8 to 12 mm.; total length of tubing, 25 cm.; inner long axis of solenoid, 4 cm.; inner short axis, 0.5 cm.; length of needles, 2 to 3 cm.; distance of the two needles, 15 mm.; surface of electrodes, about 100 sq. cm.

The whole is mounted on a stand of the kind used in electroanalysis. The electrodes are fixed in electrode holders, and the astatic needle is suspended by a cocoon fiber to the glass rod, which for this purpose is bent at the top. The external circuit should pass at a distance of at least 10 cm. from the solenoid, in order to avoid any disturbing influence upon the needle.

Using polished platinum plates as electrodes and 30 per cent. sulphuric acid as an electrolyte, the instrument showed a total internal resistance of about 50 ohms. The resistance did not change more than 0.5 per cent. when electrodes of somewhat different size were used, or when they were moved as much as 2 cm. from their original position, nor did filling of the fluid in the cells to different levels cause an appreciable change in the resistance. The total resistance of the instrument is always very nearly equal to the calculated resistance of the solenoid. These facts simplify the calculation of results, if the instrument is used for measuring purposes.

It may be mentioned that the electrolyte galvanometer can be used to advantage for measuring alternating currents. For this purpose it is only necessary to fill it with sodium phosphate solution, and to use one aluminium and one platinum electrode. Owing to the insulating layer of aluminium oxide, which is formed instantaneously if aluminium acts as anode, the current (as Graetz and others have shown) can only pass in one direction, and the direct current thus formed deflects the needle. A rational scale may be easily graduated by comparison with an electrodynamometer.

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REVIEW OF FOREIGN WORK IN AGRICULTURAL CHEMISTRY.

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OWING to the vast amount of research which has been done along the lines of agricultural chemistry during the last few years it has been found impossible to cover all of the ground thoroughly, but an attempt has been made to review briefly some of the more important work and to classify this so as to show partially the advancement which has been made in this field.

Another factor which rendered anything like a complete review possible is the very close relationship which agricultural chemistry bears to agriculture and some of the other related sciences; in fact, there is no sharp dividing line, one shading off into the other so perfectly that what many authors consider in one sphere another will place in the other. Therefore, it has been decided simply to consider in this review those articles which deal primarily with subjects which obviously fall under the head of agricultural chemistry.

Following out this plan, therefore, the work has been classified under the general heads of fertilizers, soils, field crops, feeding experiments and dairying, and then these have been subdivided accordingly as the case required.

FERTILIZERS.

Phosphoric Acid.—As there seems to have been more work done on fertilizers than on any other subject this will be noticed first. Under the general head of fertilizers is included phosphates (of all kinds), potash salts, nitrates, ammonium sulphate, organic nitrogen, barnyard manure, green manuring and nitrogen derived from the air by leguminous crops. With the foregoing substances we find accounts published of almost unending numbers of pot and field experiments, which, in many cases, bring out valuable data in regard to their value in agriculture, either for some specific crop or relatively to each other.

Of the different kinds of fertilizing materials probably more work has been done on phosphates than on any other substance. A large number of experiments are reported on the relative value of phosphoric acid in the form of superphosphate, Thomas slag, bone meal and ground mineral phosphates. In general, almost all of the experimenters along this line conclude that, except on special classes of soils, superphosphates are the most valuable. In pot experiments with superphosphates bone meal and Thomas slag Rindall[1] has concluded that superphosphate has a higher value as a phosphatic fertilizer than either Thomas slag or bone meal, and that the latter two, contrary to the results of German experiments, are about equal. As regards the value of the water-insoluble phosphoric acid contained in superphosphates, Schulze[2] has shown by experiments with oats that this form has about one-third the fertilizing value of the water-soluble phosphate and this may be increased to about one-half under favorable conditions and in case there is a lack of phosphoric acid.

[1] Landtbr. Styr. Meddel., No. 44, pp. 19-28 (1903).

[2] Deut. Landw. Presse., **30**, No. 2, pp. 12-13 (1903).

As regards the action of soil moisture on the different phosphates it is stated by one investigator[1] that the moisture content of the soil does not affect the action of the phosphoric acid of bone meal, but does affect that of Thomas slag and superphosphate, the action being favored by an increase in the water content. Ullman[2] has shown that the water-soluble phosphoric acid, when applied as a top dressing, circulated in the soil and remained soluble in water for a long time, the rate of inversion being dependent on the amount of lime, magnesia, oxide of iron, etc., present, and by this method the phosphoric acid is distributed uniformly through the soil in a fine state of division and is therefore easily assimilable by the plant, and it is to this fact that many attribute its value. However, Paturel[3] has shown that in all cases this is not true, especially in light soils, having little absorptive power and poor in lime; in this case he found a portion of the superphosphate still soluble after a lapse of several months. His results show that the plants take up their phosphoric acid in a soluble form and that the soil solutions are an important factor in furnishing it. It is not, however, necessary for all the phosphoric acid to be in a state of solution as Schloesing[4] has shown by experimenting with maize grown on soils one rich and the other poor in phosphoric acid; in the rich soil containing 1,012 mg. per 36 kg., of water-soluble phosphate, the plant removed 1,115 mg., while in the poor soil containing 199 mg. the plant obtained 451 mg. This shows that the roots of the plant are able to dissolve the phosphates without the assistance of the soil water and, therefore, it is not necessary for them to be in a state entirely soluble in water. However, in soils which have no solvent power for phosphates the roots of plants exert quite a difference in degree, it having been shown that maize exerts a very great solvent action on mineral phosphates, and that in the case of beets it is very small, while leguminosae occupy an intermediate position.

