arrangement and development can be determined very satisfactorily.

In the vegetative portion of the hypha, the nuclei are of considerable size and lie in the inner part of the wall-lining of protoplasm. They are united by peculiar plasma threads, that run parallel or obliquely to the long axis of the hypha. The nuclei are ellipsoidal, elongated in the direction of the long axis of the hypha. One can determine the existence of a small nuclear body in each nucleus. In the hypha-ends the nuclei are nearer together. Here they are found somewhat closely connected in pairs, and lying entirely imbedded in the wall-lining of protoplasm. After the formation of the partition wall, they increase in numbers, by division, in the sporangial portion, and in the mature sporangium each zoospore contains a nucleus.

CONTRIBUTIONS TO THE LIFE-HISTORY OF NOTOTHYLAS. By D. M. MOTTIER.

[ABSTRACT.]

This paper embodies the results of a study of the development of the sporogonium and sex-organs of *Notothylas orbicularis* together with that of *Anthoceros.* These results may be summed up as follows:

The capsules of *Notothylas orbicularis* possess a columella varying in size with that of the capsule.

The columella is developed, as in *Anthoceros*, primarily in the young sporogonium with the archesporium and independent of it, and is not a secondary differentiation inside the spore chamber.

The archegonium of *Notothylas* resembles more closely that of the eusporangiate ferns than does the archegonium of *Anthoceros.*

The antheridium arises from an hypodermal cell, thus differing in this respect from all other known *Bryophytes.*

THE ASH OF TREES. By MASON B. THOMAS.

The object for which this investigation was undertaken was to show by chemical analysis the amount of food a tree or shrub takes from the soil in its yearly growth. The method employed was to determine by a quantitative analysis of the ashes of trees and shrubs, the proportion of the mineral constituents of the soil that are found present in them. It seems evident that such an investigation would be of importance to the cultivator of trees, and more particularly to the fruit grower, since by determining the drain upon his land he would have a knowledge of the needs and conditions of orchard soil, and also be furnished with some valuable information regarding the care of land on which trees are to be grown. There are but few fruit growers who know with any degree of certainty regarding the exhaustion of orchard soil, in consequence of which they apply fertilizers that may or may not be for the good of the soil, and an application of a surplus of fertilizers is not only a waste of money but is found to be actually injurious. It may often be that much money is wasted in the purchase of fertilizers rich in potash salts when the less expensive sodium salts would answer as well. An analysis of the soil on which an orchard is to be planted would at once show its condition, and knowing the proportion of mineral constituents taken from the soil in the yearly growth of trees, the fruit grower would be furnished with accurate information regarding the suitableness of his land for orchard purposes, and would also know the exact constituents he could most profitably apply in his fertilizers. An analysis of the ash of two trees of the same variety, one of them attaining yearly a very vigorous growth, and the other, as it were, starving, would show, unless the stunted growth was due to a lack of proper drainage, the food that should be given to the exhausted tree for its support.

The work done by chemists upon the subject under consideration is comparatively little. Much has been done upon the amount of nitrogen and ammonia assimilated by trees, but little upon the amount of mineral constituents taken from the soil. More prominent among those who have worked upon the former subject are Justus von Liebig, Messrs. Veille and Blossingault. Some results upon the analysis of apple twigs have been published by Prof. G. E. Patrick, of the Iowa Exp. Station, but few results regarding their mineral constituents were given. Much has been done by Schroder, H. C. White of Georgia, and others upon the analysis of the mineral constituents of forest trees, but no results are given regarding fruit trees or shrubs.

An exhaustive investigation has been made of the amount of mineral constituents taken from the soil by tubers, cereals, etc., and valuable conclusions drawn. The best of these results can be found in the Journal of the Royal Agricultural Society, series 11, vols. 7, 8 and 13.

COMPOSITION OF TREES AND SHRUBS.

All vegetable productions may be divided into two great classes. First, special productions of certain peculiar plants and sometimes of particular organs in those plants. Second, those substances which are always found present in all vegetable life and which make up a greater part of the solid portion of every tree or plant. With the latter division we are to deal and for our purpose we will consider it under two heads; first, those organic constituents that are found in all trees and shrubs during their growth, and second, those mineral constituents that remain after the combustion of the wood of the plant. The organic constituents were always held to be necessary to the growth of the tree while the inorganic, since they varied with the nature of the soil, were thought to be accidental, but this idea has long since vanished and now the mineral constituents are recognized as being of the first importance to the vegetable world.

