

Facts to Consider in Fertilizing Farm Crops



Applying fertilizer on the bottom of the furrow with a plow attachment.

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THE PRIMARY OBJECT of fertilization is profitable increase of crop yields. Fertilizers are useful also in promoting a more vigorous start, earlier maturity, and often higher quality in the crop. The direct effect of commercial fertilizer in maintaining or improving fundamental soil fertility seldom is very important, except in the case of heavily fertilized crops, such as potatoes or vegetables. The amounts of plant food, particularly nitrogen, ordinarily applied on grain crops are too small to change significantly the plant food content of the soil. The principal means of soil improvement at the farmers' command are legume and grass sods, cover crops, crop residues, and manure. However, the fertilizer may have a pronounced effect on future fertility by helping to get better sods, clover and cover crops, and by stimulating their vigorous growth.

Nitrogen, Phosphoric Acid, and Potash

CONSIDERATION of any system of fertilization should include the primary functions of the three principal plant foods.

Nitrogen stimulates growth. It is especially needed in cold, wet seasons or on poor soil. Lack of nitrogen is indicated by light green or yellow foliage and in the yellowing and dying of the lower blades of corn from the midrib toward the tip in an inverted V. This is often called "firing." If applied liberally, nitrogen tends to promote a rapid growth of rank, dark green stalk and leaf; it may delay maturity somewhat and often increases the danger of grain lodging. Manure, nitrogen-fixing bacteria, soil organic matter, and legume sods turned down generally furnish enough nitrogen on fairly fertile soil for general farm crops in a good rotation.

Phosphoric acid has a very marked stimulating effect on early growth, particularly on root growth. Much of the stimulation attributed to nitrogen where a complete fertilizer is used doubtless is due to phosphoric acid. It is the most active agent in promoting early maturity and uniform ripening. It is important in the formation of grain and seeds and promotes the growth and vigor of alfalfa and the clovers. All Pennsylvania soils naturally are low in phosphoric acid, and manure supplies little of it. Phosphoric acid in general farming is the most important element and gives the largest returns per dollar invested. Until it is supplied in adequate amounts the other elements may bring little or no response.

Potash also is important in healthy, normal plant growth and in the formation of grain, seeds, and tubers. Lack of enough potash seems to hasten the death of potatoes, particularly in dry seasons, and often gives the vines an unnaturally dark green color. In potash-deficient corn the outside edges of the blades may wither and die. White spots around the margins of clover and alfalfa leaves are believed to show potash deficiency. Severe potash shortage may cause weakness of straw or stalk, but lodging of small grain generally is due to excess nitrogen and moisture rather than lack of potash. Potash is most deficient in soils of sandy or mucky nature. Manure furnishes considerable amounts of potash, most of it being in the liquid manure. Most soils contain large quantities of potash but in relatively unavailable forms. If hay, fodder, and straw are left on the land or returned to the soil as manure and bedding, the potash problem seldom is serious. Where manure never is applied, potash is needed for the satisfactory growth of most crops.

High Analysis Fertilizers

The Pennsylvania Fertilizer Law requires that all mixed fertilizers contain a total of at least 16 per cent, or 16 units, of plant food. It is now possible, through the use of high-analysis phosphates and synthetic nitrogen and phosphoric acid products, to make very much higher analysis mixtures than formerly. Some of these, such as 8-24-8 or 8-16-16, contain double the plant food in a 4-12-4 or 4-8-8 respectively. All the plant food in these high-analysis fertilizers usually is water-soluble. Experiments indicate that it is practically equal in efficiency to the standard forms when applied in equivalent amounts. Being easily dissolved, these materials are rather caustic and may injure germination if applied too heavily in the row. The high-analysis goods carry less sulphur, calcium, and some of the salts found in the standard complete fertilizers. While these usually are not considered as plant foods they may be important under certain soil conditions as foods or stimulants, especially on unmanured soils of rather low fertility. Just what the effect of the *exclusive* and continued use of high-analysis fertilizers will be is not definitely known.

