iron in the tools. Research data has failed to verify the supposition, however.

The present method of controlling blight is unsatisfactory and expensive at the best. The disease may spread very rapidly and cause a great deal of damage before it can be stopped in an indifidual orchard. If an adjoining orchard happens to be seriously infected and the owner refuses to cut out the blight, there may be a constant dissemination of bacteria to all of the nearby orchards. The problem of control is a community affair, in the larger sense of the word, and the efficiency of control depends largely upon the spirit of co-operation pervading the locality. Fortunately, however, there are at least two avenues of control remaining, which, in the opinion of men who have studied the subject, bear investigating. The first method is that of artificial immunity and the second is that of natural immunity.

The problem of artificial immunity has only been slightly investigated and little information is to be had on the subject. Artificial immunity is that form of immunity gained by inoculation with a vaccine. Mr. C. C. Cate, County Pathologist, of Jackson County, Oregon, has been experimenting with a vaccine composed of dead blight germs. He has been running experiments the last three summers at the Southern Oregon Experiment Station. He has chosen the tender growing tips of a Bartlett three year old tree for the experiment, inoculating the tips with live bacilli and then supplying the vaccine four or five inches below. His results have not been of a conclusive nature as yet, but give promise of value if carried further.

The problem of natural immunity opens up unlimited fields of research. It is a commonly known fact in pathology that certain organisms are more resistant to disease and will thrive under conditions inimical to other organisms of the same variety or species. Pears are no exception to the phenomena and already we know that certain varieties of Pyrus communis, the European pear, and many species of the oriental pears are resistant to blight.

Mr. F. C. Reimer, of the Southern Oregon Experiment Station, has been engaged in testing the relative immunity of different pears for seven years. He has undoubtedly succeeded in gathering the largest collection of pears ever collected in one place, having over one thousand varieties and species of European and Oriental pears at the station. The facilities for carrying on a resistance test are unexcelled as hundreds of varieties of Pyrus communis and hundreds of forms of Oriental pears are growing vigorously.

Mr. Reimer has made two trips to the Orient in company with the late Frank N. Meyers, Plant Explorer of the U.S.Department of Agriculture, for the purpose of finding new species of pears. The first trip was made in 1917 into the region of Northern China and Manchuria, and he brought back many new forms of Pyrus. The second trip was made in 1919, into theregion about 600 miles south of Peking. He brought back distinct specimens of P. ussuriensis, P. calleryana, P. phaeocarpa, P. serrulata, P. betulaefolia, P. bretschnederi, P. calleryana, var. Faurei, and many other types which may prove to be new specimens. He also succeeded in collecting many specimens of the edible varieties of Japanese and Chinese pears.

The method used by Reimer in determining immunity of the many different varieties and species deserves mention at this time. Pure cultures of Bacillus amylovorus were isolated from blighting twigs and cankers by the petri dish method. Colonies from the petri dishes were then transferred to beef agar slants and from these slants beef bouillon cultures were prepared for field work. Inoculations were made from these cultures into the desired parts of the trees. A platinum hook was used to transfer a drop of the culture to the place on the shoot or limb where the inoculation was to be made and then the bark beneath the drop was pricked with a needle. The relative resistance of the varieties was then determined after hundreds of inoculations had been made.

Inoculations were made in the tender growing tips and in the trunks. In the highly resistant form of the pear, the disease would usually stop after having killed the growing shoot for a distance of from six to eighteen inches, while in the less resistant forms the whole tree would often be killed. Inoculations in the trunk of the resistant forms, result often in no infection at all or small cankers, depending upon the age of the tree. One inoculation was generally made on each growing shoot and five on the trunk.

Speaking of the results accomplished up-to-date, Reimer said that Pyrus ussuriensis, or 21880 B.P.I., was found to be totally immune to the disease. He made 210 inoculations in 1916, 105 of this number were on the tips of growing shoots, 85 on branches less than one year old, and 20 on the trunk of a two year old tree. Not a single infection resulted from these inoculations. On the other hand, inoculations were made on the check t trees of our common varieties at the same time and from the same lot of bacteria, and these all blighted vigorously, thus the thoroughness of the testing can hardly be doubted.

Marked variation in the degree of resistance of the different varieties of the European pear or Pyrus communis exists. The relative immunity of some of the more common varieties as determined by Reimer, in the order of their immunity is as follows:

1. Surprise
2. Orel 15
3. Warner
4. Birkett.
5. Krull
6. Fluke
7. Anjou
8. Lucy Duke
9. Bosc
10. Comice
11. Bartlett
12. Forelle
13. Santa Clause
14. Howell

The hybrid varieties of Pyrus communis and Pyrus serotina, the Japanese sand pear, are notably resistant to blight and rank up well with the Warner and Birkett given in the above list. The two most common hybrid varieties are the Kieffer and the Le Conte.