Prof. Liebig has said "every vegetable requires for its fullest development and the fulfillment of its vital functions the presence of certain organic acids, of the use of which, however, we are ignorant, but farther it also requires that these acids be *in union with a base.*"

It appears from experiment that such substances as $\binom{\text{soda}}{Na_2O}$, $\binom{\text{potash}}{K_2O}$ and $\binom{\text{magnesia}}{MgO}$ can, to a certain extent, act as substitutes for each other, but if it so happens that the supply from the ground is insufficient for the purpose of the tree it cannot thrive unless it has the power of secreting an organic base for its own use, and with trees this is seldom possible. Prof. Liebig further shows that a certain degree of consistency attends the quantity of bases in combination with organic acids present in the same plant grown on different soils, although the proportion of bases may of themselves be very different. An analysis of two pine trees grown under very different conditions showed the quantity of oxygen present in the carbonate to be nearly the same, thus proving that the proportional quantities of organic acids in the two trees must have been united with equivalent quantities of bases. The same was also observed in two fir trees, one of which was grown in Norway and the other in France. The question now arises, Is each of the mineral constituents present in the tree essential to its development? Stohmann has shown by direct experiment that all the mineral food elements have an independent value to the growth of the tree. Potash can not take the place of soda, nor can calcium take that of magnesium. Though they are all necessary for the growth of the tree, for it has been shown conclusively by experimental investigation that the growth of a tree is a function of its *mineral* food elements, they do not all have an equal value as factors of nutrition. The growth of a tree would therefore always be proportional to the quantity of mineral constituents of nutrition present in the soil in a soluble or available form. This would of course always be more or less influenced by accidental conditions in the surroundings. With the organic constituents of trees we are not to deal, but much has already been done on this subject.

THE WATER IN TREES.

The average amount of moisture in some of the more common trees may be seen from the following:

Ash 28.7 per cent., beech 29, birch 31, elm 44.5, pine 50, oak 40, maple 34, hemlock 45, pear (Howell) 53.7, apricot (Russian) 44.4, cherry (Winslow) 51.8, cherry (May Drake) 50.1, poplar 51.1.

The samples of fruit trees were all taken on the same day, cut fine, dried at 110° C. until constant weights were obtained. The per cent. of moisture is much lower in trees than in grasses, cereals or tubers.

There is a considerable variation in the per cent. of moisture in different parts of the same tree as is shown by the following determination given by Stockhardt. Fir tree cut May 20:

Tree trunk with bark, 36.15 per cent.; thin end of trunk, 50.8; branches over 1 c. m., 47.95; branches under 1 c. m., 51.56; leaves, 52.49.

According to Galesnoff the per cent. of water after increasing from below upwards diminishes again at the summit of the trunk. Not only does the average per cent. of water vary in different parts of a tree but also in the same part there is a variation during different seasons of the year, as shown by the following table also from Stockhardt:

BEACH TREE.

	LOWER.	MIDDLE.	UPPER.
Winter	50.5	41.5	39.3
Spring	43.7	42.8	47.
Summer	42.1	44.1	48.
Autumn	39.	40.1	40.1

In ordinary dry wood there is about 15 per cent. of water.

THE ASH OF TREES.

Experiments show that while different trees and different parts of the same tree vary much in their proportion of ash, yet in the same parts of a given species of trees, the quantity of ash remains about the same and its chemical composition though widely varying in different trees is similar for the same parts of the same species, although the soils on which they are grown may differ much in character. Each individual tree seems to make not only a qualitative but a quantitative selection of the mineral food constituents best adapted to its development. *It does not follow then that out of a given mixture a tree will absorb to the largest extent the mineral constituent that is present in greatest abundance.*

The per cent. of ash found in some of the more common trees and the variations in different parts of the same tree is seen below:

PART OF TREE.	LOWER.	MIDDLE.	UPPER.
Beech wood . . .	.43	.45	.47
Beech bark	3.90	3.30	3.00
Larch wood . . .	.27	.30	.37
Larch bark	1.25	1.75	2.15
Spruce wood . . .	.35	.39	.47
Spruce bark . . .	4.77	4.29	4.53

An analysis of a Larch tree 40 years old gave the following per cent. of ash in its different parts:

Heart wood, .14; Sap wood, .30; last year's ring, .48; Cambium ring, 5.17; leaves, 5.36.

