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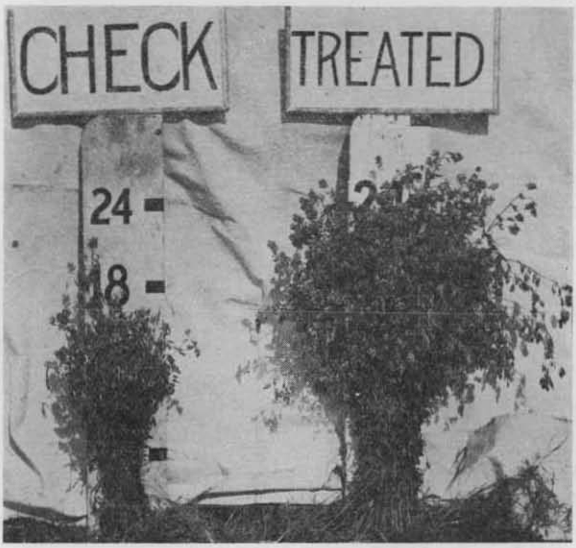
E. J. IDDINGS
Director

# Fertilizer Suggestions For Idaho Farmers

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## SOILS SECTION

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## Summary

Fertilizer trials have shown (1) that soils in many parts of Idaho have become depleted in available plant food and (2) crops growing thereon are responding very profitably to the application of fertilizers, including farm manures and green manures.

The use of commercial fertilizer should be considered as supplemental to the practice of a good rotation, the incorporation of large quantities of organic matter in the form of farm manure, crop residues and green manures, and the maintenance of good tilth.

Each of the plant foods discussed in this bulletin performs a specific function in the plant. The functions of nitrogen, phosphate, potash, sulfur, iron, boron, magnesium, and manganese are discussed. The effect on the plant of insufficient plant food as well as the presence of excessive amounts in the soil also is discussed. Information regarding the functions of plant foods not discussed in this bulletin can be obtained by writing to the Extension Soils Specialist.

The need for fertilizer applications can be determined by studying the plant symptoms, analyzing the soil for nutrient deficiencies, conducting soil pot tests, or by treating small strips in the field with various fertilizers.

The value of farm manure applications to the soils in Idaho, with the exception of areas where moisture is the limiting factor, has long been recognized.

The application of phosphate fertilizers has been found profitable on the majority of the soils in the Snake River plain area. The response has not been uniform in the southwestern Idaho area. Response from phosphate has been obtained on peat and muck soils, and certain mineral soils in northern Idaho which contain an unbalanced plant food content.

The application of nitrogenous fertilizers is profitable where insufficient farm manures and green manure crops are available. The application of small amounts of nitrogen together with phosphate has been found profitable wherever the soils respond to phosphate applications and where only moderate amounts of manure are applied.

The starting of new stands of forage legumes in northern cutover areas is facilitated by the application of small amounts of nitrogenous fertilizers.

The application of potash fertilizers has proven profitable on certain truck crops. Only in a few areas has its use been found profitable on forage legumes. Peat and muck soils respond to high potash-containing complete fertilizers. When nitrogen and potash fertilizers are used, they are usually applied in combination with phosphate.

Forage legumes in northern Idaho respond very well to the application of sulfur-containing fertilizers such as gypsum. Marked

manure crops. The amounts of the three most important plant foods hauled off the farm in forms of various crops are presented in Table 1. The difference in the amounts of plant food removed from the farm when crops are sold directly as compared with marketing through livestock fed on the farm can be calculated from the data presented in this table. It is more difficult to maintain a high state of soil fertility when all forage and grain products are sold directly from the farm in place of disposing of them through animal products. This latter system of farming permits the return of large quantities of plant food to the land in the form of farm manure.

The yields of crops can be maintained and increased in many instances under both livestock and non-livestock systems of farming by the utilization of field wastes and green manure crops, both legume and non-legume, and the judicious use of commercial fertilizers.

**TABLE 1.—Chemical Analyses of Plants and Animals Per 1000 Pounds**[1]

| Crop | Nitrogen Lbs. | Phosphoric Acid—Lbs. | Potash Lbs. |
|---|---|---|---|
| Alfalfa hay | 23.80 | 5.40 | 22.30 |
| Wheat grain | 19.80 | 8.60 | 5.30 |
| Oat grain | 19.80 | 8.10 | 5.60 |
| Barley grain | 18.40 | 8.50 | 7.40 |
| Corn grain | 15.90 | 6.80 | 3.90 |
| Potato tubers | 3.50 | 1.20 | 5.30 |
| Sugar beets | 2.60 | 0.80 | 3.20 |
| Whole milk | 5.60 | 2.00 | 1.70 |
| Fat steer—(weighing 1200 pounds) | 25.60 | 18.39 | 2.05 |
| Fat sheep | 20.80 | 10.40 | 1.48 |
| Fat hog | 12.40 | 6.54 | 1.38 |
| Asparagus | 3.50 | 1.00 | 2.50 |
| Beans | 2.50 | 0.80 | 3.00 |
| Cabbage | 3.00 | 1.00 | 4.00 |
| Cauliflower | 2.80 | 1.00 | 3.33 |
| Celery | 2.50 | 2.00 | 7.50 |
| Sweet corn | 4.50 | 2.00 | 3.00 |
| Lettuce | 2.50 | 0.80 | 4.50 |
| Onions[2] | 2.30 | 0.90 | 2.20 |
| Muskmelon | 2.20 | 0.80 | 4.00 |
| Peas | 11.50 | 3.00 | 4.50 |
| Spinach | 5.00 | 1.50 | 2.50 |
| Tomatoes[2] | 2.00 | 0.70 | 3.50 |
| Watermelons | 1.70 | 0.60 | 3.00 |

[1]Henry, W. A., and Morrison, F. B., *Feeds and Feeding*. Ed. 2, 770 P, Illus. Madison, Wis., 1923.
[2]Van Slyke, Lucius, *Fertilizers and Crop Production*. p. 493, Illus. New York, 1937.

Plants require relatively large quantities of carbon, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulfur, calcium, and magnesium for optimum development. Relatively small amounts of secondary elements such as iron, manganese, zinc, boron, copper, and others also are necessary for growth. Very little is known at present regarding the value of these minor elements under Idaho conditions. Carbon and oxygen are obtained from the air as gases, while the other nutrient elements are obtained from the solution in the soil. However, supplies of nitrogen are obtained by legume plants from the soil air by means of bacteria in the nodules, and the plants in turn supply energy-containing foods to the bacteria. Only four or five of these plant foods are apt to be limiting factors in plant development under most conditions. In Idaho these are phosphorus, sulfur, nitrogen, potash, and iron. In most instances, the lack of sufficient nitrogen can be met by the growing and the plowing under of top growth of green legume crops and by the proper utilization of barnyard manure. The above-mentioned mineral elements and others are present in the soil in readily available (soluble), very slowly available, and non-available forms. Plants can use only the readily available form.

Contrary to the belief of many people, it is not necessary to continue every year the application of commercial fertilizers, with the possible exceptions of readily soluble nitrogenous fertilizers to special crops. However, many farmers find it profitable to continue their use intermittently, probably applying them only to the legume crop or to some other crop in the rotation. The profitableness of this continued use is due to the harvesting of larger crops than otherwise would be possible.

Commercial fertilizers should be purchased on the basis of plant food content and not price. The price of fertilizers should be compared on their unit of plant food content cost basis. A unit is 20 pounds of available plant food per ton or 1 per cent. High analysis fertilizers usually cost less per unit of plant food than do low analysis products, because of the lower freight, storage, handling, and filler[3] cost.

**Soil Testing and Field Testing for Plant Food Requirements**

There are various ways of determining whether a soil is deficient in certain plant foods. Common methods are chemical soil analysis; analysis of the plant tissue; studying the symptoms of deficiency in the plant (discussed under each plant nutrient); growing of plants in pots containing small quantities of soil, each of which has received a different treatment, and conducting field trials in which each plat is treated differently.

Indications of certain plant food deficiencies in soils can be determined by means of soil analysis. Results of these analyses need to be verified by means of field trials in most instances before treating the entire field.

The University of Idaho maintains a free soil-testing service insofar as funds permit. Analyses are made of soil samples for acidity or alkalinity, limestone content, total nitrogen, available phosphate, available potash, total soluble salts, and any other analysis which might be necessary. In taking soil samples, instructions given on inside of back cover should be followed.

If the soil is wet, let it air dry before mailing. Address samples to the Extension Soils Specialist, University of Idaho, Moscow. Forms for recording field history may be secured from the county agent in your county or by writing to the Extension Soils Specialist.

[3]See meaning of "filler" under definition of terms in the appendix.