Among the other causes influencing the action of phosphates the investigations of Schreiber[5] may be mentioned; these extended over a series of years and show that on acid, peaty soils Thomas slag and mineral phosphates give better results than superphosphate. On sandy soils slag seems to be more beneficial than precipitated phosphates; liming also exerts a marked influence; it reduces the action of mineral phosphates, but renders the phosphoric acid of humus soils more available. Another investigator[6] concluded, however, that slags are preferable to superphosphates on soils containing less than 3 per cent. of assimilable lime.

Slag perhaps exerts the most lasting action; by plat experiments Wagner[7] showed that it exerted an effect on grass land nine

[1] C. von Seelhorst : *Jour. Landw.*, **50**, No. 2, pp. 167–174 (1902).

[2] Abs. in *Chem. Ztg.*, **24**, (1900).

[3] *Ann. Agron.*, **28**, No. 8, pp. 385–398 (1902).

[4] *Compt. Rend.*, Acad. Sci., Paris, **34**, No. 1, pp. 53–55 (1902).

[5] Maeseyck : Vanderdonck Robyns, 1903, p. 35.

[6] E. C. Praedel : *Sta. Agron.*, Nancy, Bull. 4, pp. 15–24 (1901).

[7] *Ztschr. Landw.*, Kammer Schleisien, **8**, p. 64 (1904).

years after its application and that medium applications continuously for twelve years were beneficial. This author also states that the higher the phosphoric acid content the less will be the application of nitrogen required and the poorer the soil in calcium carbonate, iron and alumina the smaller the application of phosphoric acid required.

As to the value of bone meal as a phosphatic fertilizer, most investigators have placed it below Thomas slag. Söderbaum[1] concludes from his experiments that while under favorable conditions it may produce as good results as slag and even as superphosphate, still its action is so affected by agencies which do not affect the action of slag that greater care must be exercised in its use than in any other form of phosphates. In the majority of cases it cannot be used to advantage on soils rich in lime.

The same investigator[2] has also carried on extensive investigations as to the fertilizing value of precipitated calcium phosphate. He worked upon a poor sandy soil, making duplicate experiments, one without the addition of lime and one with it. The fertilizers used were dicalcium phosphate, prepared electrolytically from apatite; tricalcium phosphate prepared also from apatite by a different process; precipitated phosphate which was a mixture of the two and contained 41 per cent. of total and 24 per cent. of citrate-soluble phosphoric acid, steamed bone and superphosphate. The crop experimented with was oats. The results show that the favorable effect of both the precipitated phosphate and bone meal was lessened by the addition of lime, but the superphosphate was not affected by it. The conclusion is drawn that on freshly limed soils tricalcium phosphate produced somewhat better results than bone meal, and that on soils poor in lime it gave slightly lower results, and that dicalcium phosphate was about equal to superphosphate, regardless of whether the soil had been limed or not. As regards the relative amount of phosphoric acid which plants contain, several investigations[3] have been carried on, which indicate that at least some of the crops contain ammoniacal nitrogen and phosphoric acid in proportion to form ammonium magnesium phosphate. Finally, the chemical methods for the determination of the fertility of the soil with respect to phosphoric acid may be noticed. There are numerous arbitrary methods using different strength of solutions (usually about 2 per cent.) of weak acids, such as citric, acetic, etc., or solutions of acid salts such as potassium binoxalate, bitartrate, etc. These solutions have been tested by pot experiments, but on account of the fact that plants differ so much in their power of taking up phosphates from the soil, no one solvent can be relied upon to show the amount of available phosphoric acid present in the soil. Gedroitz[4] grew twelve dif-

[1] *K. Landt. Akad. Handloch Fidskr.*, **42**, No. 1, pp. 42-53 (1903).

[2] *Medd. K. Landtb. Akad. Exptlfalt*, No. 75, p. 14 (1902).

[3] H. Pellet: Abs. in *J. Chem. Soc.* (London), **82**, No. 478, II, p. 526 (1902).