Other trees often contain a much larger per cent. of ash as in the Plum (Malabel) the bark contains 11.2 per cent. while the fruit of the tree contains only .72 per cent.

The following figures will show the per cent. of pure ash as I have found it in some of our common fruit trees, wood and bark of the tree being taken together. The composition of this ash will be found later:

Pear (Howell), .27 per cent.; Cherry (May Drake), .20 per cent.; Cherry (Winsor), .23 per cent.; Apricot (Russsan), .22 per cent.; Poplar, .31 per cent.

It can be clearly seen that there is a marked difference in the per cent. of ash in different trees and in different parts of the same tree. This is also found to vary with the seasons of the year as is seen by the following:

PART OF TREE.	LOWER.	MIDDLE.	UPPER.
Spring Beech wood	.41	.46	.67
Summer Beech wood . . .	.45	.43	.47
Autumn Beech wood . .	.44	.46	.55
Winter Beech wood . . .	.43	.46	.62
Spring Larch wood . . .	.25	.32	.41
Summer Larch wood . . .	.27	.33	.38
Autumn Larch wood . . .	.25	.26	.33
Winter Larch wood . . .	.29	.36	.41

THE ASH OF LEAVES.

The per cent. of ash in leaves and the variation during the year is worthy of special attention.

The following figures illustrate these points:

Mountain Ash, 6.42 per cent.; Cherry, 6.70 per cent.; Beech, 5.21 per cent.; Maple, 4.68 per cent.; Elm, 6.82 per cent.

The ash of leaves like that of wood is found to vary during different seasons of the year.

	ROBINIA.	CHERRY.	BIRCH.	CHESTNUT.
May	6.25			6.40
July	7.75	7.30		
September . .	8.22		4.36	4.75
October . . .	11.74	4.68	7.24	4.55
April		7.80	3.84	

It can thus be seen that the variation in the per cent. of ash in different parts of the tree during the year is very marked; the upper portion being subject to the greatest change. The ash is at its maximum in the sap wood in autumn and winter, and in the heart at its minimum. In the spring the ash in the sapwood falls, at the same time it rises in the bark. By summer both the sapwood and the bark have reached their minimum and the ash constituents go to the leaves. At all seasons of the year however the cambium and bast portions of the tree contain three-fourths of the whole amount. We have every reason to believe that every part of the tree contains a certain invariable amount of mineral matter which is absolutely essential to its existence and that besides this there may be present an inessential and variable amount of the same ingredient. The substances usually found in the ashes of all trees when burned at a low temperature are potash, soda, lime, magnesia and iron (K_2O, Na_2O, CaO, MgO, Fe_2O_3) in combination with phosphoric acid (P_2O_5), sulphuric acid (SO_3) chlorine, (Cl.) carbon dioxide (CO_2) and silica (SiO_2); iodine (I), aluminum (Al.) and manganese (Mn.) are often present. One portion of these mineral constituents exists in solution in the sap and the other in the tissue of the plant in the solid form. In burning, portions of sulphur, chlorine, phosphorus and alkalies may be lost under certain conditions, by volatilization.

The ash remains as the skeleton of the plant, and often actually retains the microscopic structure of its tissues.

THE FORM IN WHICH THE MINERAL ELEMENTS EXIST IN THE PLANT.

If we take a living tree, whose ashes are rich in carbonates of potash, and test its sap, we find instead of the usual alkaline reaction of the salts a strong acid reaction, due to the presence of vegetable acids—oxalic, tartaric, citric or malic, so united with the alkaline potash as to form an acid salt which is held in solution in the sap of the tree. Combustion converts the vegetable acids into carbon dioxide, and the latter unites with the bases.

HOW HAVE THESE SUBSTANCES BEEN ASSIMILATED BY THE TREE?

It must be remembered that the sap of the tree is charged with carbon dioxide and often sodium chloride, therefore the double silicates of ammonia and aluminum in the soil, which are somewhat soluble in such water, are furnished to the tree in sufficient quantities for its development. The silicates of iron are decomposed at ordinary temperature by carbon dioxide. They are, therefore, made soluble in water charged with carbon dioxide and exist in solution in the sap. The alkaline carbonates also bring about many decompositions in the mineral matter of the soil. It is by the introduction of atmospheric oxygen that many of the compounds entering into the double silcates of aluminum are gradually decomposed, and the alkalies—potash, soda and lime, are rendered capable of assimilation and pass in solution in the sap of the tree.