In most instances, however, the result of any soil analysis should be considered only as indicative of the deficiency condition in the soil, and field trials should then be conducted in which the deficient element is applied to verify the findings. (See indications of deficiency in the plant under "General Information Regarding Various Plant Food Elements and the Use of Farm Manure.")

In carrying on field trials only small plats need be treated. One-twentieth acre plats (20' x 109') are sufficiently large in forage, or grain fields, and 6- to 8-row-wide plats in row-crop fields.

Since there is considerable border effect next to fences, the first no-treatment area should be of double width. There should also be a check (no-treatment) bordering every treatment. Sometimes it may be advisable to repeat the series of treatments because of lack of soil uniformity. Whenever the fertilizer material is applied broadcast, it should be done before the final disking and harrowing at a heavier rate than one would use when applying it by means of fertilizer attachments on planters or drills on row-crop land. Several plats can be treated in accordance with the following plan:

| x—x—x—x Fence | 10 ft. Guard area | Check (No treatment) | Treatment 1 | Treatment 2 | Check (No treatment) | Treatment 3 |
|---|---|---|---|---|---|---|
| | | | | | | |

The profitableness of any treatment can be determined by harvesting and weighing the yield on each plat or only harvesting six areas three feet square (9 square feet) on forage and grain crop plats or 1 or 2 middle rows in row-crop plats. Only by actual harvesting known areas can accurate information regarding the profitableness of the treatment be obtained.

## General Information Regarding Various Plant Food Elements and the Use of Farm Manure

### Primary Plant Food Elements

The various plant food elements perform specific functions in the plant. Most of the research regarding the functions of these elements has been done with nitrogen, phosphate. and potash, since plants draw heaviest on the available supply of them in the soil and it becomes exhausted much sooner than that of the other necessary plant foods.

**Nitrogen.** The original soil nitrogen supply is present in the humus. Humus is the partially decomposed organic matter present in the soil which furnishes food for helpful bacteria. The majority of Idaho soils are low in humus. Nitrogen is necessary for the production of dark-green, broad-leafed. succulent growth and is needed most during the early stages of growth. It stimulates early growth of forage grasses. This is particularly noticeable in backward or late springs. Generally speaking, the presence of an excess of nitrogen retards flowering, delays maturity, and tends to make some plants more subject to certain diseases. Plants growing in soils low in available nitrogen are yellow and short stemmed. An excess of nitrogen frequently causes lodging of grains and especially is this true in soils low in available potash. The analysis of nitrogen-carrying fertilizers are shown in Table 2.

The probable sources of nitrogen for Idaho farms are in farm manures, plowed under forage legumes, ammonium sulfate, liquid ammonia, sodium nitrate, cyanamid, and nitrate of lime. A ton of average farm manure contains 10 pounds of nitrogen, 5 pounds of phosphoric acid, and 10 pounds of potash. A large proportion of the nitrogen in well-cared-for farm manure is immediately available to the plant and nearly all of it becomes available over a period of a few years. Farm manures are a valuable source of nitrogen when we consider the fact that nitrogen costs at least 10 cents per pound purchased in the form of commercial fertilizer. Most of the commercial nitrogen fertilizer used in Idaho is purchased as ammonium sulfate (21 per cent nitrogen). It is quick-acting since it is water-soluble, and the ammonia is quickly changed by bacteria into nitrate, the form in which most plants use their nitrogen. However, it is somewhat slowly available in cool springs when bacterial action is slow. It is used widely in the preparation of mixed fertilizers. Because of its slightly acid-forming effect, ammonium sulfate should be used on southern Idaho soils where there is an excess of lime. Sodium nitrate (15-16 per cent nitrogen) is usually used where very quick response is desired. Its residue has a detrimental effect on the physical condition of the soil when used in large amounts. Frequently both sodium nitrate and ammonium sulfate are used in a mixture. Fish meal (7 per cent nitrogen) is an organic fertilizer which is used when a source of slowly available nitrogen is desired. It is most frequently used in mixtures prepared for use on truck crops. The cost per pound of nitrogen is quite high. Experimental work is being done with liquid ammonia (82 per cent nitrogen) on row crops. Indications are that it may be successfully used as a nitrogen fertilizer.

The nitrogen in cyanamid (21-22 per cent nitrogen) becomes available fairly rapidly. If applied at seeding time, burning of seedlings is apt to occur. It should not be used in southern Idaho for direct application to soils because of its high lime content and consequent acid-neutralizing power. It may be used with advantage on some of the cutover lands of northern Idaho. It may also be used in composting crop residues and trashy farm manures for greenhouse and truck crop uses.

Nitrogen-containing fertilizers are of value on run-down soils where non-legume plants are grown. They also stimulate the growth of new legume seedings in the cutover areas. When mixed with phosphates it is of distinct benefit where phosphate applications are needed on soils containing only an average amount of decomposing organic matter. Nitrogen is easily leached out of the soil and, therefore, it is necessary to make yearly applications of small amounts. (See also "Crop Recommendations" and "Methods of Application.")

TABLE 2.—Composition of the Principal Fertilizer Materials[4]

| Fertilizer Materials | Nitrogen | Phosphoric acid | | Potash |
|---|---|---|---|---|
| | | Available | Total | (water soluble) |
| | Per cent | Per cent | Per cent | Per cent |
| Nitrogenous Fertilizers | | | | |
| Nitrate of soda | 16 | ...... | ...... | ...... |
| Sulphate of ammonia | 20–21 | ...... | ...... | ...... |
| Cyanamid | 21–22 | ...... | ...... | ...... |
| Nitrate of lime | 15 | ...... | ...... | ...... |
| Nitro-Phosphatic Fertilizers | | | | |
| Tankage | 6–8 | 5–6 | 7–12 | ...... |
| Fish scrap, fish meal | 7–10 | ...... | 3–6 | ...... |
| Bone meal or flour | 2 | 10 | 18 | ...... |
| Ammo-phos. "A" | 11 | 48 | ...... | ...... |
| Ammo-phos. "B" | 16 | 20 | ...... | ...... |
| Ammonium phosphate | 10 | 52 | ...... | ...... |
| Phosphatic Fertilizers | | | | |
| Superphosphate | ...... | 16–20 | 18–22 | ...... |
| Treble superphosphate | ...... | 35–45 | ...... | ...... |
| Ground rock phosphate | ...... | 2–5 | 25–35 | |
| Potassic Fertilizers | | | | |
| Muriate of potash | ...... | ...... | ...... | 48–60 |
| Sulphate of potash | ...... | ...... | ...... | 48–50 |
| Sulphate of potash-magnesia | ...... | ...... | ...... | 25–30 |
| Wood ashes (unleached) | ...... | ...... | 1.5–2.5 | 4–6 |

[4]Information regarding any fertilizer not mentioned in this list can be obtained by writing to the Extension Soils Specialist, Moscow, Idaho.

**Phosphorus.** A greater tonnage of soluble phosphate fertilizers is sold each year in Idaho than of any other fertilizer. The use of phosphate in Idaho is largely confined to the southern irrigated districts. Fine response, however, has been obtained on the drained lands in the Bonners Ferry district. Some response has been obtained on grain crops in the cut-over area. The soils of southern Idaho, as a rule, are high in total phosphorus but very low in available phosphorus which is the only form that the plant can use. In experimental work so far conducted at the Aberdeen Substation and in numerous cooperative field tests no consistent increased yields have been obtained from the application of ordinary or finely ground raw rock phosphate to southern Idaho soils. Rates of application have been as much as 2,500 pounds per acre. These soils are usually high in lime or calcium carbonate. Lime is dissolved in the soil moisture due to the presence of carbon dioxide derived from decomposing organic matter and plant growth. It is changed to the soluble calcium bicarbonate. When evaporation takes place, the insoluble calcium carbonate is again deposited. Rock phosphate is slightly soluble in carbon dioxide containing water. However, the soluble lime reacts with the phosphate to form the insoluble phosphate once more. Since it is not economical to remove the calcium carbonate, it has been found more economical to apply soluble phosphate for plant nourishment. Figure 1 shows variation in growth produced by two phosphate products.

Phosphorus stimulates early root growth and tillering and thereby stimulates the early development of the plant. This is one reason why applications of soluble nitrogen fertilizers together with phosphate frequently bring about the largest increased yields. Phosphorus stimulates the production of sugars, hastens fruit and seed production and maturity of non-legume crops although it delays the maturity of forage legumes. It stimulates the development of the leaves on forage legumes. Weak, spindly, pale alfalfa having few small green leaves is produced on low available-phosphate-containing soils. Under these same conditions, beets and other root crops are small. Under extreme conditions, the tops of root crops will be very short, although heavy applications of nitrogenous fertilizers have been made. The heads of grain crops fail to fill where there is a lack of soluble phosphate.