[4] *Zkur. Opuitn. Agron. Jour. Expt. Landw.*, **4**, No. 4, pp. 403-432 (1903).

ferent varieties of plants on the same soil, and determined the assimilability of the phosphoric acid by means of a 2 per cent. citric acid, but found no close agreement between this and the actual amount removed by the plants. Similarly, he grew oats and mustard on the same soil, and found that they varied widely in the amount of phosphoric acid which they assimilated. He further showed that the availability of the phosphates of the soil as determined by the 2 per cent. citric and acetic acid solutions was, beginning with the highest, first calcium, second aluminum, and third iron phosphates, while the relative assimilability as determined by growing crops of flax, oats and mustard on this soil was first aluminum, second calcium, and third iron phosphate.

It may, therefore, be seen that thus far there has been no satisfactory method proposed for determining this important point.

Potash.—Taking up next the subject of potash, it appears that there has not been very much work done along this line, and comparatively few points of special interest or value brought out. While it is true, that in a majority of fertilizer experiments potash has been applied, still in the majority of cases it was the nitrogen or phosphoric acid that was being studied and not the potash, it being simply added to complete the fertility of the soil. There have been a considerable number of experiments carried on in attempts to substitute soda for potash, but these have not been attended with any great degree of success. Doll[1] grew barley in pots containing soil composed of one-third sandy field soil and two-thirds pure river sand, and fertilized with sulphates and chlorides of sodium and potassium singly and combined. The chlorides gave better results in each case than the sulphates. This is thought to be due to the greater diffusibility in the case of potassium, and to the rendering of the potash of the soil available by the sodium. The best results were obtained with mixtures of the two salts, but applications of soda were less effective than potash. Analysis of the crop showed that an increase in the crop was accompanied by an increase in the proportion of potash or soda in the plant.

As regards the value of the different potash salts, quite a number of investigations have been carried on to test the relative value of 40 per cent. potash salt as compared with kainit. The 40 per cent. salt is prepared from carnallit by concentration. Coöperative[2] experiments lasting for two years were carried on by a number of German experiment stations using the 40 per cent. salt and kainit. The conclusion is reached that kainit gave better results on cereals on either light or heavy soils, and there was no injurious effect on the mechanical condition of the soil attending its use. The 40 per cent. salt produced a greater yield of potatoes both of total crop and of starch than kainit. The two salts were about

[1] *Landw. Vers. Stat.*, **57**, No. 5-6, pp. 471-476 (1902).

[2] M. Maercker and Schneidewind : Abs. in *Chem. Ztg.*, **26**, No. 16, p. 53 (1902).

equally effective on sugar-beets, both increasing the sugar content. It is pointed out, however, that the 40 per cent. salt may be better for this crop because it can be used in larger quantities without danger of injuring the mechanical condition of the soil. Bachmann[1] reports results somewhat different from these, he applied the 40 per cent. salt to oats in the spring and got a larger increase in grain and less in straw than with kainit. He also used lime in these experiments, but it did not change the relative results.

Kainit gave better results on sugar-beets than the 40 per cent. salt, if applied in the fall, but was the less effective of the two if applied in the spring. From the financial standpoint the kainit gave the better results and in every case gave the greater residual effect. Schulze[2] carried on experiments for two years on oats and barley to test the relative value of kainit, muriate and sulphate of potash; muriate stood first in regard to both yield and utilization by the crop; sulphate was second in the yield of crop produced but third in regard to the utilization of the potash by the crop.

The effect of potash on the form and composition of the plant has been studied by a number of investigators. The article[3] entitled "The Effect of Potash on Plants as Shown in Experiments with Potatoes, Tobacco, Buckwheat, Mustard, Chicory and Oats" presents some interesting data along this line. The experiments were carried on for several years, using a soil mixture almost free from potash. The potash applications were more effective in increasing the size of the plant organ containing the reserve material than in increasing the yield of leaves and stem; this was especially noticeable in the case of the beets and potatoes. By decreasing the amount of potash a similar diminution was noticed in the percentage of stem and leaves, but not in the per cent. of roots. The effect of potash on the appearance of the plant was quite noticeable, the lack of this substance producing a yellow-brown color of the leaf, with spots of a similar color, but more intense, and in some cases assuming a whitish appearance; these spots appeared between the veins while the ribs retained their dark green color. These symptoms were especially noticeable in the leaves of tobacco, potatoes and buckwheat. When there was a lack of potash in the soil this was shown by a characteristic curling up of the leaves and a collapse of the plant. When nitrogen and phosphoric acid were deficient in the soil it affected the plant quite differently. The lack of phosphoric acid showed itself by a dark green coloration of the leaves, while an insufficient supply of nitrogen produced a yellow-colored leaf. When there was a lack of potash, a heavy

[1] *Deut. Landw. Presse*, **30**, No. 15, p. 120 (1903).

[2] *Jahresber. Thät Agr. Chem. Vers. Stat.*, 1901–2, pp. 21–32.

