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The Use of Fertilizers for Washington Soils

AND

Second Annual Report of the State Advisory Council on Soils and Soil Fertility

Extension Service, State College of Washington

INTRODUCTION

The purpose of this bulletin is to furnish the best basic information now available on soil fertilization and the properties and uses of fertilizers to the farmers of Washington and to aid in developing a sound program of fertility maintenance and soil conservation. The suggestions and explanations (pages 1 to 9 inclusive) have been prepared by S. C. Vandecaveye and L. C. Wheeting of the Soils Section, Division of Agronomy, and E. L. Overholser and F. L. Overley of the Division of Horticulture, of the Agricultural Experiment Station, and Leonard Hegnauer of the Extension Service, State College of Washington. Pages 9 to 20 contain the revised 1933 fertilizer recommendations for Washington soils, as approved by the State Advisory Council on Soils and Soil Fertility.

PRINCIPLES OF SOIL FERTILIZATION

Economic returns from commercial fertilizers and farm manures are most easily obtained from soils that are naturally fairly productive. Those soils that are naturally unproductive because of combinations of plant food deficiencies, inadequate moisture holding capacity, or poor physical make-up, cannot be expected to give profitable returns from applications of moderate quantities of fertilizers, and, therefore, the accepted principles and recommendations are not applicable to soils in this class. In addition to soil conditions, satisfactory returns from commercial fertilizers depend upon many factors such as kind, amount, time and method of application, cultural practices, and others.

The use of commercial fertilizers for general field crops should not have to be continuous, but rather supplementary to other well planned soil management practices. In any good system of soil management, it should be possible to grow certain crops successfully with little or no commercial fertilizers, while other crops would require larger amounts. Crop rotations, including legumes for green manure, such for example as alfalfa, clover, sweet clover, and vetch, the judicious use of farm manure supplemented with commercial fertilizers for certain crops in the rotation, constitute good soil management practice.

desirable effects of soil acidity. These materials are not in the same class with fertilizers, and should not be used as such. A list of common soil amendments is given in Table 1.

COMMERCIAL VALUE OF FERTILIZERS

The price of commercial fertilizers is based almost entirely upon the amount of soluble nitrogen (N), available phosphoric acid (P_2O_5) and soluble potash (K_2O) they contain and not upon the amount of insoluble plant nutrients or other materials. The percentage of these soluble plant nutrients must be stated on each package offered for sale at more than $10.00 per ton, according to the Washington state fertilizer law.

Ground rock phosphate is finely pulverized rock high in phosphate bearing minerals. This rock is used extensively for the manufacture of soluble phosphate fertilizers, but is sometimes sold directly as a fertilizer. Although the ground rock phosphate may contain from 20 to 35 per cent total phosphoric acid, it seldom has more than 3 to 4 per cent citrate soluble phosphoric acid. Citrate soluble phosphoric acid is the amount that can be dissolved in neutral ammonium citrate and is interpreted by law as the available phosphoric acid.

Since the commercial value of fertilizers is based almost entirely upon the amount of soluble plant nutrients therein, and since the farmer who is buying commercial fertilizer is mainly interested in soluble plant nutrients, it is logical that the fertilizer requirements of the soil should be interpreted and purchases of fertilizers made in terms of pounds of actual soluble plant nutrients rather than of pounds of fertilizers which are essentially the plant food carriers. Therefore, the fertilizer recommendations in this bulletin are based upon actual soluble nitrogen, available phosphoric acid, and soluble potash.

For the convenience of farmers, the list of common fertilizer materials on the market is given in Table 2. This table includes the names of the fertilizers, their chemical formulas, the percentages of actual plant nutrients, and the amount of the fertilizers required for one pound of actual nitrogen (N), phosphoric acid (P_2O_5), or potash (K_2O), as the case may be.

FERTILIZER COMBINATIONS

Any fertilizer combination recommended can be made up from several of the fertilizers listed in Table 2 by the simple process of multiplying the number of pounds of the actual plant nutrients recommended by the factor listed under the heading "Amount required for one pound" opposite the fertilizer selected. For example, if a recommendation calls for 20 pounds of nitrogen and 32 pounds of phosphoric acid, and it is desired to use sulfate of ammonia and superphosphate, how will these fit the recommendation? Look up sulfate of ammonia in the table and multiply 20 by the factor 5 under the heading "Amount required for one pound" opposite sulfate of ammonia, and the result will be 100 pounds of sulfate of ammonia. Next, look up superphosphate in the table and multiply 32 by the factor 6.25 under the same heading opposite superphosphate, and the result will be 200 pounds of superphosphate. Thus, to fill the requirements of the recommendation 100 pounds of sulfate of ammonia and 200 pounds of superphosphate are needed. The same plan can be followed with any fertilizer recommendation.

COMMERCIAL FERTILIZERS

Commercial fertilizers, sometimes spoken of as chemical fertilizers, are not pure plant nutrients, but carry a certain amount of one or more of the essential plant food elements in soluble form. Thus commercial fertilizers are carriers of plant nutrients which usually are combined chemically with other materials that are not necessarily useful as plant food. For instance, sulfate of ammonia carries about 20 per cent nitrogen (N), the remainder being largely sulfate (sulphur and oxygen). Superphosphate carries the equivalent of from 14 to 18 per cent phosphoric acid (P_2O_5) and the remainder is largely calcium and gypsum (land plaster). Muriate of potash carries the equivalent of about 50 per cent potash (K_2O) and the remaining part consists largely of chlorides. Other common carriers of nitrogen, phosphoric acid, and potash are listed in Table 2.

Some of the materials that are combined with the plant nutrients in commercial fertilizers may have a distinct effect upon the reaction, that is the acidity or alkalinity, of the soil when repeated applications are made. This is called the residual effect or in other words the effect caused by the accumulated residue other than plant nutrients of the fertilizers. The repeated application of sulfate of ammonia has a tendency to make the soil more acid, while that of nitrate of soda has a tendency to make the soil more alkaline. On the other hand, the residue of certain commercial fertilizers does not appreciably change the soil reaction. Superphosphate is a good example.