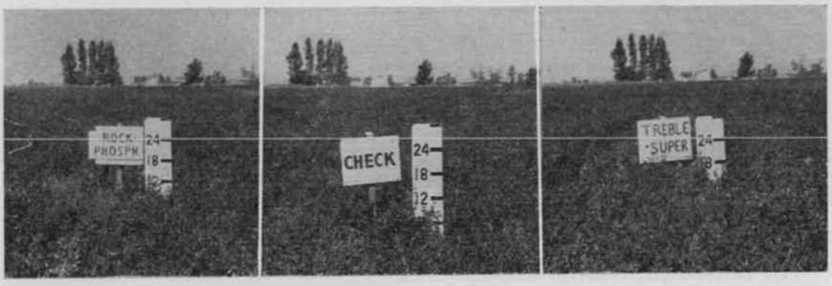


Figure 1.—Some differences in alfalfa yields obtained in Twin Falls County.

There are various forms of soluble phosphates sold in the United States, only a few of which are used in Idaho. Most of the phosphate fertilizer sold in Idaho contain 43 per cent or more available phosphoric acid ($P_2O_5$). Analyses of phosphate products are presented in Table 2.

Over 95 per cent of the phosphate in superphosphate, double and treble superphosphate is present in an available form. Approximately 90 per cent of the phosphorus in rock phosphate is present in an unavailable form. Phosphate fertilizers are applied either alone or in combination with other plant food elements. (See "Crop Recommendations" and "Methods of Application.")

The addition of superphosphate (ordinary and double strength) does not make soils more acid. It has no detrimental effect on the physical condition of the soil. It is not lost out of the soil by leaching. Phosphates spread on the surface of the soil do not move downward more than 2 or 3 inches during 4 or 5 years except in very sandy soils. However, if application is made on a side hill in irrigated districts, there is some danger of it being carried mechanically to the bottom of the hill. Discussion of methods and frequency of application and residual effect is given under "Crop Recommendations" and "Methods of Application."

**Potassium.** Idaho soils contain relatively large supplies of available potassium or potash. Its use has been profitable only for certain crops and under local conditions in some areas.

Potassium is necessary for the production and transference of starch in potatoes and grains, production of sugar in fruits and vegetables, and formation of the fibrous matter of plants. Plump, fleshy, small fruits are produced where the potash and phosphate supply is ample. Applications of potash tend to delay seed maturity and fruit production. Potash applications increase the disease resistance of plants. It aids in the formation of proteins.

Early stages of potash starvation manifest themselves in various ways. First, the leaf margins become light yellow. This chlorotic condition spreads to the areas between the veins of the leaf. The margins of legume leaves are first dotted by many pale yellow to white areas. Later on the margins turn brown and die. Frequently the leaf tips dry up without first turning yellow. Bluish-green leaves are produced by plants growing in soils lacking balance between their nitrogen and potash content. Under these conditions, the straw of grain crops will be weak and subject to lodging. The grain will be shriveled and low in starch content. Roots of potash-deficient plants are spindly, dull white to brown in color, and distinctly susceptible to root rots. Secondary roots are formed only near the root base and near the tip.

All potassium compounds such as potassium sulphate and potassium chloride commonly used as fertilizers are very soluble in water. The potassium contents of various fertilizer materials are shown in Table 2. Very little is lost in the drainage water due to its reaction with the clay in the soil. The plant can obtain its potash from this potash-clay compound.

Sandy soils usually respond to potash applications although very little response has been obtained on most of the sandy soils in Idaho. The type of crops grown seems to be the main factor in determining whether or not response will be obtained in Idaho. (See also "Crop Fertilizer Recommendations" and "Methods of Application.")

**Sulfur.** Sulfur is necessary for the formation of certain proteins and for the production of certain odorous oils contained in mustard, horseradish, turnips, cabbages, onions, garlic, and leeks. Sulfur is present in large amounts in the leaves and stems of plants. Grain crops respond to sulfur-containing fertilizers only when the soils are very deficient in this plant food element. The stand of forage legumes is very poor when grown on sulfur-deficient soils.

Sulfur-containing fertilizers consist of gypsum, flowers of sulfur, and ammonium sulfate. The application of flowers of sulfur will increase the acidity of a soil while the application of gypsum has little or no effect on the acidity. All of these are easily leached out of the soil. The application of sulfur-containing fertilizers is as important to the production of forage legumes in northern

Figure 2.—Forage legumes respond markedly to the application of gypsum in Bonner County.

Idaho and in the mountain valleys on the south side of the Sawtooth range as phosphate is necessary for forage legume production in the Snake River plain area. Figure 2 shows the increased growth which can be expected from the application of gypsum to northern Idaho cutover soils. Gypsum (17 per cent sulfur) is the best source of sulfur under Idaho conditions. It should be applied every two years to legume crops at the rate of 200 pounds per acre. (See also "Crop Fertilizer Recommendations" and "Methods of Application.")

**Secondary Plant Food Elements.**

There are many plant food elements which perform very important functions in the plant, but which are occasionally found lacking in soils. Plant growth is very adversely affected when the necessary supply is not present. Iron, boron, magnesium, manganese, and zinc are some of the secondary plant food elements which, in available form, are lacking or may become lacking in Idaho soils.

**Iron.** Our southern Idaho soils, due to their high limestone content, are frequently found to be lacking in available iron.

Iron is necessary for the production of chlorophyll, the green coloring matter in plants. In the absence of chlorophyll the plant is unable to utilize sunlight. The leaves turn yellow and sometimes white, curl, shrink, and die when there is a lack of available iron in the soil. They become yellow between the veins, which remain green for a long time. The plant is then said to be suffering from iron chlorosis. Where the available nitrogen supply is high and the iron supply is low, a shoot frequently grows so rapidly that iron compounds do not reach the growing parts in time to prevent the formation of yellow leaves. The lack of sufficient available iron is frequently observed on trees of all kinds, shrubbery, small fruits, and small ornamental plants in gardens. Soluble iron may be supplied to the plant as copperas (ferrous sulfate) iron tartrate or citrate.

**Boron.** Very little definite information regarding the need of boron applications on Idaho soils has been obtained up to the present time. Preliminary results obtained in northern Idaho on alfalfa indicate beneficial response may be expected from small applications of boron in certain areas.

Plants require very small amounts of boron for their growth and development. It is necessary for the growth of the leaf and the growing points of plants. It stimulates the production of flower and fruit which is also a function of phosphorus. It is very necessary for the movement of sugar from one part to another in a plant.

One of the earliest evidences of boron deficiency in the plant is the "dying back" of the tips of the growing shoots and roots. This dying back of the shoot stimulates the production of lateral buds.

Rust brown areas appear on cauliflower heads. The head is bitter and unpleasant to the taste. The black heart disease of sugar beets is caused by a lack of available boron. Cracked stem and heart rot of celery can be controlled by boron applications. The roots of strawberry plants are frequently black, due to a deficiency of boron. Boron deficiency is most apt to occur in soils receiving large applications of calcium-containing fertilizers such as gypsum. This is probably due to greater plant food requirements of the fast-growing plants on such soils more than it is due to the soil reaction.

Leaves of plants receiving an excess of boron first become yellow around the margin. This yellowing progresses toward the mid-vein or leaf base.

The boron requirement of plants varies considerably depending upon the type of plant grown. The root crops such as sugar beets and turnips require more of the element than do potatoes and legumes while grain crops require only small amounts.

The cheapest source of boron is borax. Boric acid contains 50 per cent more boron than does borax. (See also "Crop Recommendations" and "Methods of Applications.")

**Magnesium.** Magnesium is another plant food element which is essential for plant growth. Its functions in plants may be listed as follows: Production of chlorophyll, starting new growth, oil production, increasing and stimulating root development, and hastening maturity of some crops. Chlorosis in plants is sometimes due to a lack of available magnesium.

The central portion of the leaves of plants such as potatoes suffering from the lack of available magnesium become chlorotic (light green) between the veins of the leaves first. Soon after, small brown spots appear in the light green area. These brown spots grow and the entire leaf tissue finally becomes a dark brown, shriveled mass. These symptoms should not be confused with that of potash deficiency where the margin of the leaf dies first and the dead area spreads toward the mid-rib. The lack of magnesium delays the maturity of cabbage and causes large yellowish-white areas to form on "puckered" lower leaves which finally die. In the case of potash deficiency, the cabbage leaves first become brown with dry, ragged margins. Corn, tomatoes, and most other crops growing on magnesium-deficient soils produce leaves having stripes of yellow chlorotic tissue between the veins. The leaves soon after become ragged, stunted, and "dried out" in appearance.