Resistant species of Pyrus are confined largely to the Orientals. The following list represents the species that Reimer has tested, but the relative immunity has been determined only in the first four species:

1. Pyrus ussuriensis, or 21880 B.P.I.
2. Pyrus ovoidea
3. Pyrus variolosa
4. Pyrus calleryana
5. Pyrus sinensis--forms
6. No. 456, B.P.I.
7. Pyrus michauxii
8. Pyrus elaeagrifolia
9. Pyrus malifolia
10. Pyrus canescens
11. Pyrus fascicularis
12. Pyrus amygdalisformis
13. Pyrus pashia
14. Pyrus balansae
15. Pyrus nivalis
16. Pyrus salicifolia
17. Pyrus cotinfolia
18. Pyrus longipes
19. Pyrus siniaca
20. Pyrus bretschnederi
21. Pyrus phaeocarpa
22. Pyrus betulaefolia.

One of the most promising lines of work and one which offers the most immediate results is that of growing our commercial varieties on root systems and trunks which are resistant to blight. The French seedling, on which most of the older orchards were budded or grafted, is very susceptible to blight, in fact it is often more susceptible than some of the common commercial varieties and is responsible for the large percentage of mortality attending well developed infections on trunks and roots. Therefore, this French stock Pyrus communis, should be rapidly discarded and some stock more resistant used. Pyrus serotina is being recommended for stock purposes, as it is more resistant than the French seedling. Other species of Oriental pears will undoubtedly be found superior to the Japanese Sand Pear (Pyrus serotina), for stock purposes, and Reimer is conducting extensive experiments at the present time, with that point in mind. Of course, the question of congeniality comes in, but it is expected that the relative ease with which the Oriental and European species will unite will be determined by a large number of buds and grafts which will be made in the near future. Observations covering a period of three years indicate that Pyrus serotina makes a fair union with the European pears, although not as strong and firm as between the various varieties of communis.

It has been found practicable to grow blight resistant varieties of European pears on the Japanese seedling, utilizing them for the main frame work of the tree. The varieties are grown on the Japanese seedling stock for two or three years and then grafted over to the commercial varieties, such as the Bosc, Bartlett, Anjou. This operation obviously increases the cost of the individual tree, but the added expense is negligible when compared to the greatly increased protection given. The varieties commonly used as stock for top-working are the Surprise, Birkett, Krull, Fluke and Orel 15, all of which belong to Pyrus communis. The Kieffer was formerly recommended for top-working but the unions have practically all been weak, ill shaped, or have not been sufficiently strong to prevent the scion from breaking off. The above named varieties can be obtained from practically any reputable nursery on the Pacific Coast.

Blight resistant types and varieties can undoubtedly be produced by breeding. For example, by crossing with such high quality varieties as the Bosc or Anjou, with such blight resisting varieties as Surprise, Orel 15, Birkett, or other known varieties and then growing thousands of seedlings, it will be possible to originate a variety which will possess high quality as well as blight resistance. Many other varieties of fruit have been originated in the same manner and it is only reasonable to presume that valuable varieties of pears can be originated in that way. It should not be supposed, however, that high quality and blight susceptibility are correlated, as the Seckel, a pear of very high quality, is much more resistant than most of the low quality varieties. Very little, if any, work has been done on this problem, but it is an exceptionally fertile field of endeavor.

Description of varieties and Species.

A brief description and history of some of the better known varieties and species of Pyrus will be of interest. This description is by no means complete but some of the main points are brought out.

Pyrus ussuriensis. Maxim.

The species is native of northern China, Manchuria, and eastern Siberia where it is widely disseminated. It withstands lower temperatures than any other known pear species and for that reason will be largely used in the colder regions of the United States, largely for stock purposes. In its native habitat the tree often attains a height of eighty feet and a diameter of three feet. Many of the forms and varieties of Pyrus ussuriensis have proved totally immune to blight. The Chinese people have several edible varieties of the Ussury pear, as it is commonly called.

Pyrus calleryana. Decne.

This species is native of Central and southern China. It bears a small, brownish fruit, with a deciduous calyx. The leaves are of medium size, very glossy and the margins possess short, round, or dentate teeth. The tree is a clean, vigorous, upright grower with very smooth bark. The form from southern China is not as resistant as the northern form, blighting in two and three year old wood. Only the tender shoot of the northern form blight. Pyrus calleryana is one of the most suitable Oriental pears yet found for stock purposes, and the union is strong and smooth, and commercial varieties of European pears grow vigorously when grafted or budded on to it.