The higher analysis goods are lower in price per unit of plant food. Where the freight rate is high and the labor of hauling and handling of heavy applications is burdensome, high-analysis materials are especially economical. When applications are light, as on grain crops, it may be difficult to distribute evenly the small amounts desired of the double-strength fertilizers. Their greatest usefulness may be on potatoes and vegetables where liberal amounts of complete fertilizers high in nitrogen are profitable. The drilling condition of the higher analysis goods is generally excellent, although they may harden if exposed to the air for some time.

Mixed fertilizers, nitrogenous materials, and superphosphate are now available in granular or pellet form. Such material seems just as effective and is much less dusty to handle. It flows freely in drills and planters and is very convenient for hand application. Granular phosphate is not slippery when used on wet cow stable floors. Drills and planters must often be shut down to apply the desired amount. In a home-made mixture containing nitrogen and potash salts, the use of the *granular* superphosphate as a base will help to insure good drilling condition.

Fertilizer Ratios

On account of the higher-analysis fertilizers now available, it seems desirable to base recommendations on the best ratio or proportion of the three plant food elements, rather than a definite percentage of each. Having the three elements in *proper balance* may be as important as having them in adequate quantity. Thus a ratio of 1-2-2 would be represented by a 5-10-10, or an 8-16-16, either of which would be equally suitable for such a crop as potatoes. A 1-4-2 ratio, such as a 3-12-6 or 5-20-10, would be equally suitable for grain crops. The amount of fertilizer may be stated in pounds of total plant food per acre instead of in pounds of fertilizer of a certain analysis. Thus for potatoes, instead of saying 1000 pounds of 5-10-10 we might say 250 pounds of plant food in a ratio of 1-2-2. Six hundred twenty-five pounds of an 8-16-16 would supply the same plant food in the same ratio, or one might specify 50 pounds of nitrogen in a 1-2-2 ratio.

Authorized or Approved Ratios and Analyses

Pennsylvania Ratios	Minimum grades	Higher analyses in the same ratio
0-2-1	0-14-7	0-16-8 0-20-10
0-1-1	0-12-12	0-14-14, 0-20-20
1-4-2	3-12-6	4-16-8, 5-20-10
1-3-2	4-12-8	5-15-10
1-3-3	4-12-12	5-15-15, 6-18-18
1-3-1	4-12-4	6-18-6
1-2-2	5-10-10	8-16-16
1-2-1	5-10-5	8-16-8
5-3-2	10-6-4	
1-1-1	7-7-7	10-10-10
1-3-4	3-9-12	5-15-20
1-2-3	4-8-12	
1-3-5	3-9-15	4-12-20
1-4-0	4-16-0	Ammoniated superphosphate

The 4-8-12, 3-9-15, and 3-9-12 analyses are primarily for tobacco.

To reduce as far as practical the great number of ratios and analyses formerly sold and for the sake of simplicity and economy, the fertilizer industry met annually with representatives of the Experiment Stations and farm groups during the recent war and agreed to limit the number of ratios for the various states to the lowest number adequate to care for various crops and situations. In Pennsylvania the 14 on page 4 were agreed upon for 1945. While no longer obliged to adhere to this list, the industry probably will do so unless scarcities of materials make changes necessary. *Minimum* grades or analyses were also decided upon, all of 20 units or higher. Higher analyses in the same ratios are also listed.

Method of Application

There is no question but that fertilizer, especially in relatively small amounts, is much more effective when applied close to the seed rather than broadcast. When applied with the drill or planter it is close to the sprouting seed and has much more of the desired stimulating effect on early growth. Where applied in *direct contact* with the seed, it is not safe to use too much of fertilizers composed almost entirely of soluble, and therefore caustic, minerals. The nitrogen and potash salts are the portion most likely to cause injury to germination and early growth, especially if there is not adequate moisture at and following planting. Old-style corn planters put the fertilizer directly into the row with the seed and 200 pounds of mixed goods per acre was as much as was safe. Modern planters apply the fertilizer along the sides of the row so that applications may safely go to 300 or 400 pounds if desired. Most corn planters put the fertilizer too close to the surface for best results. With small grains one may go up to 400 pounds of mixed goods in the drill, but with over 70 pounds per acre of combined nitrogen and potash there may be danger.