Magnesium can be supplied to plants by dolomitic limestone (10-33 per cent magnesium oxide), kiesenite ("emjeo" containing 30-31 per cent water-soluble magnesium oxide) and sulphate of potash magnesia (8-10 per cent water-soluble magnesium oxide).

Magnesium deficiency is most prevalent in acid soils where large amounts of commercial fertilizers are used and in soils originating from low magnesium-containing rocks. (See further discussion under "Crop Recommendations" and "Methods of Applications.")

**Manganese.** Manganese is another plant food element which is required by plants in very small amounts. Its function in the plant is not very well known, but it is thought to be catalytic. It is very active in the young, fast-growing tissue. Fast-growing vegetable crops show marked response to its application. Spinach and other green vegetables show the greatest response.

The lack of sufficient manganese first causes the vein system of the top leaves of tomatoes and cucumbers to change from green to yellow. The blossom buds turn yellow and fall. Manganese-deficient plants appear chlorotic. Leaves of spinach become golden yellow. Gray specks appear on oat leaves growing on manganese-deficient soils. The greatest deficiency occurs on alkaline or high-lime soils. It is slowly rendered unavailable in the soil. Manganese sulfate is the most common source of available manganese. (See further discussion under "Methods of Application.")

**Farm Manure**

There is usually a deficiency of more than one plant food in many field soils. Where this is the case, it becomes necessary to add more than one plant food element at a time. Fertilizers containing two plant food elements are called semi-complete fertilizers and those containing nitrogen, phosphorus, and potash are called complete fertilizers.

Farm manure is the cheapest complete fertilizer that the farmer has available. It not only contains the three above-mentioned elements but also many of the so-called secondary or minor plant food elements, in addition to organic matter which is so necessary in crop production. This organic matter increases the water-holding capacity of sandy soils and improves the tilth of heavy clay soils, in addition to serving as a source of energy for bacteria.

A ton of ordinary farm manure contains 10 pounds of nitrogen, 5 pounds of phosphoric acid, and 10 pounds of potash in addition to its life-giving organic matter content. These values can be increased at least 50 per cent by providing proper storage. Provisions should be made to prevent leaching during the wet season and to maintain moist conditions during the dry season of the year. All Idaho agricultural soils, with the exception of the peat and muck soils, can be improved by the incorporation of organic matter in one form or another. (However, on raw peat lands, it has been profitable to apply manure.)

The functions of the various elements contained in farm manure have been discussed in the preceding pages. The amount of manure produced by various farm animals and birds per thousand pounds live weight varies widely as shown in Table 3. The relative value of the manure per ton from various kinds of livestock is also very strikingly shown.

Response has been obtained from the use of farm manures under a large number of conditions. In many instances, response has been obtained by its use where one of the commercial fertilizers has not caused an increase in yield, especially on low organic matter containing soils.

Under our southern Idaho soil conditions where there is a very distinct phosphate problem in addition to a lack of organic matter, an application of soluble phosphate should be made with the manure application. The need for this double or mixed application has been shown very definitely on some dairy farms in the phosphate-deficient areas. (Further discussion given under "Crop Recommendations" and "Methods of Application.")

**TABLE 3.—Plant Food in Mixed Excrements and Bedding for One Year Per 1000 Pounds of Live Weight**[5]

| Kinds of Animal | Weight of Mixed Excrements Tons | Weight of Bedding Tons | Weight of Total Manure Including Necessary Bedding Tons | Nitrogen Pounds | Phosphoric Acid Pounds | Potash Pounds | Value of Plant Food | Value of Plant Food Per Ton |
|---|---|---|---|---|---|---|---|---|
| Horse .... | 9.00 | 3.00 | 12.00 | 158.00 | 61.00 | 145.00 | $28.50 | $2.38 |
| Cow ........ | 13.50 | 1.50 | 15.00 | 171.00 | 47.00 | 148.00 | 29.50 | 1.97 |
| Pig ........ | 15.25 | 3.00 | 18.25 | 180.00 | 122.00 | 170.00 | 35.35 | 1.94 |
| Sheep .... | 6.25 | 3.50 | 9.75 | 154.00 | 65.00 | 175.00 | 29.60 | 3.04 |
| Steer ...... | 7.50 | 1.50 | 9.00 | 135.00 | 54.00 | 72.00 | 22.15 | 2.46 |
| Hen ........ | 4.25 | ...... | 4.25 | 85.00 | 68.00 | 34.00 | 15.15 | 3.56 |

[5]Van Slyke, Lucius, *Fertilizers and Crop Production*, p. 218, Illus. New York, 1937.

## Soil Amendment

A soil amendment is some compound which when added to the soil performs a function other than that of supplying plant food. The application of limestone to soils usually performs two functions, namely, neutralizing acidity and supplying calcium for plant nutrition. Most Idaho soils contain sufficient calcium for plant growth.

Some of the cutover, peat and muck soils of northern Idaho are slightly acid. Long Valley, in southern Idaho, contains local areas of acid soils. Very poor to no stands of legumes are obtained on such soils. Alsike and white clovers do better than does alfalfa on these soils. Grain crops and truck crops on acid soils also are improved by lime applications. Since legumes are necessary to improve the fertility of these soils, limestone should be applied wherever field trials have indicated a response. We have numerous deposits in Idaho, located near where the need is greatest. When it is used for the correction of acidity, it is called a soil amendment. Calcium carbonate, second-grade quick lime, and dolomitic limestone are the forms offered for sale in Idaho. Sixty pounds of pure calcium oxide or quick lime are equivalent to 100 pounds of pure calcium carbonate in neutralizing acidity. When quick lime sells for $7.00, ground limestone should sell for $3.92 and fresh-slaked limestone should sell for $5.30 per ton. The limestone should contain some finely ground material so that there will be some available for immediate reaction with the acids and some larger particles which will become available at some later date. Therefore, all of it should pass through a 20-mesh screen and 75 per cent should pass through a 100-mesh screen. Since large amounts are used, it should contain 90 per cent calcium carbonate or its equivalent, thereby reducing the amount of carrying or handling charges on non-required materials.

Besides correcting the acidity of soils, limestone applications bring about an improved physical condition in acid soils. Limed soils become granular, absorb more water and become easier to work and cultivate. Due to the presence of carbon dioxide in the soil moisture, limestone is dissolved fairly rapidly. Where considerable leaching takes place, a large amount of calcium will be found in the drainage water.

## Crop Fertilizer Recommendations

An attempt has been made in the following chart to present in a concise manner the responses which can be expected by commercial fertilizer applications to various crops. The author realizes that it is not complete. It is taken for granted that the grower will consult his County Extension Agent or try out the suggested treatments on small plots before treating any large acreage.

**General Commercial Fertilizer Recommendations for Idaho[5]**

| Idaho Region | Fertilizer Recommendation | Comments |
|---|---|---|
| **Northern Idaho** | | |
| 1. Overflow lands | a. Soluble phosphates on all crops. | This applies to light-colored soils containing appreciable amounts of lime. Neutral and slightly acid soils should be treated the same as cut-over soils. |
| | b. Small amounts of nitrogen together with phosphates on grains. | |
| 2. Cut-over soils | a. Gypsum for forage legumes. | |
| | b. Nitrogen for non-legumes. | |
| | c. Complete fertilizers for non-legumes. | Where little if any farm manure is applied. Commercial fertilizer applications do not take the place of farm manure. |
| | d. Lime on acid soils. | |
| | e. Farm manure on all crops. | |

[5]Following recommendations are based upon results obtained in trials supervised by University of Idaho agencies.

| Idaho Region | Fertilizer Recommendation | Comments |
|---|---|---|
| 3. Peat and muck soils | a. Complete fertilizers for general crops.<br>b. Lime on acid peats.<br>c. Manure on raw peat and muck. | Ratio of 1-6-6. |
| 4. Prairie | a. Gypsum for forage legumes.<br>b. Nitrogen for grains and grasses.<br>c. Nitrogen and phosphate (5 lbs. nitrogen plus 25 lbs. av. phos. acid). | Moisture conditions permitting on areas bordering cut-over soils. |
| **Southern Idaho** | | |
| 1. Northern irrigated mountain valleys | a. Gypsum for legumes.<br>b. Phosphates for non-legumes.<br>c. Large quantities of farm manure applied either alone or together with commercial fertilizers. | Where demonstrations have shown a profitable response from their use. |
| 2. Southwestern Idaho | a. 100 to 200 lbs. soluble phosphate applications on forage legumes.<br>b. General field and vegetable crops respond to phosphates, nitrogen and phosphates, and complete fertilizers.<br>c. Large quantities of farm manure applied either alone or together with commercial fertilizers. | Where demonstrations have shown a profitable response from their use.<br>Depending upon soils, series, and previous treatment of soil, such as rotations and amount of farm manure applied. |
| 3. Central and Upper Snake | a. Most crops respond to phosphate applications alone.<br>b. Nitrogen plus phosphate for general crops.<br>c. Large quantities of farm manure applied either alone or together with commercial fertilizers. | Soils which have received liberal applications of farm manures and green legume manures and on which a forage legume-row crop rotation is followed.<br>Some soil series do not respond. See your county agent as to which series do not respond. |
| 4. S. E. Idaho (Irrigated) (Drainage toward Great Salt Lake) | a. 100 to 250 lbs. applications of soluble phosphate for legumes and general crops.<br>b. Nitrogen plus phosphate for general crops.<br>c. Large quantities of farm manures applied either alone or together with commercial fertilizers. | On high-lime containing soils.<br>On high-lime soils of average fertility. |
| 5. Dry land wheat sections | a. Wheat responds to 35-50 lbs. soluble phosphate applications and nitrogen plus phosphate applications.<br>b. Green legume manure crops. | In years of high rainfall only.<br>Only small amounts. |