Certain materials known as soil amendments, such as gypsum (land plaster) and different forms of lime are often applied to the soil to improve the general soil condition rather than to add plant nutrients. For instance, gypsum (land plaster) is frequently applied to alkali soils to correct the alkali condition. Occasionally gypsum is used to supply sulphur in soils extremely deficient in sulphur. Lime is usually applied to correct the un-

Table 1. Common Soil Amendments and Their Effect on the Soil.

Material	Chemical formula of active part	Effect on the Soil
Ground Limestone	$CaCO_3$	Reduces harmful effects of soil acidity
Marl	$CaCO_3$	Reduces harmful effects of soil acidity
Sugar Factory Waste	$CaCO_3$ with $Ca(OH)_2$	Reduces harmful effects of soil acidity
Waste from Carbide Plants	$CaCO_3$ with $Ca(OH)_2$	Reduces harmful effects of soil acidity
Hydrated Lime	$Ca(OH)_2$	Reduces harmful effects of soil acidity
Quicklime	CaO	Reduces harmful effects of soil acidity
Gypsum or Land Plaster	$CaSO_4$	Aids in overcoming alkali. Adds sulphur when lacking. Does **not** reduce soil acidity.
Sulphur	S	Increases soil acidity. Adds sulphur when lacking. Aids in overcoming soil alkali.

Complete fertilizers as they are ordinarily sold indicate the percentage of nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O) in terms of formulas such as 3-7-10. This means that the fertilizer contains 3 per cent soluble nitrogen, 7 per cent available phosphoric acid, and 10 per cent soluble potash. In fertilizer formulas nitrogen is always stated first, phosphoric acid second, and potash third. If it is desired to use 500 pounds of a 3-7-10 fertilizer and it is the wish to make use of nitrate of soda, treble superphosphate, and muriate of potash to make up this fertilizer, how much of each will be required? First, calculate the amounts of nitrogen, phosphoric acid and potash in 500 pounds of the 3-7-10 fertilizer. To do this multiply each figure in the formula by 5 and this will give 15 pounds of nitrogen, 35 pounds of phosphoric acid, and 50 pounds of potash. Second, turn to Table 2, look up nitrate of soda and multiply the 15 pounds of nitrogen required by the factor 6.25 for nitrate of soda. Proceed in a similar manner by using the respective factors for treble superphosphate, and muriate of potash. This will give the pounds of each of the fertilizer carriers required. If these amounts are mixed together a total of about 275 pounds, which is slightly more than one-half of the recommended rates, is obtained. Nevertheless, this contains the same amount of plant food as 500 pounds of 3-7-10 fertilizer; consequently applications of such mixtures should be reduced to 275 pounds.

Suppose, now, that a recommendation calls for 50 pounds of nitrogen, 80 pounds of phosphoric acid, and 70 pounds of potash, and it is desired to find a complete fertilizer that will fit the recommendation. This calculation is made simple by dividing each of these quantities by 10 which will give the fertilizer formula. In this case the fertilizer formula is 5-8-7. To fit the recommendation, it is necessary to use 1000 pounds of the formula thus obtained. In this case it is 1000 pounds of a 5-8-7 fertilizer.

The advantages of interpreting soil fertility requirements in terms of actual plant nutrients are obvious.

1. It familiarizes the farmer with the plant food ingredients in commercial fertilizers, and enables him to make more intelligent use of these fertilizers.

2. It emphasizes the cost of plant nutrients rather than the cost of the fertilizers.

3. It makes possible a definite comparison of the differences in price of the plant nutrients in the various commercial fertilizers and therefore the selection of the most economical fertilizers on the market.

FARM MANURE

Farm manures are by-products on any farm where animals or fowls are kept. The composition of fresh manure varies considerably due to differences in amounts and kind of bedding used, differences in kind and age of animals, and differences in the kind of feed consumed. In addition, variations in method of handling, storing and composting manures bring about differences in the composition when finally applied to the soil. In practically all cases, however, manure contains a large percentage of moisture, a relatively large percentage of organic matter, and relatively small percentages of plant food constituents. Some of the facts about different kinds of manure are indicated in Table 2.

Table 2. Common Soluble Fertilizer Materials, Farm Manures, and Legume Hays, and Their Composition

Fertilizer Materials	Chemical Formula	Approximate % of † Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Amount required for one pound of actual N	P_2O_5	K_2O
NITROGEN CARRIERS*							
Sulfate of Ammonia (1)	$(NH_4)_2SO_4$	20			5.00		
Nitrate of Soda (2)	$NaNO_3$	16			6.25		
Nitrate of Calcium (2)	$Ca(NO_3)_2$	15			6.66		
Calcium Cyanamid (2)	$CaCN_2$	22			4.54		
Calurea (2)	$Ca(NO_3)_2 + (NH_2)_2CO$	34			2.94		
Urea	$(NH_2)_2CO$	46			2.17		
Leuna Salpeter	$NH_4NO_3 + (NH_4)_2SO_4$	26			3.85		
PHOSPHORUS CARRIERS							
Superphosphate	$CaH_4(PO_4)_2 + CaSO_4$		16			6.25	
Treble Superphosphate	$CaH_4(PO_4)_2 + H_3PO_4$		45			2.22	
Bone Meal (Steamed)	$Ca_3(PO_4)_2$		16			6.25	
Ground Rock Phosphate	$3Ca_3(PO_4)_2CaF_2$		4			25.00	
POTASH CARRIERS							
Muriate of Potash	KCl			50			2.00
Sulfate of Potash	K_2SO_4			50			2.00
American (Trona) Potash	KCl			60			1.66
NITROGEN AND PHOSPHORUS CARRIERS							
Ammonium Phosphate	$NH_4H_2PO_4$	11	48		9.09	2.08	
Ammonium Phosphate	$(NH_4)_2H\ PO_4$	16	20		6.25	5.00	
NITROGEN, PHOSPHOURS AND POTASH CARRIERS							
Nitrate Phosphate Potash		15	30	15	6.66	3.33	6.66
Ammonia Phosphate Potash		12	24	12	8.33	4.17	8.33
FARM MANURES							
Farm Manure		0.50	0.25	0.50	200	400	200
Cow Manure		0.57	0.15	0.49	175	625	204
Horse Manure		0.66	0.23	0.60	151	435	166
Pig Manure		0.49	0.33	0.46	204	303	217
Sheep manure		0.80	0.34	0.89	125	294	112
Dry Sheep Manure (droppings)		2.15	1.83	1.65	47	54	61
Poultry Manure (30% litter)		1.00	0.90	0.51	100	111	196
Poultry Manure (droppings)		1.30	1.17	0.48	77	85	208
LEGUME HAYS							
Alfalfa		2.45	0.50	2.10	41	200	48
Sweet Clover		2.00	0.55	1.85	50	182	54
Clover		2.10	0.50	2.00	48	200	50

