Agricultural Chemistry.

Plants.

We are all familiar with the fact that when wood is burnt there is always a certain proportion of *ash* left after all the combustible matter of the wood has been burnt away. When hay, straw or grass is burnt, more or less ash is always left behind; and this is true of all plants and of every part of them. This ash consists of the various incombustible and *fixed* mineral substances which existed in the plant. By "*fixed*" is meant incapable of being driven off in vapour by heat. The following substances are always found in larger or smaller quantities in the ash of all plants:

Potash.	Chlorine.
Soda.	Sulphuric acid.
Lime.	Phosphoric acid.
Magnesia.	Carbonic acid.
Oxide of iron.	Silica.

Other substances are sometimes found in addition to these. Thus the ashes of the beet root seem always to contain a minute portion of the rare metal rubidium.

The amount of ash is very variable, as the following table of the average percentage of ash in the dry plants shews.

	Percentage of ash.
Clover	7
Timothy	7
Turnip tops	15
Carrot tops	17
Potato tops	5
White pine wood	0·3

We see from this that different plants leave, when burnt, a very different percentage of ash. Thus dry carrot tops give 50 times as much ash as an equal weight of pine wood.

Under similar circumstances, there is but little difference between the percentage of ash in plants of the same species, but many circumstances tend to increase or diminish the quantity of ash even in the same plant. The nature of the soil has some influence upon the amount of inorganic matter. Turnip bulbs raised on sandy soil have been found to contain, on the average, 2 per cent. more of ash than similar bulbs grown on a loamy soil, while oats grown on limestone contains nearly 4 per cent. more inorganic matter than when on siliceous land.

The age of the plant makes a great difference in the amount of inorganic matter that it contains. The proportion of ash is, as a rule, diminished with the age of the plant. A diminution of 3 per cent. has been found in the proportion of ash left by oat plants from the same field in six weeks. On the 18th of June, Arendt found some oats on which he was experimenting to yield 8 per cent. of ash. On the 31st July they only gave 5 per cent. In some parts of the plant, however, the ash may increase as the plant grows older. A very great difference is observable between the quantity of ash contained in different parts of the same plant. The average percentage of ash in rye straw is 5·3. In the grain it is only 2. Pine wood, as we have seen, contains 0·3 per cent. of inorganic matter, but pine bark gives 3·3 per cent. In Arendt's experiments on oats, to which we have already alluded, when the entire plant gave 5 per cent. of ash, the leaves gave 10 per cent. and the ears only 2½. As a rule, the upper and outer parts of a plant contains the largest proportion of inorganic constituents.

This is a fact of the utmost importance in practical agriculture. The leaves of forest trees contain a very large quantity of ash compared with the wood. The wood of the elm, for instance, gives 1·9 per cent. of ash while the leaves contains 12 per cent.; and the wood of the birch yields 0·4 per cent. whilst its leaves give 4·2 per cent. Since the leaves of these trees fall off every year and give up to the soil by their decay all the inorganic matter that they contain, it is clear a very large proportion of the substances necessary to the growth of the plant are each year restored to the soil by this means, and hence we see one cause of the fertility of forest land and one reason why trees continue to flourish for so long a time on the same soil. Precisely the same effect is produced when straw, for instance, is returned as manure to the soil on which it grew. In a crop of wheat of 25 bushels of grain and 1½ tons of straw we should have 1500 lbs. of grain and 3000 lbs. of straw. The grain contains 2 per cent. of ash and the straw contains about 5 per cent.; and this would give us 30 lbs. of ash in the seeds and 150 lbs. of ash in the straw. Altogether a single crop of wheat would take from each acre of land 180 lbs. of inorganic material which is essential to the growth of this crop, and of course the land would be so much poorer at the end of the year. But if the straw were returned to the land as manure 150 lbs. of these valuable substances would be restored to the soil, while only 30 lbs. would be altogether lost. Experiment has shown that these ash ingredients are absolutely indispensable to the life of all plants, and that variable as the proportions are there is probably a limit to the amount of inorganic material in each part of every plant below which the plant cannot thrive or even maintain its existence. The proportions may, however, rise considerably above the limit from various circumstances and the ash ingredients be considerably in excess of the usual or normal amount without injury to the health of the plant.

Every part of each kind of plant has in all probability a certain standard proportion of ash ingredient but the causes which have been alluded to above, such as age and differences in soil and climate, produce variations in this proportion and make the quantity of inorganic matter to be either above or below this standard.

The composition of the ash is pretty nearly the the same in similar parts of the same plants grown under like conditions. The same circumstances, however, which produce variations in the quantity of the ash cause its composition to vary. Different plants contain the different ash ingredients which have been mentioned as being always present, in very different proportions. The following table shews the composition of 100 parts of the ash of wheat, of beans and of potatoes.