**Forage Legumes.** Alfalfa, sweet clover, and red clover have responded to the application of gypsum in northern Idaho and in the mountain valleys lying just south of the Sawtooth range in southern Idaho. The degree of response of alfalfa near Donnelly in Long Valley to gypsum applications is shown in Figure 3.

The usual application is 200 pounds of gypsum every other year broadcast in the fall. It is not necessary to disk or harrow the material into the soil, but it is usually the better way.

In the irrigated sections of southern Idaho, the application of 100 to 200 pounds of treble superphosphate has brought about the largest increased yields of alfalfa and the various clovers. Some response has been obtained by the use of potassium sulfate on alfalfa in southwestern Idaho.


Figure 3.—Yields of alfalfa in Long Valley are increased by the application of gypsum.

Fertilizers can be applied to legumes before seeding, to year-old seeding or after any cutting has been removed. Preferably, application should be in the early spring or late fall and the land given a light harrowing. Where the soil is very deficient in available phosphate a 100-pound application should be made before seeding the nurse crop and then a further 100-pound application the following spring. Phosphate is rendered unavailable slowly and is not washed out of the soil except in very sandy soils. Large applications therefore can be made without danger of loss. When applying it to old seeding, the field should be lightly harrowed after application, so as to work it into the surface soil and prevent it being carried to the lower end of the field mechanically. The application of fertilizers to forage legume fields will not increase the stand but will increase the number of stems and the size of the leaves of the remaining plants.

Red clover and alsike clover seed production has been increased markedly by the application of soluble phosphates in many areas. Maturity is delayed somewhat. Up to the present time few experiments have been conducted with the application of phosphate for alfalfa seed production. It is quite possible that the time is not far distant when alfalfa seed production will be so low that the application of phosphate will prove profitable in spite of delayed maturity of the seed crop. New seedings of forage legumes on the cutover lands have been markedly assisted by small applications of nitrogenous fertilizers. Profitable response has been obtained from the application of farm manure to forage legume land.

**Peas.** In northern Idaho, no results have been obtained from the application of commercial fertilizers to peas, due probably to the moisture situation obtaining there. In southern irrigated districts, peas have responded to the application of phosphates on soils of high fertility. Fine results are obtained from the application of nitrogen plus phosphates on soils which do not receive liberal applications of farm manure from time to time.

**Beans.** Beans respond to the application of nitrogenous fertilizers. No increase in yield of beans has been obtained by the direct application of phosphates. Some growers have obtained increased yields by phosphate application to the preceding crop while others have obtained decreased yields.

**Grains.** Response has been obtained from the application of phosphate alone, phosphate plus nitrogen, and in some instances to the application of nitrogen alone on grains in the cut-over area of northern Idaho. This is especially true on soils which have been producing grain for many years and on which no legume crop has been turned under nor any applications of farm manure made. Grain growing on the peat and muck lands respond very markedly to the application of complete fertilizers. The usual rate of application is 200 pounds of a 2-20-20.[6]

Grain crops such as wheat, barley, and oats have responded to the application of phosphates and nitrogen plus phosphates in northern Idaho prairie lands only under conditions of ample moisture supply. The rates of application are from 30 to 50 pounds of treble superphosphate and 50 to 100 pounds of ammonium sulfate per acre depending upon moisture conditions. It should be applied at planting time, preferably with a drill having a fertilizer attachment. Only phosphate at the above rates can come in contact with the seed without danger of burning. Similar results can be expected in southern Idaho under dry land conditions.

Grain crops respond to farm manure application under all conditions where moisture supply is not a limiting factor. In phosphate-deficient areas, most profitable response is obtained by the application of treble superphosphate together with the manure.

Under irrigated conditions grains respond to the application of soluble phosphates (100-200 pounds per acre) on farms high in organic matter which are subject to a rotation consisting of legumes and row crops and receive applications of farm manure at least once in the rotation. Soils which do not receive heavy applications of farm manures and do not have green legume manure crops turned under on them respond to nitrogen plus phosphate applica-

6See meaning under "complete fertilizer" in appendix.

tions and in some instances to the application of complete fertilizers. Fertilizer is usually broadcast before drilling the grain.

**Potatoes.** Potatoes respond to the application of 200 pounds of complete fertilizer having a ratio of 3-20-20 on the peat and muck soils of northern Idaho. On other soils in northern Idaho, commercial fertilizers should not be applied until the organic matter supply has been restored. Then they respond to the application of phosphate plus nitrogen and in some instances to the application of a complete fertilizer.

Potatoes growing in the irrigated sections of southern Idaho respond to the application of commercial fertilizers in varying degrees, depending upon the fertility of the soil, which is influenced by its past management. In order to obtain maximum profit from the use of commercial fertilizers, heavy applications of organic matter should be applied by turning under green legume growth, which has received an application of soluble phosphates, or by the application of farm manures to which soluble phosphate has been added. Potatoes growing on soils low in rapidly decomposing organic matter or fields not receiving large quantities of farm manure or green manure crops respond very profitably to the application of nitrogen plus phosphate. Soils which are very low in organic matter will respond most profitably to the application of nitrogen alone or the application of complete fertilizers (7-15-7). The direct application of commercial fertilizers to potatoes has not proven profitable where an abundance of nutrients exist due to heavy applications of farm manure and the turning under of large legume green manure crops which have received previous fertilizer treatment.

The rate of fertilizer application varies from 150 to 400 pounds, depending upon the plant food content of the material. Applications by means of a fertilizer attachment on the potato planter has been found the most economical in the middle western and eastern states. By means of the attachment the fertilizer is placed 2 inches to each side and 1 inch below the level of the seed piece. This method of application has not been used very much in Idaho.

**Onions.** The results which can be expected from the application of fertilizers to onions are dependent upon the fertility of the soil as influenced by rotation and its previous fertilizer treatment. Soils which have received only an application of 15 loads of farm manure during the preceding one or two years can be expected to respond markedly to the application of nitrogen plus phosphate fertilizers or complete fertilizers, while soils which have received heavy applications of farm manures will respond most profitably to the application of phosphate alone. This is especially true in case of seed production, since one of phosphate's important functions is the production of fruit. The rate of application varies from 200 pounds soluble phosphate fertilizer to 500 and 600 pounds of some complete fertilizer (7-15-7). Frequently, half of the total application is made at time of planting, and the remainder is applied in two applications by means of a fertilizer attachment on the cultivator during the early part of the growing season.

**Beets.** Beets respond satisfactorily to the application of phosphates, under most Idaho conditions. Certain heavy clay soil areas in southwestern Idaho are the main ones upon which we have not obtained any response from the application of phosphates. No results have been obtained on the Goose Creek series in the central Snake River Valley. Fields which have received only a 10- to 15-load application of farm manures one year have responded to the application of nitrogen plus phosphate, even though the field be one which was plowed out of alfalfa. This is especially true if the alfalfa has been grazed and no top growth plowed under. No profitable increased yields have been obtained from the application of complete fertilizers or potash alone on beet fields. The usual rate of application of phosphate-alone fertilizers is 75 to 200 pounds per acre. The smaller rate can safely be made at the time of planting, by means of proper fertilizer attachments, since there is then little likelihood of plant burning taking place. When heavier applications are made, they should be broadcast previous, or a part of the application broadcast and an application of 50 to 60 pounds made at time of planting by means of an attachment.

**Corn.** Corn responds to approximately the same fertilizer treatment as the small grain crops. Phosphates alone have produced the most economical increased yields on soils rich in nitrogenous organic matter. Usually 100 to 200 pounds of phosphate fertilizer are applied per acre. The most economical method of application is by means of a fertilizer attachment on the planter. This attachment places the fertilizer in a ribbon on each side of the corn hill and not in contact with the seed.