* Tankage, dried blood, and fish meal are organic forms of nitrogen carriers of variable composition and should be bought only on analysis.

† These percentages refer to soluble and available forms in commercial fertilizers.

(1) The residual effect on the soil is distinctly acid.

(2) The residual effect on the soil is distinctly alkaline.

basis upon which the accepted fertilizer recommendations for orchards were formulated.

1. **Firmness of Flesh as Measured by Pressure Tester:** (a) Fruits from plots receiving nitrogen either alone or in combination with other elements tend to be larger in size and lower in red color development. Therefore, since large sized and poorly colored fruits are softer in texture, added nitrogen tends to result in less firm apples.

   (b) With additional years' data pertaining to the Winesap there appears also to be a tendency, even with fruits of the same size and color, for apples from plots receiving nitrogen, either alone or in combination to be slightly less firm at harvest time than fruit from the untreated plots.

   (c) After three to five months' storage at 32° F., however, the differences in firmness of flesh as influenced by the fertilizer treatment are less marked and less consistent.

   (d) Seasonal environmental conditions exert a greater influence upon firmness of flesh than do the fertilizer treatments.

2. **Jonathan Breakdown:** Large size fruit is more subject to Jonathan breakdown than is fruit of smaller size. Furthermore, fruits on trees having a large leaf area per fruit is more susceptible to breakdown than fruit on trees having a limited leaf area per fruit. The per cent of Jonathan breakdown after three months' storage at 32° F. for different leaf areas per fruit was as follows: 10 leaves per apple, none; 20 per apple, none; 30 per apple, 6 per cent; 40 per apple, 18 per cent; 50 per apple, 60 per cent. Jonathan breakdown is found generally in apples packing 138 per box or larger. Hence, since the apples from the plots receiving nitrogen alone or in combination average larger than those from the plots not receiving nitrogen, the former tend to develop more breakdown. Thus, insofar as fertilizer applications may increase the size of fruit, and may give a relatively larger leaf area per fruit borne, the susceptibility to Jonathan breakdown may be increased.

3. **Soft Scald:** Observations to date indicate that factors such as delay in storage influence soft scald development more than do fertilizer applications. Nevertheless, fruit from plots receiving nitrogen alone or in combination after eight months' storage at 32° F. developed slightly more scald than did fruit from plots receiving no nitrogen. This statement is based on an average of results obtained with Jonathans from three orchards for a period of two years.

4. **Fruit Bud Injury:** Evidence indicates that there has been no measurable direct influence upon winter injury to buds from the application of fertilizers except as better vigor of the tree may enable it to withstand adverse conditions somewhat more satisfactorily than will weak trees.

   Given the same conditions as to nitrogen, the addition of phosphorus in the fertilizer program may tend to bring about an earlier dropping of the leaves and hasten maturity of the wood in the fall. Under similar conditions trees receiving applications of nitrogen alone tend to be the last to drop their leaves and to give evidence of attaining maturity of the wood.

It will be observed that average farm manure which consists, usually, of a mixture of the excrement from several classes of animals, together with more or less bedding, carries about 0.50 per cent nitrogen, 0.25 per cent phosphoric acid, and 0.50 per cent potash. This means that one ton of this material carries 10 pounds of nitrogen, five pounds of phosphoric acid, and 10 pounds of potash. The ratio of these plant nutrients is 2-1-2. Probably 1500 pounds of the 2000 pounds of manure is water, and the remainder is organic matter and small amounts of mineral matter. Poultry manure when dry, however, carries as much as 50 pounds of nitrogen per ton, with correspondingly high amounts of phosphoric acid and potash. This is why crops may be damaged by using large amounts of dry poultry manure. The quantities of plant nutrients present in the different kinds of manure are therefore variable, and due consideration should be taken of this when applications are made. Generally speaking, the greatest return per ton of manure will be had when comparatively small amounts are used.

It has been found that the ratio of two parts of nitrogen to one part of phosphoric acid to two parts of potash is not a well balanced fertilizer for most soils. There should be a larger amount of phosphoric acid present. Additions of commercial phosphate fertilizers to the manure or to the soil when the manure is spread result in a better balanced mixture. This is called reinforcing or supplementing the manure. In this manner a more economical use can be made of the available supply. This procedure is recommended in many cases in this bulletin.

Farm manures also supply organic matter to the soil, with all the attendant benefits from this material.

LEGUME HAYS AND GREEN MANURES

Legume hays, like farm manures, are unbalanced fertilizer materials, but carry somewhat higher concentrations of plant food elements, as can be seen from Table 2. When hay prices are low and much of this material is available, there will undoubtedly be some benefit derived from plowing this kind of organic matter into the soil. Probably supplements of phosphate fertilizers would also be beneficial for certain crops, because by this means a better balance in plant foods will be supplied to the soil.

Green manures have an important place in all well planned soil management programs, and if legumes are plowed under some nitrogen is actually added to the soil. The amount of this nutrient added by plowing under the above-ground portion of a green manure crop corresponds closely to the amount contained in a similar harvested hay crop. It should be remembered, however, that no phosphoric acid or potash is added, because these were originally obtained from the soil by the plants, but beneficial effects are often obtained due to the fact that these nutrients are in a more available form for succeeding crops, inasmuch as they are in organic combination. Green manure crops should be made use of whenever possible.