The relative proportion of the constituents of the ash of trees is found to vary in different trees, and also in different parts of the same tree. The following analyses were made of the ash of the young and thrifty shoots which represent a fair average of the proportion of the mineral constituents of the soil that are assimilated by the tree in a year's growth:

	SiO_2	Fe_2O_3	SO_3	MgO	CaO	P_2O_5	K_2O	Na_2O	Total.
No. 1—Pear, Duchess	.74	4.29	1.37	10.21	38.52	9 72	30.96	2.71	98.52
No. 2—Pear, Anjou	.87	3.15	1.90	9.32	31.88	13.66	26 93	9 60	97.31
No. 3—Pear, Sickles	.89	5.14	1.59	1.39	51.20	14.14	25 45	trace.	99.81
No. 4—Pear, Bartlett	2.31	4.18	1.60	2.02	36.15	11.46	29.99	10.74	98.47
No. 5—Pear, Duchess	.13	2.14	2 27	8.88	36.03	9.41	35.89	4 01	98.76
No. 6—Pear, Vicar of Wakefield	.34	1.39	2 57	43.29	4.96	10.03	37.98	trace.	100.41
No. 7—Pear, Howell	.81	5 47	.18	52 98	4.17	20.61	Cl'ds by diff 15.78		100.00
No. 8—Plum, Lombard	.38	4.35	1.79	2.55	36.89	8.86	31.02	12.43	98.27
No. 9—Plum, Lombard	.40	1.21	1.27	5.79	41.40	20.77	24.43	3.86	99.17
No. 10—Plum, Lombard Roots .	4 45	3.87	3.48	5.15	29.44	17.00	31.39	4.45	99.32
No. 11—Peach, Late Crawford .	.97	5.39	2.12	5.84	59.22	7.02	2 19	17.34	100.09
No. 12—Osage, Orange	.97	2 28	2.12	4.75	30.10	13 35	34.78	11.06	99.41
No 13—Cherry, Winslow	.65	1.84	. . .	. . .	54.20	17.64	. . .	. . .	. . .
No. 14—Cherry, May Drake . . .	1.84	2.21	1.61	3.17	54.20	12.92	Cl .50	. . .	76.55
No. 15—Cherry Wood	2.1	.07	3.3	9 2	28.7	7.7	20.8	8.4	. . .
No. 16—Cherry Bark	20.	.2	.8	5.1	42.	3.3	7.5	14.5	NaCl .6
No. 17—Apple tree	1.3	1.7	.9	7.5	63.5	4.9	19.2	NaCl .5 Na_2O .5	100.1

The analyses 1 to 14 were made by myself, and in each case parallels were carried through. The samples for the complete analyses were nearly all taken at the same time, and therefore no variation need be allowed in the different analyses for a change in the per cent. of ash or ash constituents due to its variation at different seasons of the year. The samples being all young and thrifty twigs of one year's growth, the per cent. of ash is consequently low. The analyses 8 and 9 were made from young trees growing a few rods apart; but one sample was taken three months later than the other. The sample for analysis No. 10 was taken from the roots of sample 9. The tree being only three or four years old the whole top was incinerated. The high per cent. of silica (SiO_2) in No. 8 is probably due to the fact that the sample was not thoroughly cleaned, the roots being quite knotty.

In the peach the per cent. of lime (CaO) is higher than for any other tree, but the potash is correspondingly lower.

The variation in the per cent. of mineral constituents in the ash of the two plum trees is quite marked, but this is not strange when we consider the effect of the difference in soil and of difference due to the variation in the time of collecting the samples.

It is quite noticeable that the per cent. of potash (K_2O) in the top and roots of the plum (samples 6 and 8) is nearly the same, while the per cent. of lime (CaO), though varying much, is yet quite low for both root and top. In all of the samples chlorine was found, but not in weighable quantities.

Although at first the variation in the per cent. of ash constituents in the different pears seems strange, it is nevertheless found to be true to experience, for it is well known that land on which some varieties can be grown would not answer for other varieties of the fruit.

It will be seen by the tables that a tree without fruit is not very exhaustive to the land.