Fertilizers broadcast or drilled shallow on the seedbed for corn, potatoes, etc., are relatively inefficient. Phosphate and, to a less extent, potash are not readily washed down into the soil. They also tend to combine chemically with other soil elements. If mixed with the soil by harrowing or cultivation this "fixation" is increased so that only a small part of these nutrients may reach the root zone. Soluble nitrogen is readily washed down, but may be brought back and left on the surface by evaporating soil moisture. Broadcast fertilizer may help the weeds more than the crop.

Deep Application of Fertilizer

Most good general farmers plow down manure and sods for corn. On fertile soils these may be adequate to supply enough nutrients to produce a good crop, especially if supplemented with a row application

of fertilizer. Where manure is not available or in very small amounts and where there is no legume sod to supply nitrogen, or where maximum possible production is desired, it may be desirable to apply as fertilizer more nearly the amounts of plant food required to produce a satisfactory crop. In such case they should preferably be gotten well down into the root zone where there will be more moisture to keep them in solution and available throughout the season. On some soils it may be possible to drill fertilizer deeply enough into the seedbed (at least 4 or 5 inches) so that it will not be disturbed by cultivation. Since this is often impractical, it may be applied before plowing and turned down. Plow attachments are available with which the fertilizer may be applied in a band on the bottom of the furrow where it will not be disturbed. This reduces fixation of phosphoric acid and potash to a minimum. Some mid-west experiments show better results from this "plow sole" application compared to broadcasting and plowing down, but the broadcast and plow-down method is much more convenient and seems usually to be equally efficient.

Using superphosphate in the stable and plowing it down with the manure are desirable to reduce volatilization losses of nitrogen and to balance the nitrogen and potash in the manure. Plowing under phosphate and potash may be helpful in some cases, especially with long-lived, deep-rooted crops, such as alfalfa, or where a heavy growth of clover is turned down for potatoes. However, the principal benefit evident from deep application of fertilizer on corn seems to come from the nitrogen. Ample nitrogen applied deeply has greatly reduced or eliminated the "firing" of corn in dry periods. In Ohio experiments straight nitrogen has given as great increases as complete fertilizer at about half the cost.

High-nitrogen complete fertilizer, such as 500 pounds of 10-10-10, or straight nitrogen goods, plowed down for corn will probably be most profitable where the soil is rather deficient in fertility and in the absence of manure or clover sods; also where a secondary object is to improve fertility through the residual effect of such fertilization. The succeeding crops of small grain and clover may be helped, largely by the phosphate and potash.

Where large amounts of *low* nitrogen material, such as straw, corn fodder, unharvested grass hay or weeds, or too large non-legume cover crops, such as headed rye, are plowed down they may rot slowly and tie up soil nitrogen. Plowing under with them 50 pounds or more of soluble nitrogen per acre, as in 150 pounds of ammonium nitrate, will speed up bacterial action and rotting and reduce the depletion of soil nitrogen by the decomposition bacteria.

Where liberal amounts of nitrogen or high-nitrogen complete fertilizers are plowed down on fertile soil, it will usually be necessary to

plant corn more thickly in order to utilize properly the additional fertility and obtain the maximum increase in yield. In dry seasons and on droughty soils there may not be enough moisture to support such stands.

Plowing down of fertilizer has been most profitable on such crops as tobacco, tomatoes, and hybrid corn for seed. With such crops the acre value is relatively high and a rather small percentage increase may pay for considerable fertilizer. The probable price for the crop and the relative cost of the fertilizer also should be considered.

Topdressing of corn or potatoes is not generally advisable for the reasons stated above. Sidedressing with an attachment on the cultivator has not proved worth while on corn on most soils. It may be advisable for corn on light soils where too much nitrogen applied at planting might stimulate excessive early growth, or be partly lost by leaching. Sidedressing may be profitable on some truck crops. On potatoes too much nitrogen after the tops are well grown may tend to stimulate excessive and continued vine growth and reduce and delay the set of tubers. Unless the soil is rather poor, ample nitrogen for most crops should become available from midsummer on through the decomposition of soil organic matter by bacteria.