RESPONSES OF APPLE ORCHARDS TO FERTILIZERS

The apple orchard fertilizer program is based upon responses observed from 4 to 6 years upon experimental plots of the Divisions of Horticulture and Soils of the Washington Agricultural Experiment Station. These observations, while not final, are of interest to fruit growers and are the factors that may influence intensity and amount of red color development are as follows: unfavorable growing conditions, excessively high summer temperatures, reduced sunlight through haze or cloudy weather, crowded condition of trees, insufficient or excessive pruning, inadequate irrigation, excessively vigorous vegetative growth, attacks of leaf-injuring insects, ratio of leaf area per fruit, and insufficient maturity of fruit before harvest. Under some conditions, larger size of fruit and increased total tree yield may offset possible lowered return from lessened color development, due to the application of nitrogen fertilizers.

There has been no evidence obtained that the application of either potassium fertilizers or phosphorus fertilizers improves the red color of apples. If potassium or phosphorus is applied singly or in combination, the color of the apples may be better than when nitrogen is applied, not because of the phosphorus and potassium, but because of the lack of excess nitrogen.

11. **Factors Related to Tree Growth:** Factors such as tree circumference, terminal growth (diameter and length), size and green color of individual leaves, may be benefited by the application of the element found to be a limiting factor.

12. **Water Requirements:** General observations indicate that the use of nitrogenous fertilizers may increase the tree's demand for water because of the greater leaf area. Often the cover crop growth may be so great from the application of fertilizers or without fertilization, that the water requirements of the orchard may be increased.

13. **Variety Response:** General observations and experience indicate that varieties may differ in the readiness with which they respond to the application of fertilizers. For example, the influence of fertilizers upon the factors previously discussed is more profound with the Jonathan variety than with the Winesap.

The revised 1933 fertilizer recommendations for Washington soils as approved by the Advisory Council on Soils and Soil Fertility follow:

Revised 1933 Fertilizer Recommendations for Washington Soils

The recommendations for the use of fertilizers in the State of Washington during 1933 have been arranged under three headings. These are:

I. Recommendations for Western Washington.

II. Recommendations for Eastern Washington.

III. Recommendations for Orchard Fertilization.

Fertilizer and soil management practices for the most important crops grown in these areas, and recommendations for the fertilization of apples are given in detail in the following pages.

5. **June Drop:** The variation in the amount of June drop between the trees within a plot has been as great as between plots receiving different fertilizers. Unfavorable environmental factors, including inadequate pollination, insufficient soil moisture, winter injury, cultural practices, tree load, certain spray programs, and insect attacks, exert a greater combined influence than do fertilizers upon the June drop, except where trees may be weak because of inadequate mineral plant foods. When, however, either phosphorus or potassium is used alone, the June drop has been consistently greater, even with a lesser fruit set, than that on unfertilized plots.

   The vigor of the trees, which may be influenced by fertilizer applications and particularly by nitrogen fertilizers, is a direct factor in determining the extent of the June drop, the latter often being greater with weak trees.

6. **Set of Fruit:** Nitrogen alone or in combination with phosphorus and potash has favored an increased percentage set of fruit in comparison with unfertilized plots and plots to which phosphorus or potassium alone has been applied.

7. **Thinning:** By thinning, the crop on each tree may be made nearly uniform. With trees having a heavy set, more fruit is thinned than with trees having a light set, so the ultimate crop matured may be nearly alike in amount. For example, thinnings from the trees in the plots receiving nitrogen alone or in combination with phosphorus and potassium have been much greater than the thinnings from trees in plots not receiving nitrogen, but to date the actual number of specimens harvested has not shown marked difference.

8. **Yield of Fruit per Tree:** Total yield is profoundly influenced by climate, cultural practices, size of tree, and soil type. Nevertheless, where nitrogen has been a limiting factor, the addition of nitrogen either alone or in combination with phosphorus or potassium fertilizers has generally resulted in increased yields. The other element, which with certain soils has benefited yield, is phosphorus when applied in combination with nitrogen.

9. **Size of Fruit:** Size of fruit is influenced by tree load, leaf area available, and moisture relationships, in addition to the effect of the fertilizers. It does not, therefore, necessarily follow that fertilizers will result in size increase of fruit if at the same time tree load is increased. Observations, however, indicate that nitrogen alone or in combination tends to maintain size of individual fruits notwithstanding an increased tree load as compared with unfertilized or non-nitrogen fertilized plots. The use of phosphorus or potassium singly has tended to reduce the individual size of Jonathan apples, but the use of the two in combination apparently neither favors nor opposes size increase as compared to fruit from unfertilized plots.

10. **Color of Fruit:** With normal trees nitrogen either alone or in combination tends to oppose maximum red color development, primarily by: first, delaying maturity attainment of the crop, and second, by giving more shade from increased leaf development. Certain other

2. On soils that are not giving satisfactory yields, make a spring application of a complete fertilizer equivalent to approximately 20 to 25 pounds of nitrogen, 60 to 80 pounds of phosphoric acid, and 40 to 60 pounds of potash per acre.

3. For potatoes use 50 pounds of nitrogen, 60 pounds of phosphoric acid and 80 pounds of potash per acre applied under the hills.

Pastures

Properly managed pastures that are well supplied with available plant food yield palatable, good quality feed, usually higher in mineral constituents than do plants from unfertilized pastures.

1. For intensive fertilization, select only pastures that are naturally well supplied with moisture throughout the growing season or that can be irrigated economically during the dry season and that are composed initially of good pasture grasses and clovers.

2. Divide pasture in at least two fields (three or more are better if convenient). Graze alternately or successively as the case may be, changing fields often enough to avoid over-grazing of the pastured field and to prevent over-growth of the grass in the unpastured field or fields. When stock is moved from a pastured field, cut ungrazed patches of grass, harrow droppings, and apply liquid manure if available.