	Wheat.	Beans.	Potatoes.
Potash	23·7	33·5	55·7
Soda	9	10	1·9
Lime	2·8	5·8	2·
Magnesia	12	8	5·3
Oxide of iron	0·7	0·6	0·5
Phosphoric acid	50	33	12·6
Sulphuric acid	0.3	1	13·6
Silica	1·2	1·2	4·2
Chlorine	trace	0·7	4·2

This table shews us that there is a great diversity in the composition of the ash of these three agricultural products. The potash contains more than twice as much potash as the wheat grain, while the wheat contains four times as much phosphoric acid as the potato. The bean in both cases occupies an intermediate position. We also find that whereas there is only a very minute quantity of sulphuric acid in the wheat and in the bean, there is a comparatively large quantity in the potato.

Different parts of the same plant vary greatly as to the composition of the ash which they yield. For example the ash of wheat straw, contains only about 3½ per cent. of phosphoric acid, while that from the grain gives 50 per cent.; and on the other hand, the ash of the straw contains 65 per cent. of silica, while the grain yields an ash containing only a little over 1 per cent. of this substance. The same is true with all the other cereal grains, but as the grain of barley is not usually separated from the husk like that of wheat its ash contains a large amount of silica.

This difference in the composition of the ash in different plants is a very important one in an agricultural point of view. It is a matter of every day remark that certains soils will suit some kinds of plants excellently, while others will not thrive on them at all. Each plant has its favorite soil on which it arrives at the greatest perfection and the soil that is best suited for one plant may be totally unfitted for another. We now see one cause for this fact. Different plants require different quantities of certain inorganic materials for their proper nourishment, and a soil which may contain a supply of some particular ingredient which is ample for one plant, may be utterly unable to furnish it in a quantity sufficient for the healthy growth of another. A soil for instance which contains plenty of phosphoric acid to support a crop of potatoes might be quite unable to afford a quantity of that substance adequate to meet the wants of a crop of wheat. So also a crop of wheat must take from the land far more phosphoric acid than a crop of potatoes would, and hence, as far as phosphoric acid goes, successive crops of wheat would exhaust the land much sooner than successive crops of potatoes would. A rotation of crops permits the land to recover by natural processes from the losses which it has suffered from a crop of one kind while it is at the same time supporting a crop of a kind that does not require a large supply of more substances which the soil was obliged to furnish in large quantities to the preceding crop. When the supply of these inorganic materials is exhausted, it becomes necessary to add them to the land by means of artificial manures. If it is true, as it undoubtedly is, that each crop takes away from the soil a certain proportion of these inorganic substances, it is quite clear that if year after year crops are raised on the land and no attempt is ever made to restore to the soil what the crops take away, sooner or later the supply of these materials in the soil will be inadequate to meet the demand which successive crops make upon them and, as a natural consequence, the land will cease to be fertile. This process may be, nay must be slow, but it is nevertheless sure and when it has once taken place, it is only by great labor and enormous expense that the land can again be rendered fit for successful cultivation.

It has been found by means of a number of experiments that of the various constituents of the ash of plants that have been already mentioned, the following five are essential to the growth of the plant viz: potash, lime, magnesia, phosphoric acid and sulphuric acid. Unless supplied with these the plant cannot live.

Soda is invariably found in plants, but the quantity is exceedingly variable constituting as much as 30 per cent. of the ash of some plants that grow upon the sea shore, while in grain and in potatoes it sometimes exists in quantities too minute to be weighed. The quantity of chlorine, too, is very variable, and it has frequently been set down as altogether absent. It seems probable, however, that more or less is always present, although the amount may be exceedingly small.

Only a very minute proportion of oxide of iron is necessary, but some portion of this substance is absolutely necessary. There is a considerable variation in the amount that is found. In grains for instance the amount varies from a trace up to 3 per cent. If a plant is made to grow in a soil destitute of iron, it loses its green color and becomes pale and unhealthy like a potato sprout growing in a dark cellar. The property of assimilating carbon and liberating oxygen from carbonic acid upon which the growth of the plant so much depends, resides in the green portion of plants. Their green color is due to a substance called *chlorophyll* which exists in the cells of the exterior of the leaf, and of other green parts of plants, and this *chlorophyll* seems to preside in some way over the important changes by which the mineral substances, carbonic acid and water are decomposed and their carbon, hydrogen and part of their oxygen converted into organic matter and applied by the plant to its own nutriment. When iron is absent the leaf cells contain none of this green coloring matter, and hence the plants present the pale appearance already alluded to. Hence too, they cannot grow in a healthy manner by assimilating new plant food, and it soon sickens and dies. If, however, before the plant is too far gone, a few drops of sulphate of iron be added the green color is quickly restored to the plant and healthy growth is resumed. The quantity of iron requisite to produce these effects is in most cases very small indeed.

Silica is always found in the ashes of plants grown in the usual way, but it appears from some interesting experiments that some plants may be grown almost without this substance. The cuticle of plants of the grass family usually contains a considerable quantity of silica. The bamboo contains a large quantity, and concretions of silica are found occasionally in its joints and known as tabasheer. The straw of wheat, &c., also contains 50 or 60 per cent. This was generally supposed to maintain the upright position of the stalk and prevent the plant from "laying," but a number of experiments seem to have shown that plants of oats and of Indian corn nearly free from silica were just as firm in stalk as those which contained the usual quantity of this substance, and the sulphuric and phosphoric acids are the source of the sulphur and phosphorus that have been mentioned as being essential ingredients of certain parts of plants.