The method of analysis was in the main that found in Prof. G. C. Caldwell's Agricultural Chemistry, but some modifications of it were deemed necessary for practical working. The value of these results will be shown by a little explanation.

Subsequent calculations are based on figures given by a prominent fruit grower, modified by experiment and approved by several horticulturists. It is estimated that pear trees such as those from which the samples were taken (six inches in diameter) will add to their growth in a year 10 pounds of wood above ground, and an equal amount below. Experience shows that the sum of these will not vary more than from 16 to 24 pounds for the total weight of wood added to the entire tree in a year's growth. The trees in question yield on an average 3 bushels of fruit each year, weighing 45 to 50 pounds per bushel. The weight of leaves produced on the same tree is about 20 pounds, and varies in about the same proportion as the wood. The number of dwarf trees (10 by 12 feet apart) on an acre is 363.

The following tables will show the exhaustion of the mineral constituents of the soil by weight in pounds, in the yearly growth of wood above ground on an acre of orchard in which the arrangement of trees is as above indicated:

The pure ash of the wood of the pear we found to be .27 per cent.

	S_1O_2	SO_3	Fe_2O_3	CaO	MgO	P_2O_5	K_2O	Na_2O
No. 1—Pear, Duchess	.07	.13	.43	3 88	1.03	.98	3.11	.27
No. 2—Pear, Barre Anjou . .	.09	.19	.34	2 22	.93	1.38	2.68	.98
No. 3—Pear, Sickles	.09	.16	.52	5.17	1.40	1.43	2.57	. . .
No. 4—Pear, Bartlett	.23	.16	.42	3.65	.20	1.16	3.02	1.08
No. 5—Pear, Duchess	.01	.23	.22	3.64	.90	1.20	3.63	.40
No. 5—Pear, Vicar of Wakefield	.34	.11	.26	4.47	.5	1.01	3.83	. . .
							cl'ds by diff.	
No. 7—Pear, Howell	.08	.02	.55	5 35	.42	2.08	1.59	
No. 8—Plum, Lombard	.14	.67	.16	1.38	.56	.33	1.16	.47
No. 9—Plum, Lombard	.15	.45	.49	1.53	.22	.78	.90	.15
No. 10—Plum, Lombard Roots	.17	.13	.15	1.1	.19	1.18	.16	.64
No. 11—Peach, Late Crawford .	.03	.07	.13	1.6	.16	.21	.48	.06

These tables give quite an accurate idea of the amount of mineral constituents a tree takes from the soil and also of the exhaustion of orchards to the land.

The amount of lime (CaO) taken up by the trees on an acre varies from 3.6 lbs. to 5.3 lbs. The potash (K_2O) from 2.5 lbs. to 3.6 lbs. and the variation in the other mineral constituents taken from the soil can be seen in the tables. The Bartlett pear is the least and the Sickles pear the most exhaustive to the land. Plum trees are not one-half so exhaustive as pears while the peach tree is less exhaustive than either.

The figures regarding the number of trees on an acre, also the yield of fruit per tree and its weght, are taken from Prof. Bailey's Horticulturist's Year Book. The weight of wood added to a standard pear tree is five times that added to a dwarf tree, but the number of trees on an acre is one-fifth as many, therefore the exhaustion to the land would be about the same. It is interesting to compare the amount of mineral constituents required for the yearly growth of trees, with that necessary for some of the more common field crops.

The following analyses were made by Thos. Way and G. H. Ogston and will give an idea of the drain upon land which is used for cereals, hay, &c. Pounds per acre:

CROPS.	SiO_2	P_2O_5	SO_3	CaO	MgO	Fe_2O_3	K_2O	Na_2O	NaCl	KCl
Oats	69 8	22.3	5.8	12.	9.1	2.7	36.5	3.6	3.8	6.3
Barley	107.2	24 3	4.3	15.6	8.8	1.6	38.3	2.6	.6	.7
Hay	184.7	57 3	31.3	74.	19.7	7 4	273.3	.3	21.1	77.8
Flax	22.1	25 6	8 2	51 1	12.1	9.7	59 5	6.	18.3	2.2
Hops	47.6	28 4	6 6	60.4	11.4	.9	44 6	none	6.1	15.0
Corn	36.4	31.4	6.5	13.5	12.4	3.	56 6	.9	.3	none.