**Fruit Trees.** Prunes have responded to the application of nitrogenous fertilizers. General observation and reports of growers indicate that nitrogenous fertilizers might also prove profitable on peach trees. Chlorosis has been reduced considerably by means of ammonium sulfate applications in a few prune and peach orchards, according to some growers. The rate of application has been one pound to each 4 to 5 years of age of the tree. It is broadcast in the early spring in a circle under the spread of the tree. Results with the use of phosphates and potash-containing fertilizers in apple and prune experiments have not been profitable. There is little doubt but that in some areas benefit has been obtained indirectly by the stimulation of growth of the legume cover crops by phosphate and potash application.

**Truck Crops.** Response from fertilizers on truck crops is dependent upon the type of crop grown and soil conditions. Heavy applications of farm manures should be considered as pre-treatment for the production of truck crops. Root and fruit truck crops have responded to phosphates alone and to complete fertilizers high in potash. Leafy vegetables growing in soils high in nitrogen and containing an average amount of available phosphates have responded to potash alone applications. Celery and lettuce in particular have responded markedly to potash alone applications.

Growers have reported that fall spinach suffering from chlorosis has been benefited by manganese sulfate applications. (See also "Methods of Application.")

**Pastures.** The carrying capacity of Idaho pastures can be increased considerably by the seeding of better pasture mixtures, practice of pasture management, and judicious use of commercial fertilizers.

The most economical milk production is possible when cows receive most of their feed from pastures. The grazing season can be lengthened and the carrying capacity increased by the application of farm manures and commercial fertilizers.

The growth of the legume fraction in the pasture mixture is especially increased by the application of soluble phosphates in southern Idaho and gypsum in northern Idaho. Grasses are also benefited by phosphate applications when growing on low soluble phosphate-containing soils. The weed population is reduced in old pastures by the application of commercial fertilizers.

Fertilizers such as ammonium sulfate and treble superphosphate should be broadcast in late fall, winter or very early spring, preferably during the winter. They can be applied at the rate of 100 to 200 pounds per acre. If applied to new seeding, they should be applied previous to final seedbed preparations. They should be applied previous to any cultivation or rejuvenation of the pasture. Nitrogen-containing fertilizers are carried to greater soil depths very easily while phosphates will be carried only 1 or 2 inches deeper during 3 to 4 years. On very sandy soils, both elements are leached out of the soil fairly rapidly. Where farm manures are to be applied to the pasture, the commercial fertilizers can be applied with the manure.

When straw mulching is practiced, 150 pounds of ammonium sulfate should be applied during the late winter of the second year. Straw contains very little nitrogen. Bacteria decomposing the straw will rob the grasses of soil nitrogen, if the amount present is insufficient for both plant and bacteria, in order to carry on their life processes.

### Methods of Application of Commercial Fertilizers

Fertilizers can be applied in various ways. Cost of the application, desired response, and type of crop are factors to be considered in choosing a method of application. The lowest cost of application is possible when applied in the same operation as planting or cultivation. Where considerable residual effect is expected, it should be broadcast. If applied in the row to one crop, the growth and maturity of the following crop will be quite variable. The application should be broadcast on established forage crops and the soil stirred slightly by light harrowing or by the use of brush drags. The maximum immediate response from its use on row crops other than beets is obtained when applied in bands 1 to 2 inches to the side and 1 inch below the seed. Fine response has been obtained when applied 1 inch to the side of the beet row.

Some fertilizers such as gypsum and calcium cyanamid should be applied the previous fall or two to three weeks previous to planting. Calcium cyanamid can be used in composting strawy manure. Fifty pounds of it should be mixed with each ton of straw.

Since there is very little loss of available potash by leaching and fixation into unavailable forms, applications need be made only when the plants have removed most of the previous treatment. Relatively large applications can be made. It is more profitable to make small applications of fertilizers each year when they are to be applied locally or in close proximity to the seed.

Farm manure can be spread at all seasons of the year. When the ground is frozen, it can be applied on all cultivated crop and pasture land on the farm. The grass starts early in manured pastures. Manure can also be applied on beet and forage legume ground in the early spring. Later on it can be applied to potato ground. During the row-crop growing season it can be applied on pastures and on grain land after harvest.

Pea, bean, and forage legume land, which will be planted to beets and early potatoes the following year, should receive an application of manure in the fall previous to disking, crowning, or plowing. Early spring pasture grazing is possible where manure is applied to the pastures in the fall.

The rate of application of farm manure is determined by the amount available each year. At least 10 loads per acre should be applied at a time. Where considerable feeding is practiced on the farm, 30 load applications per acre are sometimes made on truck crop land. Each field in a rotation should receive an application at least once during the rotation. Where there is insufficient manure produced to cover the entire farm during the rotation, green manure crops are turned under on the fields once every rotation or every other rotation.

Due to the fact that many of our irrigated soils are very deficient in available phosphorus and the manure is relatively low in available phosphorus, the application of phosphorus together with farm manures has proven very profitable at all seasons.

The rate of application of boron varies from 20 to 60 pounds of borax per acre. Excessive amounts must not be applied. This material can be applied broadcast or mixed with farm manures or other commercial fertilizers. Boron fertilizers should first be applied on only a small plot of land to determine its value before applying it on the entire field. Fall applications are preferable.

Where magnesium is needed the rate of application varies with the crop. When magnesium-containing fertilizers are applied to potatoes growing on sandy soils, only 10 to 15 pounds of available magnesium are applied. Twenty-five pounds of available magnesium oxide should be applied on magnesium-deficient soils planted to cabbage. Magnesium can also be supplied by the application of large quantities of farm manure which contain about 10 pounds of readily available magnesium oxide per ton.

Manganese is usually applied in the form of manganese sulfate. The rate per acre varies with the crop. If applied broadcast, 40 to 75 pounds per acre is sufficient. It can also be sprayed on the young growing plants. If chlorosis has already started, spraying will usually stop its spread. It is applied on garden crops by spraying during the first three to four weeks of growth. When it is applied as a spray, 100 pounds are dissolved in 500 gallons of water. It can also be mixed safely with other fertilizers before application. It is slowly rendered unavailable.

Frequently, it is advantageous to make only part of the total fertilizer application at planting time, and then make one or two smaller applications during the growing season. In the case of truck crops and leafy vegetables this is a common practice.

Liquid ammonia is usually applied in the irrigation water in two applications during the early part of the irrigating season. A representative of the firm selling this product is always present at time of application for the purpose of adjusting the flow of the ammonia into the irrigation stream.

Limestone is usually disked or harrowed into soils known to be acid before seeding legumes or any other crop. It may also be applied in the fall of the year to any crop, but preferably it should be applied to the legume fields where its value will show very strikingly. Application should be made on a dry clear day when there is no dew on the plants. It can also be applied together with farm manures. It should be disked into the soil rather than plowed under. It can also be applied by means of a limestone or an end-gate spreader. The rate of application varies from one to three or more tons, depending upon the individual soil requirement.

## Home Mixing of Fertilizers

It is frequently desirable to apply commercial fertilizers containing two or more elements such as nitrogen and phosphorus or nitrogen, phosphorus and potassium, or any other combination. They are called complete fertilizers when they contain these three elements. These mixtures are usually prepared by mixing two or more single element-containing materials. However, nitrogen and phosphorus can be obtained as ammonium phosphate, potash and nitrogen as potassium nitrate, and phosphate and potash as potassium phosphate.

Mixed and complete fertilizers vary widely in the percentage of nitrogen, phosphorus and potash which they contain. Mixed or unmixed fertilizer materials containing high total percentages of these constituents are known as high grade or high analysis while those containing low percentages are known as low grade or low analysis. Between these two terms, there are all possible degrees of gradation.[7]

Mixed fertilizers should always be purchased on the basis of unit content and not on a price basis. Low analysis fertilizers contain high percentages of fillers.[8]

[7]See appendix for definition.
[8]Same as above.

A part of the cost of the fertilizers is consumed by freight and handling of filler material which does not contribute to the fertilizer value. Therefore, only high-analysis products should be purchased. By increasing the total plant food content, the cost per pound of plant food is frequently reduced one to three cents per pound.

Where large quantities of mixed fertilizer are used, a considerable saving in cost frequently can be obtained by the user doing his own mixing. When the spread between the retail cost of ingredients and retail price of mixed goods per ton is only $5.00 to $8.00, it may not be worth while to practice home mixing.