[3] H. Wilforth and G. Wimmer: *Arb. Deut. Landw. Gesell.*, No. 68, pp. 106 (1902). Abs. in Expt. Sta. Record, Vol. XV, No. 3, p. 235.

application of nitrogen reduced the relative yield of tubers, and also the percentage of starch, this being noticed in the case of beets and potatoes where an experiment was run under the same condition, but using a small application of potash.

A study was also made of the amount of water transpired per gram of dry matter produced. An application of potash increased this; this the author believes to be due to the check in growth when the supply of potash is used up, as in that case the transpiration continues while the production of dry matter stops. For each gram of dry matter produced it was found that the tobacco transpired 300 grams, potato 200, and oats 460. With the exception of the potassium nitrate, there was no great difference in the effect of the different salts used. On the potatoes potassium sulphate and chloride gave practically equal yields, but the sulphate produced the higher percentage of starch. It was found that for each gram of potash taken up, potatoes produced 36 grams, and oats 29 grams of starch. The content of sugar in the beets was also very much affected, being 8 grams of sugar per gram of potash taken up, when there was no potash added, and 25 grams when there was a large amount of potash present.

As regards the manner of applying potash salts, most authors[1] favor top dressing, this being shown especially in the case of winter grain, where the weather conditions were well suited to dissolve and distribute the salt in the soil. It has also been pointed out that they should not be applied when the plants are moist with dew or rain, since they tend to stick to and injure the leaves. Therefore, the best results are generally obtained by applying the salt in dry weather just before a rain.

Finally, the point brought out by Bolin[2] should be noticed. In coöperative experiments with barley and oats, using different mixtures of fertilizers, it was shown that fertilization with nitrogen and phosphoric acid, on an average, gave a smaller increase in the weight of kernels than the nitrogen and potash fertilizer, which indicates that the potash has at least as much effect on the seed formation as the phosphoric acid. Noticing now the nitrogenous fertilizers, namely, nitrate of soda and sulphate of ammonia, it has been found that considerable work has been done comparing the relative value of these two. Bachmann,[3] for instance, in working on different kinds of plants, concludes that if ammonium sulphate is applied in the proper time and manner, it will give often better results than nitrate of soda, and he shows that Wagner's ratio of 100 : 90 is not correct. He found early spring applications most effective with most crops, and also that a considerable after-effect was exerted, which was not the case with the nitrate of soda.

[1] Bachmann : *Deut. Landw. Presse.*, **29**, No. 97, pp. 735-6 (1902).

[2] *K. Landt. Akad. Handl. Och Tidskr.*, 1903, p. 133.

[3] Fühlings : *Landw. Ztg.*, **52**, No. 4, pp. 132-138, No. 5, pp. 183-190 (1903).

Another author[1] reached quite a different conclusion in that he finds Wagner's figures too high; he places the effectiveness of sulphate at 86 per cent., which falls to 80 per cent. in soils poor in lime, and to 63 per cent. in soils very rich in lime. According to the results of Wagner,[2] 100 parts of ammoniacal nitrogen yielded 93 parts of nitric nitrogen in the soil. These experiments consisted of a number of coöperative experiments carried on at different German stations. On the average, the crop used the nitrogenous fertilizers in the following order: nitrate of soda, 100; sulphate of ammonia, 94. With oats the ammonium salts were 98 per cent. as effective as the nitrate of soda. However, in field experiments with a number of different crops, the sulphate of ammonia only showed an effectiveness of 70 : 100 compared with sodium nitrate; this the author attributes to the loss of nitrogen in the form of ammonia. It was also found that soda increased the yield, but the continued use of sodium salts is cautioned against as being injurious to the physical properties of the soil.

The action of sodium nitrate on the physical properties of the soil was studied at Rothamstead,[3] where it was discovered that the plats on which sodium nitrate had been added did not contain the very fine particles which were found in adjoining plats to which there had been no sodium nitrate added.

This was especially noticeable in the mangle field where there had been continued cultivation, but was not noticed on grass fields where the sod protected the ground from washing. This the author attributes to the deflocculation by the sodium nitrate, and the washing of the finer particles into the subsoil. Analysis of the soil supported this view in that the finer particles of the subsoil were richer under the plat to which the nitrate had been added, and the condition of the soil showed every indication of deflocculation.

As has been pointed out in discussing potash, a deficiency of nitrogen in the soil manifests itself by the plant becoming a light green or yellowish, changing finally to a light, brownish yellow color.

Nitrogen.—The action of nitrate nitrogen is decidedly affected by large quantities of organic matter, being diminished considerably by applications of straw, peat, etc. Lastly, it has been noticed that nitrates tend to increase the period of growth and retard ripening; therefore, great care must be exercised in applying it to late crops. It is also much quicker in its action than sulphate of ammonia, but it is not fixed by the soil, and unless the crop is growing rapidly there is great danger of it being washed out by rain and lost. If, however, the conditions are unfavorable for nitrification it will usually prove more effective than sulphate

[1] S. Gradeaw: *Jour. Agr. Prat.*, N. Ser. 5, No. 10, pp. 308–309 (1903).