Pyrus ovoidea. Rehder (Syn. Pyrus simonii)

This species ranks next to Pyrus ussuriensis in blight resistance. The tender growing shoots seldom blight more than eight inches when inoculated in the tips. The disease has always failed to develop in trunks of trees more than one year old. A promising tree for stock purposes, but not as good a Pyrus calleryana, because the unions are not as good. Trees of the species are vigorous growers and produce medium sized fruit, egg shaped and with a persistant calyx. It is native to northern China.

Pyrus variolosa. (Syn. Pyrus pashia)

The species is very resistant, ranking next to Pyrus ovoidea. Blight infections seldom extend more than fifteen inches back from the growing tips and trunk inoculations on one year old trees sometimes girdle and kill the trees. Inoculations on two year old trees rarely form a canker more than two square inches in extent. The trees grow vigorously. Produced a medium sized pear sized fruit, with a persistant calyx. The species form a fair union when grafted or budded to the European pears.

Pyrus Communis

All of the commercial variety of pears have originated from this so called "French Seedling" The resistant to blight varies greatly with the different varieties, ranging from high susceptibility to relative immunity. The common commercial varieties are notably susceptible to blight, although varying. Native of Southweatern Europe. Strong, upright grower, attaining height of seventy feet frequently. Leaves mostly oblong ovate with prominent point, hard in texture and light green, serrature small and much appressed and obtuse. Calyx is persistant, rarely deciduous, stamens fifteen or twenty.

The Surprise is highly resistant variety of the species. The parentage is not known except that it was originally sent to the Missouri Experiment Station from the Stark Brothers' Nursery, Louisiana, Missouri, about twenty years ago. The tender tips will blight from two to six inches while the one year old wood will not blight to any extent. The two year old wood has never developed any infection. The tree is a strong upright grower and will prove of great value for stock purposes.

The Orel 15 was introduced from Russia by the late Professor J. L. Budd, of the Iowa Agricultural College, Ames, Iowa, about 1880. The tender growing tips will blight for a distance of four or five inches but no infection has developed on the one or two year old wood. The tree is a strong upright grower, excellent for stock purposes.

The Douglas is a seedling of the Kieffer and the Angouleme, originating on the farm of O. H. Ayer, in Douglas County, Kansas. The tender growing tips blight for a distance of six inches but the one and two year old wood never becomes infected. The value for stock purposes has not been established, but experiments are being conducted with it.

The Warner originated on the farm of Dr. Boor, Henry County, Indiana, in 1832. It has shown a high degree of resistance, the tender tips blighting only a short distance while the one year old wood has not blighted. The Warner is valuable for stock purposes.

The Birkett originated near Peoria, Illinois, about one hundred years ago and appears to be identical with the variety known as the "Sudduth". The tender growing tips blight seriously, but the one and two year old wood seldom blights. However, it is not as resistant as the preceding varieties and is not as heartily recommended for stock purposes.

SUMMARY

The following points have been brought out in this brief discussion of Bacillus amylovorus and represents the latest information that the writer has been able to obtain.

History:

1. Pear blight was known as early as 1794.
2. Bacillus amylovorus followed two well defined routes in its spread to the Pacific Coast.
3. Professor T. J. Burrill of the University of Illinois discovered the true nature of pear blight in 1879.

Characteristics:

1. Pear blight attacks every tree and shrub of the pome fruit family.
2. The organism has distinct properties when grown on culture media.

3. The disease is easily recognized on the pear trees, either as blossom blight, body blight, or as cankers.
4. Certain temperature and soil conditions favor the spread of pear blight.

Preventive and Remedial Measure:

1. Insects are the most common carriers of pear blight and should be controlled as much as possible.
2. Blighted twigs, spurs and branches, should be cut out at least once a week.
3. Every wound should be disinfected with solutions of cyanide of mercury, 1-500, and a solution of corrosive sublimate,(bi chloride of mercury), 1-500 parts water.
4. Knives, saws, pruning instruments of any sort should be disinfected <u>every time</u> a new wound is made.
5. Native pomaceous fruits should be removed for a radius of at least one-half mile.
6. Water sprouts should be kept closely rubbed off.

7. The growing of blight resistant varieties of commercial pears offers an opportunity of solving the question of control.
8. The ravages of pear blight can be materially reduced by growing the commercial varieties on root systems and trunks resistant to blight.
9. A description of the more resistant forms of Pyrus communis and other species of Pyrus is given.

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