There is nothing difficult about mixing fertilizers. A little care in selection of materials and performing the mixing in a workmanlike manner are the main factors to be considered. Some of the terms used by the fertilizer mixing trade are:

(1) *Fertilizer formula*: The term formula should be interpreted as expressing the quantity and grade of the crude stock materials used in making a fertilizer mixture. For example, 800 pounds of 16 per cent superphosphate, 800 pounds of 9-20 tankage, and 400 pounds of sulphate of potash-magnesia constitute an open fertilizer formula.

(2) *Analysis*: The word analysis, as applied to fertilizers shall designate the percentage composition of the product expressed in terms of nitrogen, phosphoric acid, and potash in their various forms. For example, 5-15-5 means that the mixture contains 5 per cent nitrogen (N), 15 percent available phosphoric acid ($P_2O_5$) and 5 per cent available potash ($K_2O$).

(3) *Unit*: A unit of plant food is 20 pounds or 1 per cent of a ton. For example, ammonium sulfate contains 20 per cent nitrogen which is equivalent to 20 units of nitrogen per ton (400 pounds).

The Idaho fertilizer law provides that all bags of fertilizer offered for sale must be labeled stating the percentage of each ingredient present therein. (See Appendix.)

Certain materials cannot be mixed without producing a product which will cake and therefore will not drill satisfactorily.

Table 2 contains the most common fertilizer materials offered for sale in Idaho. The mixing can be done during slack seasons. List of firms selling fertilizers can be obtained from your County Agent.

The necessary mixing equipment is simple—a small platform scale, shovels or hoes, and any tight barn floor or wagon box. The mixture should be passed through a ¼-inch mesh screen and spread in layers, the bulkiest first, followed by the next bulky and so on until the least bulky is spread over the pile. It should then be

**Fertilizers and Soil Amendments Which May or May Not Be Safely Mixed.**[9]

| | | |
|---|---|---|
| Calcium oxide (quicklime)<br>Calcium hydroxide (slacked lime)<br>Calcium cyanamid | Should not be mixed with | Ammonium, sulfate, nitrate, chloride, or phosphate<br>Animal materials (bone, tankage, blood, fish scrap, farm manure, etc.)<br>Leunasaltpeter, leunaphos, etc. |
| Calcium oxide<br>Calcium hydroxide<br>Calcium carbonate<br>Wood-ashes<br>Basic calcium nitrate<br>Calcium cyanamid<br>Basic slag phosphate | Should not be mixed with | Soluble phosphates |
| Calcium oxide (quicklime)<br>Calcium hydroxide (slacked lime)<br>Basic calcium nitrate<br>Basic slag phosphate | Should not be mixed with except just before application to soil | Sodium nitrate<br>Calcium nitrate<br>Potassium salts<br>Potash manure salts: Urea |

[9]If some fertilizer not discussed in this bulletin is used, information regarding its use can be obtained by writing to the Extension Soils Specialist.

thoroughly mixed by shoveling or hoeing as in mixing mortar. This will require turning four times. Two men with shovels should screen, mix, and bag a ton of fertilizer in one-half to three-quarters of an hour. The rotary mixer used for concrete mixing can also be used for mixing fertilizer. The mixing should continue until the materials are uniformly mixed and no streaks of color are apparent. The material should then be sacked and stored in a dry place until used.

In calculating the number of pounds of each material required, it is not necessary to calculate the exact percentage or pounds required. A sample calculation is given herewith. A ton of 5-15-10 mixed fertilizer is to be prepared, in which ammonium sulfate (21 per cent nitrogen), treble superphosphate (43 per cent $P_2O_5$) and potassium sulfate (50 per cent $K_2O$) will be the sources of nitrogen, phosphoric acid, and potash respectively. The amount of ammonium sulfate required to make 1 ton of the mixture will be

$$\frac{\text{5 (percentage of nitrogen desired in mixture)}}{\text{21 (percentage of nitrogen present in ammonium sulfate)}} \times$$

2000 pounds (ton) equals 476 pounds of ammonium sulfate.

The amount of treble superphosphate required to make one ton of the mixture will be

$$\frac{\text{15 (percentage of } P_2\,O_5 \text{ desired)}}{\text{43 (percentage of } P_2\,O_5 \text{ present in treble superphosphate)}} \times$$

2000=700 pounds in round numbers of treble superphosphate. Likewise the amount of potassium sulfate required will be $10/50 \times 2000$ pounds=400 pounds. The total weight of plant nutrient carriers will be $476+700+400=1576$ pounds. It will then be necessary to mix 424 pounds of some filler with the above ingredients in order to prepare a ton of 5-15-10 fertilizer.

It usually happens that the sum of the amounts of the various ingredients is less than 2000 pounds. It then becomes necessary to apply either a smaller amount of the fertilizer or to include a filler. A filler is usually some inert material having no fertilizer value. This material may function as a drier or an absorbent of moisture.

**TABLE 4.—Quantities of Fertilizer Ingredients to Be Used to Give Definite Percentages in a Ton of Mixture**[10]

| Ingredient | 1 per cent lbs. | 2 per cent lbs. | 3 per cent lbs. | 4 per cent lbs. | 5 per cent lbs. | 6 per cent lbs. | 7 per cent lbs. | 8 per cent lbs. | 9 per cent lbs. | 10 per cent lbs. |
|---|---|---|---|---|---|---|---|---|---|---|
| **Carriers of Nitrogen (N):** | | | | | | | | | | |
| Sodium Nitrate (16%N) .. | 125 | 250 | 375 | 500 | 625 | 750 | 875 | 1000 | 1125 | 1250 |
| Sulphate of ammonia (21%N) .................... | 95 | 190 | 286 | 381 | 476 | 571 | 666 | 762 | 857 | 952 |
| Fish scrap (8%N)............ | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 | ...... | ...... |
| **Carriers of Phosphoric Acid ($P_2O_5$)** .................. | | | | | | | | | | |
| Super-phos. (16%$P_2O_5$).. | 125 | 250 | 375 | 500 | 625 | 750 | 875 | 1000 | 1125 | 1250 |
| Triple super-phos. (43%$P_2O_5$) .................... | 46 | 92 | 139 | 186 | 232 | 279 | 325 | 372 | 418 | 465 |
| Triple super-phos. (45%$P_2O_5$) .................... | 44 | 89 | 133 | 178 | 222 | 266 | 311 | 356 | 400 | 443 |
| **Carriers of Potash ($K_2O$):** | | | | | | | | | | |
| Potassium chloride (50%$K_2O$) .................... | 40 | 80 | 120 | 160 | 200 | 240 | 280 | 320 | 360 | 400 |
| Potassium chloride (60%$K_2O$) .................... | 33 | 67 | 100 | 133 | 166 | 200 | 233 | 266 | 300 | 333 |
| Potassium sulphate (50%) ............................ | 40 | 80 | 120 | 160 | 200 | 240 | 280 | 320 | 360 | 400 |

[10] Where the combined materials do not total 2000 pounds, a filler may be used to bring up the weight.

thereby preventing caking of the mixture. Finely ground fillers often improve the drilling qualities of the material. Frequently, the filler is some additional fertilizer element. Fine dry muck and peat are excellent driers but are very bulky. Some other driers frequently used are finely ground rock phosphate, fine sand, gypsum

**TABLE 5.—Fertilizer Mixtures and Amounts of Ingredients Required in Their Preparation**

| Analysis of Fertilizer Mixture | Sodium Nitrate 16 % N Lbs. | Ammonium Sulfate 21 % N Lbs. | Super-phosphate 45%$P_2O_5$ Lbs. | Super-phosphate 43%$P_2O_5$ Lbs. | Potassium Sulfate 50%$K_2O$ Lbs. | Total Fertilizer Material Lbs. | Filler to make 2000 Lbs. |
|---|---|---|---|---|---|---|---|
| 3-20-20 | ...... | 285 | 888 | ...... | 800 | 1995 | 5 |
| 2-20-20 | 250 | ...... | ...... | 930 | 800 | 2002 | ...... |
| 4-20-6 | ...... | 381 | ...... | 930 | 240 | 1573 | 427 |
| 5-15-5 | ...... | 476 | ...... | 698 | 200 | 1374 | 626 |
| 4-8-8 | ...... | 381 | ...... | 372 | 320 | 1073 | 927 |
| 6-20-8 | ...... | 571 | ...... | 930 | 320 | 1821 | 179 |
| 7-20-10 | ...... | 666 | ...... | 930 | 400 | 1996 | 4 |
| 5-20-12 | ...... | 476 | ...... | 930 | 480 | 1886 | 114 |

(gypsum should not be used in southern Idaho), fine granular dry earth, and ground sheep manure. If the grower does not desire to use filler, he can use a smaller amount of the mixture. For example, if the total weight of the plant food carrier ingredients is 1500 pounds in place of 2000 pounds, then only 75 per cent of the usual rate of application will be necessary.

