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CHEMICAL EXAMINATION

OF THE ASHES OF THE

HEMP AND BUCKWHEAT PLANTS,

WITH REMARKS ON ITS BEARING ON

HEMP CULTURE IN KENTUCKY.

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CHEMICAL EXAMINATION OF THE ASHES OF THE HEMP AND BUCKWHEAT PLANTS, &c.

The hemp crop is of considerable importance in Kentucky agriculture, more especially in the richer portion, called the Blue Grass region, where the soil has been formed by the disintegration of the fissile layers of the lower Silurian limestone—rich in the mineral elements of plant nourishment.

According to the State Auditor's report, the gross amount of hemp fibre produced in our State was 18,981,819 pounds in 1872, and 21,375,306 pounds in the more productive, moist season of 1873.

Of this latter quantity seventeen counties, situated wholly or in part in the Blue Grass region, produced 21,194,445 pounds, and the five counties of Bourbon, Fayette, Jessamine, Scott, and Woodford produced 17,951,350 pounds. Mason county, the next in this industry, having also raised 828,300 pounds. It is, therefore, evidently a crop which is believed to be profitable only on our richest lands. The soil which best suits it is the rich, pervious, and well-drained loam, well charged with *humus* or the dark mould resulting from vegetable decomposition, such as results from the completely decomposed sod of recently cleared woodland pastures, or blue grass or clover ground, well plowed and made thoroughly fine and uniform in texture. Such land, in a favorable season, has been known to produce as much as 1,200 pounds of hemp to the acre, and it will yield an average of about 800 pounds for ten to fifteen years in succession, if properly managed, in ordinary seasons. As the price of hemp rarely falls below one hundred dollars per ton of 2,240 pounds, and this crop usually brings in cash, the great value of this industry is evident.

The hemp plant, under favorable conditions, is of most rank and luxuriant growth, attaining on our rich lands a height of ten to fourteen feet in favorable seasons, even when sown so thick, as is the practice, that it is closely crowded, and so completely covers the ground that not a weed can grow amongst it. It therefore requires a soil which can readily and quickly furnish to it the mineral elements necessary to its rank and rapid development, and at the same time furnish the large supply of moisture it requires without losing that highly porous condition and absorbing power which invites the penetration of the gases and vapors of the atmosphere, on which this plant is so greatly dependent for nourishment and growth.

The well-drained loam of this Blue Grass region, which is charged with black vegetable mould or *humus*, offers these conditions; the *humus* not only having great power of absorption, but containing in a soluble and available state the mineral elements of plant nourishment, and, moreover, acting as a solvent for those which are contained in the earthy constituents of the soil itself. We can therefore readily understand why the hemp plant thrives upon such land; but why so luxuriant a growth can be maintained on the same surface for ten to fifteen years in succession, without any material exhaustion of the soil, is another question.

The observing hemp farmer has long since arrived at a correct conclusion in this respect. He saw that while this most luxuriant plant produced an immense green crop, and required the richest soil to supply its rapid demand for nourishment during its short season of growth (of four months only), yet all its leaves and other green tissues, together with all that is removed from it in the process of dew-rotting, in the ordinary mode of hemp culture, are restored to the soil which produced it, and nothing is sold and carried off from the land but the cleaned hemp fibre, which, if well cleaned, contains very little but atmospheric elements, the removal of which can therefore cause but very little deterioration of the soil.

Moreover, during a great part of the year the ground is more or less shaded and protected, first by the growing plant, then by the roots left in the ground after cutting, which somewhat diminish the washing action of rains and improve it in their gradual decay, as do also the leaves which fall and the hemp when spread on the ground to dry, after being cut, and lastly, when it is spread out upon it in the winter process of dew-rotting, as it is called, during which all the readily decomposable parts of the plant are washed out and decomposed by the rains and dews and the action of the air; enriching the surface soil beneath.

Managed in this way, and commencing with suitable rich land, the scientific observer understands, that although the growing plants may temporarily draw heavily on the soil for the mineral (earthy) ingredients necessary to their growth, amongst the most important of which are potash and the earthy phosphates, yet in the subsequent processes, the most of these are returned to the ground again in the decay of the leaves and other green parts, and in the soluble and decomposable matters which are leached out of the stems in the process of rotting; and that any small loss of these from the arable surface which may occur from the sale of the hemp fibre may be more than compensated by the action of the tap-roots in bringing them up from the lower strata of the ground. He understands further, that all the mineral elements thus restored, being left in organic combination in what is termed the humus or vegetable mould which results from this decay, are in a very soluble condition, and most available for the quick nourishment of the subsequent crop.