It must be remembered that there is added to the roots of a tree an amount of wood equal to that added to the top, the composition of which as compared with the top may be seen in analyses Nos. 9 and 10, but since the wood of the root is never taken from the ground the mineral constituents which are a part of its composition can never be said to be taken from the field, yet in a growing tree the fact must be remembered and a rate of exhaustion allowed for the roots equal to that of the branches.

There is also taken up by the leaves an amount of mineral constituents, the per cent. of which is shown by the following table taken from Dr. Wolff's ash analysis.

	LEAVES OF				
	APPLE.	CHERRY.	BEECH.	MAPLE.	ELM.
K_2O	24.75	23.23	21.83	25.41	23.67
Na_2O	2.67	9.60	3.26	.93	2.16
CaO	53.39	42.64	44.37	30.89	29.31
MgO	5.56	12.33	7.29	10 49	8.41
Fe_2O_3	1.08	.91	2.37	1 98	6.86
P_2O_5	6.71	6.36	7.83	9.56	7.63
SO_3	3.32	2.21	2.49	9.67	2.05
SiO_2	2.31	2.73	10.56	11.07	19.91
CO_2	22.02	23.29	11.59	14.08	11 38

Much of this material, however, returns to the land and need not be considered as very important in the calculations.

The only part of the mineral constituents absorbed by the tree that are carried away from the field is that portion contained in the fruit. The amount of fruit grown on different trees varies within such wide limits and its mineral constituents vary so much with the quality of the fruit that only very general conclusions can be given.

The results below, taken from Dr. Wolff's ash analysis, show the composition of the ash of some of the common fruits:

FRUITS.

	APPLE.	PEAR.	CHERRY.	PLUM.
K_2O	35.68	54.69	51.85	59.21
Na_2O	26.09	8.52	2.19	.54
CaO	4.08	7.98	7.47	10.04
MgO	8.75	5.22	5.46	5.46
Fe_2O_3	1.40	1.04	1.98	3.20
P_2O_5	13.69	15.20	15.97	15.10
SO_3	6.09	5.69	5.09	3.83
SiO_2	4.32	1.49	9.04	2.36
Cl			1.35	
Pure ash	1.44	1.97	2.20	1.87

These results give the amount of mineral constituents an average growth of fruit takes from the soil. The following statements, together with the previous calculations, serve as a basis in the determination of the results given in the table which follows:

APPLES.

Every alternate year a full grown tree produces 30 bushels weighing 48 pounds per bushel. There are on an average 20 trees on an acre.

CHERRIES.

The average yield of a cherry tree is 5 bushels, and the weight of a bushel 40 pounds. There are 135 trees on an acre.

PLUMS.

The average yield of a plum tree is 6 bushels, and the weight of a bushel is 55 pounds. There are 135 trees on an acre.

PEARS.

The average yield of a dwarf tree is 3 bushels, and the weight of a bushel is 48 pounds. There are 363 trees on an acre.

	K_2O	Na_1O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	S_1O_2	Cl
Apples.									
Single tree	7.39	5.41	.84	1 81	.29	2.83	1.26	.89	
Acre	147.9	108.1	16.92	36.28	.58	56.76	25.25	18.29	
Cherries.									
Single tree	2 28	.69	.33	.24	.08	.70	.22	.39	.05
Acre	308.	.12	44.58	32 43	11.76	94.86	30.23	53.69	8.01
Plums.									
Single tree	3.55	.03	.60	.32	.19	.90	.23	.14	
Acre	480.	4.37	81.39	44.27	25.94	122.	31.	19.14	
Pears.									
Single tree	1.55	.24	.22	.14	.02	.43	.16	.04	
Acre	563.1	87.72	82.17	53.75	10.71	156.5	58.5	15.34	

We next consider the per cent. of nitrogen found present in trees, and also its variation in the different parts of the same tree. The following table is from Dr. Wolff's Aschen Analysen, and shows the variation in the fir tree:

	LOG WOOD.	BILLET WOOD.	BRANCHES.	END OF BR.
Wood	.11	.11	.17	.68
Bark	.65	.59	.67	1.10
Sap	.17	.18	.32	.78

The variation during different parts of the year is also given:

	TREES—CHERRY.	BIRCH.	PINE.	CHESTNUT.
April	2.00	. .	. .	. .
May	. .	. .	3.59	2.12
June	. .	2.43	. .	. .
July	.95	2.32	2.81	. .
August	. .	1.57	. .	. .
September	.84	1.28	1.68	.70
October	.11	.49	.70	.62

The table represents the per cent. of N in wood dried at 100°C.