[2] *Arb. Deut. Landw. Gesell.*, No. 80, pp. 340 (1903).

[3] A. D. Hall: *J. Chem. Soc.* (London), **85**, No. 501, pp. 964–71 (1904).

of ammonia, since only certain plants have the power of taking up ammonium salts. It is also stated[1] that commercial sodium nitrate always contains chlorates and perchlorates of sodium and potassium; since both of these are injurious to plants, it may be that some of the bad effects reported in the use of sodium nitrate may have been due to the presence of these substances.

A large amount of the work which has been done on barnyard manure has been in trying to devise a suitable method of preserving it so as to prevent loss of nitrogen. These methods have been of both physical and chemical nature, using chemicals such as lime, gypsum, superphosphate, sulphuric acid, etc., and also by storing in heaps and similar physical means.

Most authors[2] conclude that sulphuric acid is the most effective preservative, since it entirely prevents the loss of nitrogen, but it also has the disadvantage of being difficult to obtain, dangerous to handle, and also it imparts an acid reaction to the manure.

Lime, calcium, carbonate, gypsum and superphosphate are all very uncertain in their action, at times giving good results.

Schneidewind[3] has concluded that sulphuric acid effectually prevents loss of nitrogen, but it also interferes with the decomposition of the manure. He also states that the preservative materials such as gypsum, lime, copper sulphate, etc., are useless, and that peat and earth are the most satisfactory preservatives that can be used.

The storage in heaps, whether loose or packed, has also proved very unsatisfactory, since a large loss of nitrogen occurs, especially in the early stages of the storage.

As regards the fertilizing value of barnyard manure it is generally concluded that owing to its physical action on the soil it will often produce effective results where commercial fertilizers fail. In one case[4] it has been shown that the maximum yield of root crops was only obtained by an application of barnyard manure in conjuncture with commercial fertilizers, this being attributed to the physical action, since even with a heavy application of nitrate of soda the quantity of nitrogen taken up was increased by an application of barnyard manure. A larger yield of potatoes and turnips was also produced by a heavy application of barnyard manure than by the application of a complete commercial fertilizer.

In comparing[5] the deep stall manure with the barnyard manure it was found that the former gave larger yields than the latter, but the yield was not in proportion to the larger quantity of soluble nitrogen which it contained. It is also noticed that the stall manure suffered greater loss when spread on the field than did

[1] H. Pellet and G. Fribourg: *Ann. Sci. Agron.*, No. 2, pp. 199–225.

[2] J. Sebelien and E. Forfang: *Norsk Landmandsblad.*, **23**, No. 11, p. 135 (1904).

[3] *Oesterr. Chem. Ztg.*, **6**, No. 18. p. 412 (1903).

[4] M. Gerlach: Abs. in *Chem. Centrbl.*, II, No. 11, p. 764 (1902).

[5] W. Schneidewind, D. Meyer and W. Gröbler: Landw. Jahrb., **31**, Nos. 5 and 6, pp. 826–908, 963–968 (1902).

the barnyard manure, and, therefore, it should only be supplied in quantities sufficient to furnish the crop.

On soils[1] poor in nitrogen, liquid manure, when applied alone, gave larger yields than when used in conjuncture with fresh manure and straw. This is believed to be due to the fact that fresh organic substances furnish food for certain soil bacteria which withdraw the nitrogen from the use of the plant, and this results in a diminished yield on soils deficient in nitrogen. However, on soils rich in nitrogen the manure did not decrease the yield, since here there was a plentiful supply for the denitrifying bacteria, and also for the crop.

Noticing now the work on green manuring, the principal crops which have been used for this work are peas, beans, vetches, clover, alfalfa, buckwheat, etc. It is generally concluded that beans and peas produce the best results. Green manuring generally exerted an effect for about two years, and finally disappears about the third year.

For preserving[1] the nitrogen of the soil during the fall months the legumins are generally considered the best, since they not only preserved the soil nitrogen, but also added a supply from the air. Some authors place their value as nitrogen furnisher at about 40 per cent. compared with nitrate of soda. The practice of green manuring for sugar-beets is said to decrease their quality, but this is more than made up by the increase in the total crop.

As regards the fixation of atmospheric nitrogen by the bacteria of the soil, many varieties have been separated and while most of these when grown in the proper media, and usually with the addition of grape-sugar, have the power of assimilating nitrogen, still when they are applied to the soil they do not seem to produce any favorable effect on the crop; in fact, many investigators have procured a decrease in the crop by inoculating the soil with them. Whether this is due to symbiosis or not has not yet been proved. The nitrates of the soil also affect the assimilation of free nitrogen, the assimilation increasing as the amount of nitrates decreases.