When mixtures are made a considerable time before application, or if the season is damp, a drying filler should by all means be included. The mixed materials should be stored in as dry a place as possible until time for application.

The calculated amount of each fertilizer required in preparing a ton of various fertilizer formulas is shown in Table 5. To make a ton of the various mixtures shown in column 1, use the amounts shown in columns 2, 3, 4, and 5, or combinations of them. The required amount of filler is shown in column 7. If other ingredients are to be used, then the amounts can be calculated in accordance with method shown in Table 4 and discussed above.

Fertilizers should be purchased on the unit of plant food basis and not on the basis of price of mixed goods since low-priced goods usually contain high-priced units of plant food.

Further information concerning home mixing of fertilizer can be obtained by sending for Leaflet No. 70, Office of Information, United States Department of Agriculture, from which some of the preceding material was taken.

## Residual Effect

The amount of benefit which can be expected by the crop following the one receiving the application is influenced by the size of the application, kind of fertilizer applied, type of crop, and the kind of soil to which the application was made. Table 6 presents some data obtained in Cassia county during the past several years. The residual response is quite large in the fourth year after application. If the application was equal only to the amount contained in the first crop, little residual effect can be expected. Most nitrogen fertilizers recommended for Idaho are water-soluble and are, therefore, easily leached out of the soil. Applications of nitrogen fertilizers should not be larger than what will be required by that year's crop. Phosphates and potash-containing fertilizers are not leached out of soils very readily. It is only in the drainage water from sandy soils that appreciable amounts of these two plant nutrients are found. Phosphates and potash fertilizers move downward in the soil very slowly. Under most Idaho conditions, sufficiently large applications of phosphate- and potash-containing fertilizers can be profitably made at one time to last for several years.

In spite of the fact that there is an insufficient amount of some element available in the soil at any one time to produce maximum yield, there is frequently sufficient of it becoming available which, together with the amount applied, will cause increased yields to be obtained long after the crops have utilized the amount present in the original application. Field demonstrations are useful in determining the required frequency of applications necessary for obtaining maximum yields.

**TABLE 6.—Influence of Rate of Application on the Residual Effect of Phosphate Applications Made to Alfalfa in 1934[11]**

| Year | Cutting | Increase in Yield Over Untreated Areas Due to the Application of | |
|---|---|---|---|
| | | 125 lbs. Treble Superphosphate | 250 lbs. Treble Superphosphate |
| 1934 | 2nd | 7 pct. | 30 pct. |
| 1935 | 2nd | 20 pct. | 125 pct. |
| 1936 | 1st | 19 pct. | 81 pct. |
| | 2nd | 38 pct. | 30 pct. |
| 1937 | 1st | 50 pct. | 87 pct. |

[11]Results obtained in cooperative demonstration in Cassia County.

## Appendix

A. Definitions of terms used in the fertilizer industry.

1. *Available or soluble phosphoric acid*—The sum of the water-soluble and the citrate-soluble phosphoric acid.
2. *Commercial fertilizer*—Any form of plant food not obtained from animal manures or plant residues. They may be pure chemicals or by-products of some industry. They contain definite amounts of plant food.
3. *Complete fertilizers*—Fertilizer mixtures containing nitrogen, phosphorus, and potash. They may be present in various ratios which may be or may not be suitable for the specific crop. For example 3-16-10.
4. *Concentrated* (or multiple strength)—See low grade.
5. *Filler*—Any material which is added to a mixture of straight fertilizers for the purpose of improving the mechanical condition of the mixture, acting as a drier or adding bulk to the mixture. Sheep manure is probably the best filler for use in Idaho, since it contains some plant food as well as organic matter. Fine sand, gypsum, and muck are other materials which can be used.
6. *High grade*—See low grade.
7. *Insoluble*—Not soluble. As applied to phosphoric acid in fertilizers it means that portion of the total phosphoric acid which is neither soluble in water nor ammonium citrate. It is a plant food or plant food constituent which is in such form or combination that plants cannot utilize it. Or it may become available so slowly under favorable conditions that it does not furnish appreciable amounts of plant food utilizable by growing crops.
8. *Low-analysis or low-grade fertilizer*—Can be considered only as a general term. As an approximate generalization, complete mixed fertilizers containing a total plant food content of less than 15 per cent of nitrogen, available phosphoric acid, and water-soluble potash are regarded as low analysis or low grade. Medium-grade fertilizers are those containing 16-20 per cent; high grade are those containing 20-30 per cent; concentrated- or multiple-strength fertilizers are those containing over 30 per cent.

9. *Medium grade*—See low grade.
10. *Mixed goods*—Materials containing more than one element.
11. *pH*—A symbol for expressing the relative acidity or alkalinity of the soil. All values less than 7.0 mean that the material is acid in reaction. All values greater than 7.0 mean that the material is alkaline in reaction.
12. *Phosphoric acid* ($P_2O_5$)—Phosphorus present expressed as its oxide in the fertilizer.
13. *Plant food*—A substance which supplies any constituent necessary for the nourishment of plants.
14. *Potash* ($K_2O$)—Potassium present expressed as its oxide in the fertilizer.
15. *Straight goods*—Materials containing only one plant food element.

B. Some of the provisions of the Idaho fertilizer law.

This law governs the sale of all products sold for fertilizing, manurial, soil enriching, or soil corrective purposes with the exception of animal manures which have not been artificially treated. The fertilizer containers must have printed on them a statement of the contents or have a tag attached which includes the following information:

a. The net weight of the contents of the package.
b. The name, brand, or trademark.
c. Name and principal address of the manufacturer or person responsible for placing the commodity on the market.
d. The minimum percentage and source of nitrogen in available form.
e. The minimum percentage and source of potash ($K_2O$) soluble in distilled water.
f. The minimum percentage and source of available phosphoric acid ($P_2O_5$), and also the total phosphoric acid content.
g. The content of any other material from which a benefit is claimed shall be stated.

All containers of unmixed products such as nitrate of soda, sulfate of ammonia, sulfate and muriate of potash, lime, gypsum, aluminite and phosphate, or other fertilizer or soil correcting substances shall have stamped thereon a plain statement in the English language of the name of said material and the guaranteed per cent of the elements or element contained which give the commodity its value as a fertilizer.

The law provides for analysis of samples of the various fertilizer products at least once a year for the purpose of determining whether or not they conform to the law. The results of these analyses are published each year in the report of the Commissioner of Agriculture.

Copies of the complete fertilizer law may be obtained by writing to the State Commissioner of Agriculture, Boise, Idaho.

## Soil Sample Data Sheet

Date.............................................................. Lab. No..........................................................

Name.......................... County.................. P. O. Address.............. Section....... Twp........

Range............ Located .............. Miles & .............. Miles .............. of ...........................
(N, E, W, S.) (N, E, W, S.) (N, E, W, S.)

Discuss your soil problem, if possible, with your county agent before taking samples.

**INSTRUCTIONS FOR TAKING THE SOIL SAMPLE:**

The area should be uniform as to drainage, topography, and underlying parent material. Remove straw and litter from spot to be sampled. Sample the area in six to eight places to a depth of six to nine inches or plow depth, but never into the subsoil. A bucket and a spade are the necessary tools. Dig a hole to the desired depth. Shave off one side of the hole with shovel to make smooth and uniform. Cut a thin slice along smooth wall. Place the middle vertical three inches of this slice in bucket. Take six to eight samples in this manner. Mix these samples together thoroughly. in the bucket or on a canvas. Place a one to two pound portion of the mixture in a clean, tight, cloth or paper bag, clean ice cream carton or similar clean container for mailing. If the soil is wet, let it dry before mailing.

Address sample to Extension Soils Specialist, University of Idaho, Moscow.

**INFORMATION**

Crop this year......................... Crop last year..................... Crop two years ago...................

Crop three years ago....................... Crop four years ago........................ If in forage crop

for past four years, what is age of present seeding?............................. Kind of subsoil

(gravel, clay, loam, hardpan, etc.)...................... Depth to subsoil...................... Drainage

(good, poor, seepage, etc.)...................................... Symptoms of difficulty (poor growth,

salts on surface, poor stand, poor yield, etc.) .............................................................................

...........................................................................................................................................

When was barnyard manure applied last?.................................. and how much was

applied..........................(T). How frequently do you apply manure on field?.................

If in orchard, do you grow cover crop?...................................... How and when do you

cultivate cover crop?.........................................................................

Comments:

...........................................................................................................................................

**RESULTS OF EXAMINATION:**

Texture.................... Color.................... Total Salt Content.................... $CO_3$...................

$HCO_3$............ $SO_4$............ Cl............ pH.................. Av. P................... Lb. per A.............

Av. $K_2O$.................................................. Total N...........................................................

Cut here