The source of the mineral constituents of the trees must be the soil, while the atmospheric carbon dioxide, water and ammonia, furnish the organic compounds which enter into the growth of trees. The H used by the tree comes from the water, the carbon from the carbon dioxide and the nitrogen from ammonia. There appears at present to be but little certain knowledge as to the power of trees to absorb combined N directly from the air as distinguished from that obtained from the same source through the agency of the soil. The organic materials used by trees are the remains of animals and plants, but even these must assume the mineral form before they can become food for trees. The other mineral constiuents are absorbed from the soil by the roots, after being first made soluble by the decomposition going on in the soil, which renders them capable of being taken up by the sap and distributed to all parts of the tree. NH_3 is of the first importance to the vegetable world, and for its retention in the soil four alkaline bases are made responsible. It is, therefore, always present in an available form. Usually enough ammonia and nitric acid are present in the atmosphere for vegetation, and by cultivation and accumulation may take place in the soil. The mineral constituents necessary to the growth of the tree are potash, lime, magnesia, and iron, phosphoric acid, sulphuric acid, with possibly the addition of soda.

The analyses of Bibra, Zoeller, Arendt, Bretschneider and others upon the per cent. of soda in trees and plants leads to the conclusion that in some trees, or in certain parts of trees, it may be wholly wanting, while in others it may occur in abundance. It has not been proven, however, that soda is entirely wanting in any entire tree or plant grown on natural soil. The general conclusion is, then, that the quantity of soda present in a tree is an extremely variable one, and though generally present in some proportion, yet in some parts of a tree it has not been found present in weighable quantities.

An important question now arises: Can soda take the place of potash? The result of the investigations of Halm-Horstmar, and more recently of Knop and Schreber, have demonstrated that it cannot entirely do this, since potash is absolutely essential to the growth of the tree. Cameron concludes that soda can partially replace potash, and this appears to be indicated by many facts. It may be, however, that the soda which often appears to replace the potash is accidental, and that the replaced potash was present in the tree in an excess of that really needed for its growth. The amount of either absorbed would depend on the nature of the soil.

Potash is of the next importance to the vegetable world. The organic acids require alkalies and alkaline earths to form the salts which exist in the tree, and in most cases it would be impossible for these acids to be formed were it not for the presence of these bases. There is every reason to believe that the alkalies are peculiarly connected with the formation of carbohydrates, and that an increased assimilation of alkalies is co-ordinate with the increased formation of carbohydrates.

Lime is of the next importance. Its great abundance in nature is a guarantee of its presence in an available form for the tree.

Of the remaining ingredients, iron, is perhaps, of the greatest importance. It is abundantly proven that its presence is necessary to the development of the tree or plant. It is usually found in the greatest abundance in the bark; much of it is accidental and not necessary to the development of the tree.

Cl is never totally absent from a tree, but if necessary to its development, only a small quantity is needed. Its absence in many reported analyses is due, without doubt, to the fact that it is easily driven off from the ash when it is at the temperature necessary for the combustion of the wood.

Silica is not indispensable to the growth of trees but analyses show that it is always present in the ash of trees grown on natural soils. It is usually found most abundant in the stem and sometimes occurs to the extent of 30 per cent., as is often the case in the pine tree. It also varies greatly with the age of the tree, and is frequently found as a coating on the bark. Halm-Horstmar's investigations seem to indicate that silica is indispensable to vegetation, but the later investigations of Sachs, Knop, Nobbe, Stiegert, Wolff and others, indicate that it is not essential to the physiological development of the plant. Its great abundance in the soil, however, accounts for its occurrence in the ash of all trees.

Lucanus' investigations show conclusively that the oxide of manganese is inessential to the development of the tree.

It must be remembered that all the ash constituents which are necessary to the growth of the tree may be absorbed by it in a much larger quantity than is essential.

The effect of an abundance of any one of the ash constituents of a tree upon its vegetable products has been given some study, but no definite conclusions have been reached. It is known, for example, that pears will flourish on ground that would yield apples scarcely palatable, but the mineral constituent wanting and necessary for the full development of the apple is not known.