Fertilizing Specific Crops

Corn responds to row application of fertilizer with much more rapid early growth, earlier maturity, and generally increased yields. Much of this effect is due to the phosphoric acid and, with manure and high fertility, 200 pounds of superphosphate *may* be all that is profitable on corn planted in a warm soil. Where fertility is not high and where no manure has been applied a complete fertilizer, such as a 3-12-6, 4-12-8, or 4-12-4, will be advisable, also perhaps where corn is planted *early* before soil nutrients become adequately available, or in the northern and high-altitude counties where springs are often late and cold.

As stated before, the amount of fertilizer applied with the planter may vary, depending on the apparent need and how the planter applies it. Two or three hundred pounds an acre in the row are enough to give the crop the desired start. If more nutrients seem needed, additional nitrogen or a high-nitrogen complete fertilizer may be plowed down or drilled deeply as described earlier. Experiments on this practice for corn have given variable results; factors such as adequate stand, moisture, etc., are important. It cannot be generally recommended but with the soil and weather conditions discussed under "Methods of Application," it deserves consideration. A row application to act as a starter is still needed with plow-down treatment.

Wheat and winter barley are very responsive to fertilizer. Where manure is applied before sowing the wheat, or was applied for



Unfertilized drill width in comparison with stimulation to early growth by fertilizer in a wheat fertilizer demonstration.

the crop preceding the wheat, or where the wheat follows potatoes, 200 or 300 pounds of superphosphate to the acre usually will be most profitable. Larger amounts of superphosphate in the drill have sometimes reduced wheat yields. Where no manure has been applied for over a year, 20 to 50 pounds of potash should be added as in 300 to 400 pounds of an 0-14-6 or 0-12-12, or an equivalent amount in a higher analysis. The use of a complete fertilizer is customary on wheat and in many experiments it has proved profitable. On soils of *below* average fertility, or where wheat follows an exhaustive crop, such as soybeans or buckwheat, it is certainly advisable, especially if seeding is late. Where a complete fertilizer seems needed 300 to 400 pounds in a 1-4-2 or 1-3-2 ratio, such as a 3-12-6 or 4-12-8 would be suitable.

Since a legume is often sown on the wheat, its needs for phosphate and potash, over the one or more years it will be mowed for hay, should be kept in mind. Too many farmers use only about 200 pounds of 3-12-6, which supplies too little of these elements for the grain crop and leaves little or none for the clover or alfalfa crops which follow. Too much nitrogen on fertile soil *may* increase the danger of the grain growing too large and lodging.

Experiments on topdressing wheat with nitrogen in the spring have given variable results. It should never be done where there is danger of lodging, since it will stimulate greater straw growth and increase that hazard. Any stimulation to straw growth is also likely to have a decidedly depressing effect on the clover or alfalfa seeding, even where lodging does not occur. Topdressing will probably give the greatest

increases (1) on soils of only fair fertility or below, where yields average 25 bushels an acre or lower; (2) where no manure has been applied or clover sod plowed down within a year before the wheat is sown; (3) when precipitation during the late winter and spring has been heavy with little frost in the ground, resulting in heavy leaching out of available soil nitrogen as shown by yellowing of the spring growth of wheat; and (4) where ample phosphate and potash were applied when the grain was sown. It will be more likely to be profitable when the price of wheat is high.

Stalk-ground wheat, which often is not seeded down, and which seldom lodges, might be profitably topdressed under the conditions listed above. Not less than 20 and not over 40 pounds of nitrogen in the form of nitrate, sulphate, or ammonium nitrate, might be used, preferably before April 15. There seems to be no data on topdressing winter barley but it might respond profitably under the above-named conditions.

Oats is not so responsive as wheat to fertilizer but may be fertilized in a similar manner. The needs of the hay crop sometimes sown with the oats also should be supplied. On well-manured land or following a heavily fertilized potato crop, 200 to 300 pounds of superphosphate an acre may be adequate. On less fertile land where there is *no* danger of lodging, a complete fertilizer such as a 3-12-6 or 4-12-8, will generally be advisable at the rate of 250 to 400 pounds. A complete fertilizer may produce a somewhat more *uniform* early growth following crops heavily fertilized in the row.