Manure System for Pastures

1. When farm manure is not needed in the other fields, apply to pasture in fall or winter at the rate of 6 to 8 tons per acre. Ordinary farm manure contains about 10 pounds of nitrogen, 5 pounds of phosphoric acid and 10 pounds of potash per ton. Sheep manure and poultry litter contain larger amounts. The application recommended in this case would be equivalent to 60 to 80 pounds of nitrogen, 30 to 40 pounds of phosphoric acid and 60 to 80 pounds of potash.

2. Supplement farm manure with a fall or winter application of approximately 48 pounds of phosphoric acid per acre.

3. Top dress the pasture fields systematically with nitrogen fertilizers during the growing season, because nitrogen is required to produce the large amounts of protein in the young grass.

4. Early in the spring use 20 pounds of nitrogen per acre. It is very desirable to rotate grazing of pasture. When this rotation is practiced, use a second 20 pounds of nitrogen per acre in April, and a third in May.

5. In any case where rotation of grazing is impossible, apply early in May 40 pounds of nitrogen per acre, omitting the additional applications recommended in the preceding paragraph. This method, however, is much less desirable than the recommendations where rotation grazing is practiced.

Commercial Fertilizer System for Pastures

When farm manure is not available, substitute commercial fertilizers as follows:

Apply 15 pounds of nitrogen, 50 pounds of phosphoric acid and 50 pounds of potash per acre during the late fall or winter, followed during the spring and summer with 3 applications of 20 pounds each of nitrogen per acre.

I. FERTILIZER RECOMMENDATIONS FOR WESTERN WASHINGTON

Throughout this report whenever pounds of plant nutrients are mentioned in recommendations it is understood that these materials shall be supplied in soluble or available form.

The recommendations for pasture and general farm crops are based partly upon the results of a large number of field experiments and partly upon careful observations.

GENERAL FIELD CROPS

1. Make a suitable rotation of crops in which a legume such as clover, vetch, sweet clover, or alfalfa is grown for hay or for green manure at least every third or fourth year, if possible.

2. To reduce the labor required in combating weed growth often resulting from manure, apply available manure as much as possible on nonlegume hay meadows, such as the mixed grasses, at the rate of 6 to 8 tons per acre in fall, winter or early spring. This is ordinarily sufficient fertilization for such meadows.

Cereals

Nitrogen seems to be the plant food element that is usually most deficient for cereals on many of the western Washington mineral soils (soils other than muck and peat). Because of the relatively small cash returns from cereal crops, fertilizers should be applied sparingly.

1. On oats grown for grain, use 12 pounds of nitrogen, 30 to 40 pounds of phosphoric acid and 21 to 28 pounds of potash per acre drilled in with the seed.

2. On cereals grown for forage use 20 to 40 pounds of nitrogen, and on soils known to be deficient in available phosphorus use 30 pounds of phosphoric acid.

Alfalfa and Clovers

Phosphorus and potash are the important plant food elements for alfalfa and clovers, because these crops can secure a large part of the nitrogen they require from the air, provided they are properly inoculated.

1. On soils not giving satisfactory yields of legumes, and for new seedings on such soils, make a spring application of a complete fertilizer, equivalent to approximately 15 to 20 pounds of nitrogen, 50 to 60 pounds of phosphoric acid, and 35 to 40 pounds of potash per acre.

2. Wherever possible, prepare soils one or two years in advance of new seeding of legumes by applying such manures as are available and producing a cultivated crop or crops as a means of controlling weeds.

Root Crops and Tubers

Root crops respond best to complete fertilizers (nitrogen, phosphoric acid and potash), and are well adapted to follow legume crops or meadows.

1. Where farm manure is limited the most economical returns are obtained by applying only 6 to 8 tons per acre supplemented with 40 to 60 pounds of phosphoric acid.

3. If growth is not satisfactory, side-dress with 20 to 40 pounds of nitrogen per acre.

4. When manures are not available, use on both mineral, and muck and peat soils an early spring application of 60 to 75 pounds of nitrogen, 100 to 120 pounds of phosphoric acid and 40 to 50 pounds of potash per acre. If desirable, half of this amount may be applied at planting time and the other half as a side-dressing when the plants are abount one-third grown.

Lettuce

1. Use 75 pounds of nitrogen, 90 pounds of phosphoric acid, and 120 pounds of potash per acre on mineral soils, or 45 pounds of nitrogen, 150 pounds of phosphoric acid, and 150 pounds of potash per acre on muck and peat soils.

Cabbage, Beets and Turnips Grown for Seed

1. Use 30 pounds of nitrogen, 100 pounds of phosphoric acid, and 100 pounds of potash per acre.

Root and Seed Crops

(Table Beets, Peas, Beans, and Sweet Corn)

1. Manure applications are especially beneficial.

2. For table beets and sweet corn when manures are not available, use on both mineral and muck or peat soils an early spring application of 40 to 50 pounds of nitrogen, 100 to 120 pounds of phosphoric acid, and 60 to 70 pounds of potash per acre.

3. If growth is not satisfactory, side-dress with 30 to 40 pounds per acre of nitrogen, preferably before the plants are one-third grown.

4. On garden peas and beans use 30 pounds of nitrogen, 100 pounds of phosphoric acid, and 100 pounds of potash per acre applied in the row.

Bulbs and Bulb-like Plants

1. When manures are available, apply on mineral soils 10 to 12 tons of well rotted farm manure per acre, or half those amounts if sheep or poultry manures are used. To allow time for thorough decomposition, the manure should be applied three to four months before planting the bulbs and should be supplemented with 80 to 115 pounds of phosphoric acid. Early incorporation with the soil is important, especially if fresh strawy manures are used, and they may be applied 6 months or more in advance.

2. On muck or peat soils, use the same amount of phosphoric acid, but reduce the application of manure to one-half the amounts suggested in the preceding paragraph and add 35 to 50 pounds of potash.

3. When manures are not available, use from 30 to 45 pounds of nitrogen, 100 to 150 pounds of phosphoric acid, and 70 to 100 pounds of potash per acre.