Fruit growers agree that by the use of fertilizers you may affect the growth of wood very much, but not the quality or quantity of fruit. The best form to apply the mineral constituents to the soil is in the use of stable manure which has the following average composition: Water 75 per cent., organic matter 19.2, ash 5.2, nitrogen .5, potash .63, soda .19, lime .7, magnesia .18, phosphoric acid .26, sulphuric acid .16, silica .16, chlorine and fluorine .19.

The composition of the ash of trees certainly does not of itself afford sufficient data to determine, with anything like certainty, which fertilizing constituents or manuring mixtures should be applied to the various trees in order to produce the largest yield of fruit. A knowledge of the composition of the ashes of trees, however, gives us warning that our trees will become unhealthy if the soil on which they are grown is either wanting or contains insufficient quantities of one or more of the ash constituents necessary for the growth of the tree. Often the amount of growth is sought to be increased by the addition of ammonia when really the soil may be starving for mineral food. An excess of ammonia over the proper proportion of mineral constituents does not enter into the growth of the tree, or in other words, as before stated, the increase in growth in a tree is proportional to the mineral elements of nutrition present in the soil in a soluble or available form, and an excess of ammonia will not supply this deficiency. The aim should be to apply enough and just those elements that will increase assimilation of mineral constituents. Often the increase of mineral food may prove effectual far beyond the increase of nitrogenous matters, but the effect will depend most closely upon the amount of CO_2 and solar energy available for use, and the reverse must be remembered, solar energy is limited by the amount of soil materials present. Endeavor also to use salts of those acids which are present in the least quantity in the soil. The effect of the addition of ammonium salts is not what NH_3 would be, for they contain an acid which acts on the constituents of the soil and renders the earthy phosphates more soluble in water.

Experiment shows that trees die if the supply of mineral food is exhausted, even though they be still supplied with organic food in abundance. It must be remembered that the roots of trees go down deep in the soil and bring to the surface much that would not be available were ordinary crops grown on the field.

An experiment made by George Ville will show the effect of fertilizers upon vegetation. The plant taken for the investigation was hemp. The characters of the plant taken into consideration are color, stature, weight: "Seven soils were used. First, intense manure (100 kilos of N); second, complete manure (75 kilos of N); third, manure without nitrogen; fourth, manure without phosphates; fifth, manure without potash; sixth, manure without lime, and, seventh, soil without manure. Plants treated with intense manure were of the deepest green, height 1.25 metres, weight 11.22 kilos; complete manure, height 1.20 metres, weight 11.15 kilos, color less deep; manure without N, height .61 metres, weight 4.74 kilos, color yellowish green; manure without phosphates, height .97 metres, weight 8.22 kilos, color medium green; manure without potash, height .40 metres, weight 5.22 kilos, color light yellowish green; manure without lime, height 1.15 metres, weight 10.57 kilos, color slightly paler than those without phosphates; plants in unmanured soil, height .18 metres, weight 2.17 kilos, color pale green."

This experiment gives us a fair knowledge of the effect of different fertilizers, and may be of some aid in the selection of those intended to be used on orchard land.

The object of this investigation has been to place at the disposal of the fruit grower some definite knowledge of the drain upon his orchard land

and also to give him an idea of how much and what mineral constituents he must apply from year to year to meet the demands of a thrifty tree.

The writer is indebted to Prof. G. C. Caldwell, of Cornell University, for the material and assistance that enabled him to carry on this investigation

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Poisonous effects of cyprepedium spectabile. By D. T. McDougal. Published in the Minnesota Botanical Studies, Part I; 32–36.

Symbiosis of isopyrum biternum. By D. T. McDougal. Published in the Minnesota Botanical Studies, Part II; 139–142.

The stomates of cycas. By Mason B. Thomas.

Our present knowledge of the distribution of pteridophytes in Indiana. By Lucien M. Underwood.

The purpose of this paper is not primarily to convey any new information although it contains reference to some plants not hitherto reported from this state; nor for the purpose of criticizing what has hitherto been accomplished though it notes the necessity of cutting out some of the plants reported from the state that never belonged to its flora. Its purpose is rather to indicate the paucity of information we have at hand regarding the distribution of even the best known groups of plants; to indicate the extensive portions of the state that are practically untouched by the hand of the collector; to indicate how futile and useless it is to publish or even make manuscript lists of the plants of any region and leave nothing to represent this information aside from a mental recollection or a printed or written line; to outline the limits of our definite in-