Bonnema,[2] however, has advanced the theory that the assimilation of free nitrogen is a chemical process and not due to bacteria. He calls attention to the iron content of the root tubercles of leguminous plants and from this he believes that there is a considerable amount of iron hydroxide present which is essential to the process of assimilation of nitrogen by the bacteria. Denitrifying organisms also occur in the soil, which have the power of reducing nitrates, and these organisms also occur in horse manure and straw. Klyncharev[3] has studied the effect of bringing solutions of nitrates

[1] W. Schneidewind: *Landw. Jahrb.*, **31**, Nos. 5 and 6, p. 826 (1902). Abs. in Expt. Sta. Rec., Vol. XIV, No. 9, p. 852.

[2] Tiddskr. Landbr. Planteavl, **5** (1899).

[3] *Chem. Ztg.*, **27**, No. 67, pp. 825-826 (1903).

[4] Izv. Moscow. Khoz. Inst. Ann. Inst. Agron. Moscow, **8**, No. 2, pp. 107-149 (1902). Abs. in Expt. Sta. Record, Vol. —, No. —, p. —.

into contact with soil in cylinders. He concluded that the rate of denitrification was dependent on the amount of organic matter (such as starch) present in the soil.

Lastly, the other form of atmospheric nitrogen, *viz.*, the so-called lime nitrogen, has so far not come into extensive use, but may in the future play an important rôle in agriculture.

This substance is cyanamide and it is formed from calcium carbide in the manufacture of acetylene gas; it contains about 15 to 25 per cent. of nitrogen. Earlier experiments[1] with this substance as a fertilizer placed its value as a nitrogen furnisher nearly as high as nitrate of soda, but more recent investigators have found this figure to be too high and that it possesses only about three-fourths the value of nitrogen in the form of nitrates. It has also been found to give better results when applied late rather than early, and that on certain classes of soils it has an injurious effect, due, it is thought, to the formation of dicyandiamide which apparently is poisonous to plants. It is, however, a quick-acting fertilizer.

Lime.—In concluding the subject of fertilizers lime will be noticed briefly. As a fertilizer the action of lime is generally admitted to be indirect, since there are few soils which do not contain a sufficient supply to furnish the needs of the plant. In acid clayey soils it nearly always proves effective. It has also been found to increase nitrification. Ulbricht[2] reports results of experiments on barley, using lime fertilizers, which produce a marked increase; however, by applying lime in February he reduced the weight of grain. The use of lime and magnesia increased the tilling of the grain. Heavy applications of lime with small magnesia content increased the entire growth, but of straw more than of grain, the weight of the grain was also less. The action of lime is also believed to be due to the neutralizing of the injurious effect of magnesia. The ratio which the lime in the soil should bear to the magnesia has been also extensively studied.

Some authors place the lime magnesia ratio at about 3 : 1 for crops which have an abundant leaf production, while for cereals about 1 : 1 gives the best results.

SOILS.

Taking up next the subject of soils, it is noticed that there are numbers of analyses published, including every variety of soil. These have been both physical and chemical and generally with a view of establishing a method whereby the fertilizer requirements of the soil may be ascertained or the available fertilizing ingredients determined. Besides this there has been a large amount of work done on the soil temperature, moisture content, humus content, soil solutions, etc.

[1] *Mitt. Deut. Landw. Gesell.*, **19**, No. 8, pp. 45-46 (1904).

[2] *Landw. Vers. Stat.*, **57**, No. 1-2, pp. 103-166 (1902).

In studying the water content of the soil Tretyakov[1] has shown that under papilionaceous plants the moisture content is 0.32 per cent. lower than under graminaceous plants. This is believed to be due to unequal root development of the two families. He also showed that an alfalfa field ploughed up in the fall, winter or spring contained more moisture than those remaining under the alfalfa. Deep ploughing also increased the moisture content, which was noticeable for three years.

Barnyard manure exerted a favorable influence on the moisture content, which was also noticeable for several years. Another author,[2] in studying the evaporation of water by wheat as affected by fertilizing and the different moisture content of the soil, has shown that a high moisture content increases the effect of fertilizing. He also showed that when the moisture content was small, water was evaporated at the rate of 500 units of water per unit of yield. In cases of large moisture content tilling began earlier and the straw and root developed more strongly, while the head became shorter.

The consumption of soil moisture by different crops is also quite different. Von Seelhorst[3] studied a variety of plants and found that rye drew less moisture than wheat, clover left the soil very poor in moisture, while peas and potatoes left the soil very moist.

He concludes that there is a close relation between the yield and growth of individual plants and the water content of the soil.

As to the composition of the different particles of the soil, Rudzinski[4] has reported quite a lengthy work on this subject. By mechanical analysis he separated the different soil particles and studied their relative fertility. He mixed the different particles with sand and grew oats, also using check experiments applying fertilizers. He concluded that the total content of nitrogen, phosphoric acid and potash in the mechanical elements of the soil investigated decreased with an increase in their size; however, assimilable substances for the plant are contained in both the silt and the coarser particles, and since the finer particles are present in small quantities in most soils, the fertility of the soil must depend largely on the coarser particles.