Buckwheat is very responsive to 200 pounds of superphosphate an acre. It is often grown on rather poor soil, in which case 200 to 300 pounds of an 0-14-7 is advisable. With low fertility a 3-12-6 will pay, especially on a seedbed which was plowed and prepared late. Nitrogen, except on poor soil, may cause lodging, and nitrification should be rapid while buckwheat is growing.

Soybeans and their inoculating bacteria are very likely to be injured by fertilizer salts drilled with the seed. One hundred fifty pounds per acre of superphosphate or 0-14-7 is as much as is safe. Nitrogen should not be needed if the beans are inoculated as they should be. Fertilizer may help the weeds more than the beans. Plowing down of phosphate and potash may help beans but they have shown the least response to fertilizer of any common crop; on very acid soils a few hundred pounds of ground limestone in the drill is safe and may be more beneficial than fertilizer. Where beans are planted in wide rows with a corn planter, extra care must be taken to keep the fertilizer away from the seed.

Potatoes are a high acre-value crop and will pay for liberal fertilization. During the war, when potatoes and labor were high and

fertilizer relatively cheap, many growers in Pennsylvania radically increased fertilizer applications. There is some question as to whether much over 1200 pounds of normal-strength fertilizer applied with the planter is consistently profitable. With manure or a legume sod turned down, 250 pounds of plant food in a 1-2-2 ratio, such as 1000 pounds of a 5-10-10, is a good treatment. Without manure, especially on early potatoes, this might be increased somewhat. With late potatoes, especially Russets grown on fertile soil, if there has been a tendency to make excessive or prolonged vine growth, a 1-3-3 ratio, such as a 4-12-12 used in somewhat smaller amounts may produce adequate vines and a better set and yield.

With applications up to 1000 pounds all the fertilizer may as well be put on with the potato planter. It should be placed in bands on each side of the row, at least 2 inches from the seed and about as deep as possible. Care must be taken that the planter does not get out of adjustment and put the fertilizer in contact with, above, or below the seed, especially with heavy applications. Where one wishes to put on over 1000 pounds of normal-strength goods, it seems advisable to plow one-third to one-half of it under and apply the remainder with the planter. This reduces danger of injury from too much fertilizer close to the seed, lessens labor during the rush planting period, and generally increases yields especially in dry seasons. A ratio similar to that used in the planter is generally plowed down.

Timothy, top dressed in early spring with 20 to 30 pounds of nitrogen, as in 100 to 150 pounds of nitrate or sulphate of ammonia or 75 to 100 pounds of ammonium nitrate an acre, will produce at least 1000 pounds more hay, especially on soils capable of producing only about a ton without treatment. The percentage of protein and the leafiness of the hay may also be increased. One hundred to 200 pounds of superphosphate mixed with the nitrogenous material generally will give a further increase or one may use 200 to 300 of a 10-6-4 or 10-10-10. The phosphate and potash will help *maintain* production where the sod is to be mowed for several more years. Too *much* nitrogen may result in lodging and coarse, stemmy hay.

Alfalfa and seedings of Ladino clover or pasture mixtures, made without a grain crop, should be well fertilized when sown. On very fertile or well-manured fields phosphate may be the principal thing needed and 300 to 400 of superphosphate an acre may be adequate. Usually the addition of potash will be profitable as in 400 to 600 pounds of 0-14-7 or 0-12-12. A complete fertilizer, such as 400 pounds or more of 3-12-6, 4-12-8, or 4-12-12 will give a better start on rather thin soil. The fertilizer should be gotten well down into the soil by deep drilling. With very heavy applications of phosphate and potash for long-lived stands, part of it may well be plowed down.

Alfalfa which has been mowed one or more years may profit from fall or early spring topdressings of 400 pounds of superphosphate, or better phosphate and potash in an 0-1-1 or 0-2-1 ratio. If manure is used liberally and often, the potash may not be needed. Ladino clover may be made more productive, and the stand better held, by similar treatment. Alfalfa, and perhaps Ladino and the other clovers, sometimes suffer from deficiencies of boron. This shows as a yellowing and shortening of the *terminal* growth of the second crop of alfalfa and in light blooming and seed setting. Commercial borax applied by hand or with a grass seeder at the rate of 25 to 40 pounds may correct this condition, or one may use 400 pounds of a commercial mix of 0-19-19 to which 100 pounds of borax has been added per ton. Boron and potash shortages seldom appear in the first cutting, and spring applications may be wastefully used by the first crop, so that applying borax or borax-potash and phosphate right after harvesting the first cutting may be advisable on alfalfa or where a crop of clover seed is desired.