Tree Fruits

No experimental data on fertilizers for tree fruits in western Washington are available and no definite recommendations can be made at this time. Until such data are obtained, the tree fruit growers are referred to the recommendations made on page 18 under "Fertilizer Recommendations for Orchards."

SMALL FRUIT, TRUCK CROPS, BULBS AND TREE FRUITS

Although farm manures give good results on all soils, they can be used most advantageously on mineral soils (soils other than muck and peat). Therefore, when only limited quantities of manures are available, they should be used preferably on mineral soils, or in reduced amounts if used on muck and peat soils.

Raspberries and Blackberries

Raspberries and blackberries are perennial crops requiring fertile soil and special care in order to make profitable returns. Raspberries should be planted only on well drained soils that are in good physical condition.

1. With raspberries and blackberries on mineral soils (soils other than muck and peat), make a fall or winter application of 65 to 95 pounds of phosphoric acid per acre, in addition to 8 to 12 tons of farm manure, or 5 to 6 tons of green sheep manure (droppings) or fresh poultry litter, per acre.

2. With blackberries on muck or peat soils make the same phosphorus treatment, but reduce the application of manure to one-half the amounts suggested in the preceding paragraph and add about 35 to 50 pounds of potash per acre. Late winter or early spring applications are preferable.

3. When manure is not available for either mineral, muck or peat soils, make a late winter or early spring application of 20 to 35 pounds of nitrogen, 75 to 120 pounds of phosphoric acid and 50 to 75 pounds of potash per acre.

Strawberries

For new plantings of strawberries the soil should be prepared one or two years in advance of planting by making fall applications of such manures as are available, supplementing the manure with 50 to 60 pounds of phosphoric acid per acre.

1. If farm manures are used following harvest of the crop or during the fall, they may be applied at the rate of 6 to 8 tons of farm manure, or 3 to 4 tons of green sheep manure (droppings) or poultry droppings per acre, supplemented with 65 to 95 pounds of actual phosphoric acid. It is not practical to apply strawy manures on strawberry plants after setting them in the field.

2. If well rotted manures are not available, apply in late summer from 30 to 60 pounds of nitrogen, 40 to 80 pounds of phosphoric acid, and 30 to 60 pounds of potash per acre. For spring fertilization, use one-half of the recommended amount of nitrogen.

Leafy Vegetables

(Cabbage, Asparagus, Celery and Rhubarb.)

1. When manures are available apply on mineral soils in fall or before planting time, 12 to 15 tons of farm manure, or 6 to 8 tons of green sheep manure (droppings) or poultry litter per acre, supplemented with 90 to 125 pounds of phosphoric acid.

2. On muck or peat soils make the same application of phosphoric acid but reduce the application of manure to one-half the amounts suggested in the preceding paragraph, and add from 35 to 50 pounds of potash.

Manure System for Pastures

1. Grass pastures should receive manure, when available at from 6 to 8 tons per acre, applied in fall or winter.

2. Supplement farm manure with a fall or winter application of approximately 50 pounds of phosphoric acid per acre.

3. Top-dress the pasture systematically with nitrogen fertilizers during the growing season to build protein in the young grass.

4. Early in the spring, use 20 pounds of nitrogen per acre. If the rotation system of grazing is practiced, apply a second 20 pounds in mid-spring, and a third late in May or early June.

5. If rotation grazing is impossible, apply 40 pounds of nitrogen per acre in May, omitting the additional applications recommended in the preceding paragraph. This method, however, is less desirable than the recommendations where rotation grazing is practiced.

Commercial Fertilizer System for Pastures

When manure is not available, substitute commercial fertilizers as follows:

1. For low yielding grass pastures make a fall or winter application of 15 pounds of nitrogen, 50 pounds of phosphoric acid, and 35 pounds of potash per acre, and in addition top-dress with 20-pound applications of nitrogen two or three times during the growing season.

2. In the case of legume pastures, on soils known to be deficient in phosphorus make a fall or winter application of 50 pounds of phosphoric acid per acre.

TRUCK CROPS AND SMALL FRUITS IN IRRIGATED DISTRICTS

The suggestions for fertilization of these crops on soils in the irrigated valleys are based partly on experimental data available from plots carried on during the last ten years and partly on careful field observations.

Asparagus

1. Apply in winter or early spring 10 to 12 tons of farm manure or 6 to 8 tons of sheep manure per acre. After the cutting season, add from 30 to 60 pounds of nitrogen per acre.

2. As a rule, the tops are cut in the fall and disked in to increase the organic matter content in the soil. Care must be exercised to avoid injuring the crown of the plants when fall disking is practiced. At this time broadcast 80 pounds of nitrogen per acre.

3. If available phosphorus or potash or both are known to be deficient, an application of 64 pounds of phosphoric acid or 80 pounds of potash per acre, or a combination of the two may be applied.

4. If manure is not available, use 60 pounds of nitrogen, 72 pounds of phosphoric acid, and 96 pounds of potash per acre, supplemented after the growing season with an application of 80 pounds of nitrogen per acre.

II. FERTILIZER RECOMMENDATIONS FOR EASTERN WASHINGTON

Throughout this report whenever pounds of plant nutrients are mentioned in recommendations it is understood that these materials shall be supplied in soluble or available form.

The soil management in general farming should be so conducted that a large part of the nitrogen required by the crops is obtained by growing legumes, such as alfalfa or clover, in the crop rotation system.

GENERAL FIELD CROPS IN IRRIGATED DISTRICTS

Cereals

1. When cereals are grown following a legume, no nitrogen fertilizer should be needed.

2. If the soil is very deficient in available phosphorus, use approximately 30 pounds of phosphoric acid per acre.

3. If cereals are grown following non-legume crops on the less productive soils, a light top dressing early in the spring of 20 to 40 pounds of nitrogen per acre is generally profitable.

4. For corn make the same applications as for other cereals, but increase the nitrogen application from 30 to 60 pounds per acre.