He states finally that it is impossible to judge of the fertility of a soil from its mechanical composition, since the particles of soils, even of like geological origin, are unlike in chemical composition.

Of the methods of soil analysis perhaps the most reliable for determining the fertilizer requirements of the soil is the so-called

[1] Pochvovedenie: *La Pedologie*, 4, No. 3, 219-234; 4, 378-392 (1902).

[2] Yanovchik: *Kherson*, 9, pp. 142 (1902).

[3] *Jour. Landw.*, 50, No. 2, pp. 151-164 (1902).

[4] Izv. Moscow. Selsk. Khoz. Inst. Ann. Inst. Agron. Moscow, 9, No. 2, pp. 172-234 (1903): Abs. in E. S. R., Vol. XVI, No. 4, p. 345.

physiological analysis. Vanderyst[1] has defined this as follows: Physiological analysis of the soil consists of two or more comparative synthetic culture experiments, executed systematically with one or more species of cultivated plants, in a soil modified in various suitable ways by simple and chemically pure fertilizers with the object of determining, on the basis of the examination of the plants and the quality, quantity and mineral composition of the crop produced, the one or more necessary or useful fertilizing elements which are required by the one or more species of plant experimented with, under the conditions of environment in which the experiment is made. This, the author points out, differs materially from fertilizer experiments, but he also shows that this method should be supplemented by fertilizer trials. He also points out that this method is very faulty, owing to the large number of factors which may affect the results, some of which are the variability of the mineral composition of the plant with an excess of some one ingredient, the physical action of the fertilizer on the soil, the difference in solubility, etc. He further points out that chemical analysis only shows the percentage composition of the soil, but cannot be relied upon to show the availability. It may, however, be of great value in showing the nature and total quantity of elements necessary and the existence of useful, indifferent or poisonous substances which may be present.

As to the bacteriological character of the soil quite a large quantity of work has been done, but as yet the data on the subject is of a very uncertain nature, and a large part of it is conflicting.

FIELD CROPS.

Taking up next the field crops and noticing briefly a few of the most important of these we find that:

Of the cereals, more work has been done on wheat than on any of the others. The investigation has been chiefly along the lines of fertilizing, variety tests, effect of environment, composition and in combating diseases, chiefly smut.

As regards the fertilizer experiments, there do not seem to have been any points of special interest brought out, since most of them are of local importance only. Nitrogen[2] has been shown to lengthen the lower internodes and shorten relatively the upper ones, and nitrate of soda produced this more than sulphate of ammonia. This increases the tendency to lodge. Ammonia also produces a stronger plant and also seems often to produce a better quality of grain, though, as a rule, the yield is not as large as with nitrate.

The composition of the wheat has also been extensively studied. Starch[3] has been shown to come from the stem into the head of

[1] *Rev. Gen. Agron. Louvain.*, **11**, No. 9, pp. 410–412 (1902); Abs. in E. S. R., Vol. XV, No. 8, p. 757.

[2] H. Claussen : *Jour. Landw.*, **49**, No. 4, pp. 365–388 (1902).

[3] Deherain and Dupont : *Ann. Agron.*, **28**, No. 10, pp. 522–527 (1902).

cereals, and does not gather in the leaves as it does in the other plants.

There have been quite extensive studies made of the nitrogenous bodies in wheat. Gliadin and glutarine are the most important; these substances exert a great effect on the baking quality of the flower. They are not generally thought to be formed from the same substance nor to have the same composition. In the unripe grain the nitrogenous bodies are mostly soluble, and the process seems to consist of a change from soluble to solid and stationary bodies, the amido bodies going over into albumen.

As to the work on cereal diseases, this has been principally in attempting to obtain a satisfactory method of preventing smut. Many different chemicals have been used on the seed, including copper sulphate, corrosive sublimate, formalin, etc.; hot water has also been used, but these have only been partly successful. It has also been suggested that by studying the effect of soils, fertilizers, exposure, etc., in all countries on cereal rusts, it may be possible to breed a more rust-resistant variety.

One other point in cereals is the relation of the mineral matter in the stem to lodging. The results of Lienan[1] point to the fact that there is a close relation between the mineral fertilizers added and the thickness of the cell walls, as well as to the amount of total ash in the stem. Phosphoric acid was very marked in producing thick walls, but this effect was lessened by applications of lime or potash at the same time. Potash increased the size of the cell lumen, as did also nitrogen, which also reduced the thickness of the cell walls; however, a large application of phosphoric acid at the same time counteracted this. Ammoniacal nitrogen weakened the stems less than nitrate. Liming also weakened the cell walls.