Permanent Pasture sods that are rather poor and weedy need fundamental soil improvement. Lime usually is the first essential if a test shows the need of more than a ton of limestone to the acre. Superphosphate also should be applied at the rate of at least 400 pounds per acre. On soils lacking in potash, 50 to 100 pounds of muriate may well be added, or an 0-14-7 or 0-12-12 applied liberally. Such treatment will bring in white clover and the better grasses, thicken the turf, and greatly improve the quality and quantity of the grazing. Four hundred pounds of superphosphate applied every other spring on a limed soil in a State College experiment at Kylertown has more than doubled production, brought in bluegrass and white clover, and increased the lime and phosphorus content of the herbage 25 per cent. Fertilization every few years and liming at longer intervals should maintain satisfactory production. For prompt and satisfactory improvement of limed pasture, especially on very poor soil, a fall or winter application of manure re-inforced with 50 pounds of superphosphate per load is the ideal initial treatment.

The profitable place of nitrogen on pasture is probably limited to good grass sods containing little white clover which are to be intensively grazed with high-producing cows. Forty to 50 pounds of nitrogen an acre, as in about 300 pounds of nitrate, sulphate of ammonia, or 150 to 200 of ammonium nitrate, or 400 to 500 of a 10-6-4 or 10-10-10, applied in early spring will stimulate an earlier and more luxuriant growth of grass during May and June. The effect of nitrogen application, however, is relatively short-lived and does not overcome the normal shortage later in the summer. Nitrogen treatment should be supplemented with lime, phosphate, and potash at suitable intervals. Applying nitrogen tends to reduce the amount of white clover in pasture unless

it is closely and evenly grazed, thus cutting off the natural supply of nitrogen from the clover. The effect of small amounts of nitrogen as in 4-12-4 or similar mixtures is slight, short-lived, and generally unprofitable.

Chemical Soil Tests

Soil tests can be made with fair accuracy to determine whether the soil is acid. These tests also will show how badly lime is needed, or about how much lime would be required to make the soil neutral. County agricultural agents each year make thousands of acidity tests.

Testing the soil by so-called quick methods to determine the amount of available plant food, in order to ascertain fertilizer needs, has received much attention. When such tests are made by an experienced chemist in a well-equipped laboratory on properly taken soil samples, they may be of some assistance in special cases in diagnosing soil troubles. In amateur hands, however, they are of little value and may be actually misleading. Available phosphorus is almost invariably low in Pennsylvania soils. In winter and spring when soil samples are more likely to be tested, available nitrogen generally is low because of leaching by rains and the lack of bacterial activity. The same soils may contain ample available nitrogen in warm weather.

Apparently the best guide for economical fertilization of grain crops is the past treatment of the soil. Some years ago a large number of fertilizer demonstrations were put on with the drill on wheat, during several seasons and on most Pennsylvania wheat soils, the idea being to show relative responses from normal farm fertilization. Where manure was applied for the wheat, or the crop preceding the wheat, 200 pounds of 16 per cent superphosphate gave an average increase of 6 to 7 bushels over no fertilizer, but neither nitrogen nor potash averaged much increase. Where the manure had been applied for the corn two years before, as is the common practice, 300 pounds of 0-10-5 gave an average increase of only .8 bushel of wheat over 200 pounds of 16 per cent phosphate, and 300 pounds of 2-10-5 averaged only 1.3 bushels over the superphosphate. In some cases the potash gave profitable increases, and in a few instances the nitrogen showed a profit, but on the average both were applied at a loss. The mixed goods cost much more than the phosphate and an increased amount was required to furnish enough phosphoric acid. On fields where *no* manure had been applied recently, 300 pounds of 0-10-5 averaged 2.9 bushels over the superphosphate and the complete fertilizer averaged 3.6 bushels over the phosphate. Here the potash gave a profitable increase in the wheat crop and often improved the clover seeding, while the nitrogen also gave a good increase in the wheat.