Alfalfa and Other Legumes

1. The only fertilizer that can be recommended at the present time is phosphorus. Sixty-four pounds of phosphoric acid per acre is recommended.

2. In the Ellensburg District small quantities of nitrogen in addition to phosphorus have given beneficial results.

Root Crops

Root crops, such as beets, carrots for livestock, and mangels should preferably follow a legume. Phosphate and potash are the most important nutrients that may be required under such conditions.

1. On soils that appear to be deficient in available phosphate and potash, use a combination in the spring of approximately 50 to 70 pounds of phosphoric acid and 40 to 60 pounds of potash per acre.

2. Farm manure may be substituted if available and should be applied at the rate of 6 to 8 tons per acre supplemented with about 50 pounds of phosphoric acid.

3. With either treatment make an additional top dressing of approximately 40 pounds of nitrogen per acre before the plants are one-third grown.

Pastures

Pastures should be divided into two or more fields and rotation grazing practiced, changing fields often enough to prevent over-grazing of one field and over-growth in others. Properly managed and well fertilized pastures yield feed of superior quality.

3. Phosphorus should be applied at the rate of about 80 pounds of phosphoric acid per acre in addition to the nitrogen fertilizer on soils known to be deficient in available phosphorus.

4. On soils known to be deficient in available potash, apply 64 pounds of potash per acre in addition to the other fertilizer.

Melons

1. Manure is very desirable in the production of melons, particularly cantaloupes. Use 10 to 12 tons of farm manure per acre, or 40 to 80 pounds of nitrogen per acre.

2. Where phosphorus is deficient it should be supplied at the rate of 48 to 96 pounds of phosphoric acid per acre.

Strawberries

1. A good supply of organic matter is desirable for soils to be planted to strawberries. This may be accomplished by the application of 10 to 12 tons of farm manure per acre, by plowing under a good leguminous cover crop, or by plowing up an established alfalfa or sweet clover field. On soils low in available phosphorus, apply in addition to the organic matter the equivalent of 80 pounds of phosphoric acid per acre, and on soils low in available potash, apply 96 pounds of potash per acre.

2. During the second and succeeding year, apply at the time one-half of the row is turned under following harvest, from 50 to 100 pounds of nitrogen and, if needed, from 50 to 100 pounds of phosphoric acid and 96 pounds of potash per acre.

3. In the irrigated sections nitrogenous fertilizers are applied in the late summer or early fall with resulting benefits to fruit bud formation.

DRY LAND CEREALS OF EASTERN WASHINGTON

Although much work has been done on wheat soil fertilization, from an economic viewpoint it seems undesirable to make specific recommendations at this time. The use of legume crops on hilltops for pasture, hay, or green manure crops is desirable where rainfall is sufficient and it is otherwise practicable. Light applications of a nitrogen fertilizer on hilltops may in some cases be justified.

NORTHEASTERN WASHINGTON

Only a limited amount of experimental evidence is available for the soil fertility requirements of northeastern Washington. In Pend Oreille county the best responses have been obtained with nitrogen, but in several cases nitrogen in combination with phosphorus, and complete fertilizers have resulted in additional increases in yield. Some experimental work is under way, but more experimental data are needed to make specific recommendations.

Lettuce

Lettuce may well follow early potatoes.

1. If manure has not been applied for potatoes, use 10 to 12 tons of farm manure or 6 to 8 tons of sheep manure per acre, and on the soils low in phosphorus, supplement the manure with 48 to 80 pounds of phosphoric acid. If growth is not satisfactory, side-dress with 20 to 40 pounds of nitrogen per acre, preferably before the plants are one-third grown.

2. If manure has been applied for early potatoes, use 40 to 80 pounds of nitrogen per acre at planting time. If growth is not satisfactory, side-dress with 20 to 40 pounds of nitrogen per acre, preferably before the plants are one-third grown.

Potatoes

1. Where potatoes are a part of the rotation, the use of leguminous cover crops as green manure is recommended.

2. Where erosion is not a problem it is advisable to plow under the green manure crop in the fall previous to the spring planting of potatoes.

3. When the field has not been in alfalfa or sweet clover for three or more years, if available, apply in the fall 12 tons of farm manure per acre. It is preferable to apply the manure as a top dressing to the preceding crop, and the field should be plowed in the fall.

4. On soils where alfalfa or sweet clover has just been plowed under or where adequate manure has been added, no additional nitrogen need be applied.

5. During the second year following alfalfa or manure, use 40 to 80 pounds of nitrogen per acre.

6. On soils giving low potato yields, a fertilizer supplying 50 to 75 pounds of nitrogen per acre, and where phosphorus or potash are known to be deficient, from 50 to 75 pounds of either or both should be included.

Onions

1. When the field has not been in alfalfa or sweet clover for several years, apply 12 tons of farm manure per acre.

2. On soils where alfalfa or sweet clover has just been plowed under, no additional nitrogen need be added. During the second year following alfalfa, use 40 to 80 pounds of nitrogen per acre. During the third year following alfalfa or sweet clover, use 100 to 120 pounds of nitrogen per acre.

3. If phosphorus or potash or both are known to be deficient, an application of about 64 pounds of phosphoric acid or 96 pounds of potash per acre, or a combination of the two should be applied.

Tomatoes

1. On soils where alfalfa or sweet clover has just been plowed under, no manure or nitrogen fertilizer should be required.

2. On older soils that have not been in alfalfa recently, or where fertility and organic matter have not been maintained, use preferably from 5 to 6 tons of manure per acre. If manure is not available, use 40 to 60 pounds of nitrogen per acre.

WILL EXPAND RECOMMENDATIONS NEXT YEAR

The Advisory Council on Soils and Fertility, meeting December 16, 1932, adopted the foregoing recommendations and suggestions as the best that can be made for the ensuing crop year. They are based upon the best experimental data of the experiment stations of the State College of Washington, the test plots supervised throughout the state by county agricultural agents and Smith-Hughes high school agricultural instructors in co-operation with the Soils Section of the State College, and widespread observation of the practices of successful growers.