If the hemp plant, instead of being dew-rotted on the ground on which it had been grown, is entirely removed from it and submitted to the process of water-rotting, the culture becomes eminently exhausting to the land; mainly because so much of the elements of fertility is necessarily carried off in the water used. This was proved many years ago in relation to the flax crop of Ireland, in the chemical analyses of the water in which the flax had been steeped, and of the plant and the lint, by Dr. Kane; and experience to a certain extent in this region, in the water-rotting of hemp, has given the same result. It is, perhaps, fortunate for our farmers, therefore, that this process, although several times proposed to them, has never been received with much favor.

The foregoing facts being of common experience, the writer desired, by the chemical examination of the mineral or earthy constituents of the hemp plant, as given in the *ash* in different periods and conditions of its growth, in different parts of the plant, and the various stages of its preparation, to study more fully the relations of this crop to the soil, and to understand, if possible, the true reasons why it is not an exhausting product when properly managed, as well as to learn the best conditions for its successful culture.

The first step in this investigation is to ascertain the average composition of the mineral ingredients of the entire hemp plant as given by the chemical analysis of its ashes; and as the works accessible to the writer give but very limited information on the subject, he procured from his own farm, and submitted to this analysis, five different samples, produced in two different seasons, grown under different conditions, and collected in different stages of their growth. The ashes of these, obtained by careful incineration at a moderate heat, were analyzed by the approved processes—several comparative analyses of the same ash having been made to secure greater accuracy—and the results are tabulated below in comparison with the average of two hemp-ash analyses published in 1865 by Professor Emil Wolff, of the Royal Academy of Agriculture, at Hohenheim, Wirtemberg, which are republished in the Appendix, page 378, of "How Crops Grow," by S. W. Johnson.

The samples examined may be described as follows:

Sample A. Entire hemp plants, including roots, leaves, &c.; collected on September 4th, 1874, when fully mature and ready for cutting; grown on somewhat elevated, very rich ground, the second year only from the broken up blue grass sod of woodland pasture, which had not been previously cleared or cultivated within the memory of the present race, but which had been the site of a large circular earth-work* by the ancient mound-builders, and which seemed to have been enriched by a long residence upon it of these prehistoric people. The sample, notwithstanding the great fertility of the land, was very small, in consequence of *a continued drought which prevailed during the season of its growth*, it not being more than six to seven feet in height.

Sample B. Mature hemp plants, taken as it is usually cut, the roots and a small portion of the stems being left in the ground, and having only the top leaves, the others having fallen; collected September, 1873; grown on the field described above *in a very moist* and favorable season, so that it was very tall and large stemmed. The samples were about twelve feet high. Some hemp plants this year attained a height of fourteen feet.

Sample C. Six hemp plants entire, leaves, roots, and all; collected, before full maturity, on July 27th, 1874, from the same rich field, in the *very dry season.* The plants were about six feet high, and were in full leaf and in flower.

Sample D. Entire hemp plants, including roots, leaves, and immature seeds; grown on the experimental field selected by my son, Benj. D. Peter,† for practical experiments in hemp culture. This ground had been long in cultivation—at least fifty years. This sample was grown on lot 3, to *which about* 200 *pounds of plaster had been applied* early in the growing season. The sample was collected on September 8th, 1874. The plants were quite small, not more than from five to six feet high, in consequence of the continued drought of this season and the condition of the land.

Sample E. Similar to sample D; grown on the neighboring lot 4, of this experimental field, under similar conditions, except that *no plaster or any other fertilizer was applied to this lot.* A part of this lot 4, however, where a fence row formerly stood, happened to be somewhat richer than any part of this

* Fully described in Collins' History of Kentucky.

† See Prof. N. S. Shaler's Report.

or the plastered lot, as shown by the greater luxuriance of the growth of the hemp in that part.

F. The average of the analyses of the ashes of two entire hemp plants as given by Prof. Emil Wolff, as above stated.

In this table, as well as in the following ones, the carbonic acid of the ash is excluded in the calculations, for more complete comparison of the proportions of the *essential* mineral ingredients of the ash.

TABLE I. A. OF THE CHEMICAL COMPOSITION OF THE ASH OF THE ENTIRE HEMP PLANT, CALCULATED IN 100 PARTS OF THE ASH, WITH EXCLUSION OF CARBONIC ACID.