Analysis indicated that phosphoric acid had a tendency towards decreasing the total ash and some of its components, while nitrogen, potash and lime had an opposite effect. It also seemed that the thickness of the cell walls was inversely proportional to the total ash content. The author points out that when it is necessary to add large quantities of lime or nitrogen, a larger application of phosphoric acid should also be used to counteract the tendency towards lodging which these produce by weakening the stems.

The root crops have been the subject of larger numbers of fertilizer experiments, including the effect of different fertilizers on the growth and quantity of the crop. Among this class of experiments may be mentioned the effect of chlorine on the starch content of the potato, and the influence of fertilizers on the sugar content of the beet.

Chlorides[2] have been shown to lower the starch content. Potash has been shown to increase both the quantity and quality, while phosphoric acid exerts a detrimental effect on the crop and

[1] Inaug. Diss. Univ. Königsberg. 1903, p. 91.

[2] *Jour. Landw.*, **47** (1899).

produces an abnormal leaf and stem development. It is also true that the leaves of potatoes rich in starch contain more phosphoric acid and potash than those poor in starch.

With sugar-beets[1] it is noticed that insufficient potash decreases the sugar content, while a large quantity of nitrogen exerts a similar effect and also seems to produce a tendency towards disease, while a small quantity of nitrogen, under similar circumstances, produces a larger and healthier crop; used in connection with phosphoric acid the effect is not so marked; a lack of potash increases the growth of leaves, while a subnormal quantity of phosphoric acid produces a beet with a fair sugar content and a subnormal quantity of nitrogen produces one of very high sugar content. The leguminous crops have been studied quite extensively, both as a means of furnishing nitrogen and from a bacteriological standpoint, numerous experiments being carried on in inoculating the soil with various kinds of bacteria and testing their effect on the leguminous crops.

Another branch of agricultural chemistry which has received considerable attention is that dealing with seeds, principally their selection and germination. The influence of temperature on germination is very important, an elevated temperature producing quick germination, but the root system being small and the roots themselves having but few branches. It has also been noticed that many seeds can stand a high temperature for a short time and still retain the power of germination; if, however, they be heated long they lose this power. Seeds have been found which would germinate after being heated one hour at a temperature of 110 to 120, but if heated several days at from 95 to 97 they were killed.

Other important factors in germination, such as the effect of moisture, sunlight and age, have all received considerable attention.

The weed problem is another one which is being extensively studied. Many experiments have been carried on in attempts to produce methods by which objectionable weeds might be eradicated. It has been pointed out that both the yield and money value of crops is very seriously affected by weeds. Korsmo[2] investigated the effect of weeds on the value of several different crops, in which he calculated a loss of about 47 per cent. in money value.

Spraying with different chemicals, such as copper sulphate, has been tried quite extensively in weed eradication, but with doubtful results.

DAIRYING.

The subject of dairying will only be noticed very briefly. The

[1] *Deut. Landw. Presse.*, **29**, No. 11, p. 84 (1902).

[2] Tidsskr Norske Landbr., **10**, No. 6, pp. 247-280; No. 7, pp. 295-330 (1903).

work along this line has been largely in testing the effect of different feeds on the quantity and quality of the milk and butter. Besides this the bacteriology of milk and butter has been largely worked upon.

The kind of food seems to exert a direct influence on the butter; this has been noticed in the case of cows fed cotton seed cake, when the butter gave the Halphen reaction. In fact, it seems that some of the fat passes through the body into the milk without undergoing any change, it having been noticed that some of the constants for the butter vary exactly with those of the fat fed. The quantity of volatile fatty acids in the butter also changes with a change in ration, but whether this is due to the change in food or in nutrition has not been definitely decided. The food also affects the secretion of milk, but the general conclusions are that while different food-stuffs exert a specific influence outside of their food value, this is not constant with different animals and therefore no feeding-stuff has money value higher than its food value.

As regards the quality of the milk as affected by inequalities in the intervals of milking this seems to be slight and of little importance.

FEEDING EXPERIMENTS.

Taking up lastly the feeding experiments, it is noticed that these are not so extensive as are carried on at home. Sugar-beets and other root crops have been tested considerably as foods and also in comparison with grain and oil cakes, it having been shown that an equal quantity of dry matter in root crops is about equal in value to grain. Sugar-beets have proved a fairly good feed, but they are generally concluded not to be as good as mangles. For milch cows they are said to give good results by increasing the milk flow and not decreasing its quality. Molasses has also given fairly good results, it having been found that by using bagasse as an absorptive a food can be made that contains 70 per cent. of digestible carbohydrates.

The character of the fat in the body of the animals is affected by feed, palm-nut cake having been shown toproduce hard fat.

No very important work seems to have been done on the concentrated foods. They are usually reported as giving good results and many of the authors advise more their use in place of the common food mixtures. The digestibility of cellulose and pentosans has been a subject for considerable study. The digestibility of pentosans is said to be parallel to, and vary directly with, that of carbohydrate. Cellulose seems not to exert any influence on the cleavage of protein. It does, however, protect fat and may therefore be called a nutrient.

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