The Council Recommends:

1. That farmers who are in doubt as to the fertility requirements of their soils consult with their county agent, or Smith-Hughes agricultural instructor, or write to the Soils Section of the Department of Agronomy at the State College of Washington, Pullman.

2. That whenever practicable, individual farmers, establish test plots on their own farms, with the assistance of the county agents, the extension service, agricultural instructors, or experiment station men, when possible, and keep accurate records to determine whether available nitrogen, phosphorus, or potassium are deficient in their soils.

ORGANIZATION AND PERSONNEL, STATE ADVISORY COUNCIL ON SOILS AND SOIL FERTILITY

Upon the call of the Washington State Chamber of Commerce, a meeting of representatives of the State College of Washington, the State Department of Agriculture, State Department of Vocational Agricultural Education, farm organizations, fertilizer companies, State Bankers Association, agricultural divisions of the railroads, and the agricultural press, was held in Seattle, December 18, 1931, for the purpose of considering ways and means of developing a long-time program in soil conservation and soil fertility for the state of Washington. Among actions taken, was authorization of the appointment of an Advisory Council on Soils and Soil Fertility.

This Council made fertilizer recommendations for Washington for 1932 and on December 16, 1932, in a meeting at Yakima, Washington, on the basis of additional information revised the recommendations and brought them up to date.

The members of the Council serving at the time the foregoing recommendations were adopted were as follows:

Balmer, F. E., Director, Extension Service, Wash. State College, Pullman.
Bonnel, J. J., J. J. Bonnel, Nurseries, 2600 E Galer, Seattle.
Bradley, J. W., Washington Bankers Assn. ,Old National Bank, Spokane.
Cannon, Geo. J., Agr. Dev. Agt. Great Northern Railway, Spokane.
Clemens, F. W., Asst. to Mag. Edr. The Washington Farmer, Spokane.
Clapp, William, Swift and Company, Portland.
Durdle, E. C., County Agent, Benton County, Kennewick.
Dwinnell, D. W., Washington Farm Bureau Federation, Outlook.
Gille, H. J., (Chairman Ex-Officio) Chairman, Land Utlan. Comm., WSCC, Director, Agr'l. Industrial Development, Puget S. P. and L. Co., Seattle.
Guitteau, J. A., Director, Vocational Agricl. Dept. of Public Instruction, Olympia.
Goss, A. S., Master, Washington State Grange, Kulien Bldg., Seattle.
Gilbert, Elon, Fruit Interests, Yakima.
Hobson, Henry R., Washington Agricultural Council, Wenatchee.
Johnson, E. C., Dean, Coll. of Agric. and Director, Agric. Exp. Sta., W.S.C. Pullman.

III. FERTILIZER RECOMMENDATIONS FOR ORCHARDS

Throughout this report whenever pounds of plant nutrients are mentioned in recommendations it is understood that these materials shall be supplied in soluble or available form.

Compared with more quickly maturing crops, the growing of the orchard crop is an enterprise which extends over a long period of time. It is a matter of considerable importance to so manage the orchard that the trees may be kept in a vigorous condition, producing a strong system of branches ample in extent and suitably spaced to carry good crops of fruit.

Along with suitable training and judicious pruning, fruit trees must be properly nourished for greater vigor and for maintaining optimum yields of better quality fruit.

Experimental and Observational Data

In the fertilizer program nitrogen is likely to be the first limiting factor with fruit trees on irrigated soils of Washington east of the Cascades. Under average conditions, sufficient nitrogen may be supplied by several means.

1. Farm manure, if available, can be employed at the rate of 5 to 8 tons per acre or its equivalent in leguminous hay (1 to 2 tons). These materials should preferably be applied to the ground any time from late fall to early spring. If the manure is not well composted and has a high straw content, its decomposition will be aided by the addition of 20 to 30 pounds of nitrogen per acre.

2. Leguminous cover crops such as alfalfa or sweet clover may be grown in the orchard when available water supply and light conditions permit a good stand to be maintained. The active organic matter introduced by either manure or leguminous cover crops is beneficial in addition to the nitrogen added thereby.

3. Unless a heavy cover crop growth can be maintained, the annual addition of about one-half pound of nitrogen per tree may be justified. On trees lacking in vigor or with varieties where color and early maturity are not factors in obtaining fruit of a profitable grade and where tonnage and size of individual specimens are primarily desired, the nitrogen annually applied may be increased to one pound or more per tree. A suitable time to apply this nitrogen either as a supplement to the manure or as a fertilizer without manure is during the dormant season, preferably on a snowfall, if the ground is relatively level and not frozen.

4. Experimental data are as yet inadequate to justify specific recommendations as to phosphate and potash. In some orchards, phosphorus is of indirect benefit to the trees through the influence on the growth of the leguminous cover crop.

LIME IN SOIL MANAGEMENT PROGRAM

The place of lime in the general soil management program is a subject worthy of study and observation. A considerable amount of experimental work is under way and in contemplation but data so far are inadequate to warrant the making of specific recommendations.

Kalkus, J. W., Supt. Western Washington Experiment Station, Puyallup.
Knutson, Senator, W. J., Dairy Interests, Burlington.
Hegnauer, Leonard, Extension Agronomist, Washington State College, Pullman.
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Orton, U. N., Puget Sound Bulb Exchange, Sumner.
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Stuart, Geo. B., Pres., Western Wash. Horticultural Assn., Monroe.
Taylor, M. C., Magnolia Fertilizer Co., West 47th. and 14th. N. W., Seattle.
Vandecaveye, S. C., Head, Soils Section, Dept. of Agronomy, College of Agric. and Agricultural Exp. Station, Washington State College, Pullman.
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Hill, Thomas B., (Secretary) Mgr. Wash. State Chamber of Commerce, Seattle.

The Revised 1933 Fertilizer Recommendations and the introductory statement on "The Use of Fertilizers for Washington Soils" are being published by the Agricultural Extension Service of the State College of Washington as helpful information to the growers and the agencies serving them relative to soil fertility problems.

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