	A.	B.	C.	D.	E.	F.
Lime	38.482	31.299	48.689	50.623	45.263	43.4
Magnesia	8.558	6.017	6.445	8.576	11.225	9.6
Potash	37.475	43.739	29.118	23.519	23.933	18.3
Soda	.378	1.438	1.280	.472	.009	3.2
Phosphoric acid	8.667	14.164	10.384	11.721	13.233	11.6
Sulphuric acid	2.272	1.622	.940	1.472	1.445	2.8
Chlorine	.984	.522	.640	.301	.273	2.5
Silica	3.181	1.199	2.749	3.316	3.342	7.6
Per cent. of earthy phosphates	18.186	29.773	21.692	28.460	27.427	. . . .
Per cent. of ash to the air-dried plants, carbonic acid excluded	4.223	2.563	5.055	4.126	4.203	4.6
Per centage of ash, carbonic acid included	5.569	3.357	6.754	5.288	5.346	. . . .

This table shows some notable differences in the ash proportions and composition. For example, sample B, grown in the moist season, as compared with the others grown during the drought, gave a smaller ash per centage to the dried plants; its ash contains smaller proportions of lime, magnesia, and silica, and larger proportions of potash, soda, and phosphoric acid.

The immature sample C, gathered in July, as compared with the other samples (A, D, and E) of the same dry season, which were gathered in September, shows a larger per centage of ash to the dried plants.

The samples D and E, grown on the old land, while they give about the same average of ash to the dried plants, show a smaller proportion of potash.

Not much importance is attached to the proportion of silica, which is evidently stated much too high in the analyses quoted by Wolff. The hemp plant, being somewhat viscid on its exterior, always has more or less fine silicious dust adhering to it, derived from the soil, which cannot be removed by washing the plants. This the writer attempted to exclude, in his analyses, by dissolving the ash in diluted acid (nitric or chlorohydric), and excluding all that remained undissolved as most probably fine earth accidentally adhering to the plant. This may, in some cases, be a slight cause of error, but probably not so great as the retention and analysis of the adhering fine dirt with the plant ash, which seems to have been done in the analyses quoted by Wolff. For the same reason the alumina and iron oxide were also excluded.

The real significance of these differences of proportion and composition of these ashes can better be seen where the comparison is made with the proportions of the dried plants themselves to the several ingredients of the ash, as given in the following table:

TABLE I. B. OF THE QUANTITIES OF THE ASH INGREDIENTS IN 100 PARTS OF THE AIR-DRIED HEMP PLANTS, CARBONIC ACID EXCLUDED.

	A.	B.	C.	D.	E.	F.*
Lime	1.624	0.802	2.461	2.103	1.968	1.74
Magnesia	.361	.154	.312	.356	.475	.30
Potash	1.582	1.121	1.472	.977	1.012	.74
Soda	.016	.037	.065	.019	a trace.	.15
Phosphoric acid	.366	.363	.525	.488	.560	.47
Sulphuric acid	.096	.042	.047	.061	.061	.10
Chlorine	.041	.013	.022	.012	.011	.10
Silica	.134	.031	.139	.135	.141	.30
Per cent. of earthy phosphates	.768	.763	1.103	1.182	1.150	....
Per cent. of ash to dried plants	4.223	2.563	5.055	4.126	4.203	4.00

* See Wolff's tables, "How Crops Grow," page 383. Calculated to the dried plants.

This table shows, that while the smallest proportion of mineral or ash ingredients, to the dried plants, was given in the season when the hemp had a luxuriant growth because of the regular supply of moisture, the difference was occasioned mainly by the greater quantities of lime, magnesia, and silica in the plants of the dry season, and not by any material variations in the proportions of the alkalies or phosphoric acid.

It is well known that the external tissues of all growing plants become more or less charged with earthy salts, especially carbonates of lime and magnesia with some phosphates, which have been carried from the soil to their surfaces in solution in water containing carbonic acid (which is in all the water of the soil) and left there in a form insoluble in water upon the escape of that acid and the evaporation of the water which brought them up. As all the moisture of the fertile earth contains this solution, which is drawn up and evaporated from the general surfaces of the plants exposed to the air, it can readily be seen, that because of the greater evaporation and the more concentrated nature of the soil solution, in the dry season, there must necessarily be a larger accumulation of this surface deposit in the dry than in the moist or wet season, when evaporation is measurably checked. For the same reason the ash per centage of the leaves and bark of plants is greater than that of the interior parts, and that of the leaves of deciduous plants greater than that of the leaves of evergreens, which give off less water by evaporation.

The effect of this evaporation has very justly been compared to the deposit of the limestone crust in the steam-boiler and the formation of stalactites in caves; and this irregular increase of the ash per centage causes many apparent discrepancies in the mineral ingredients of plants, and increases the difficulties in the chemical study of plant nourishment; for while it is generally admitted as fully demonstrated, that certain mineral ingredients, to be found in the ashes of all vegetables, are essentially necessary to their growth, it must be acknowledged that some or some portion of these ingredients are of no more significance than the incrustation in the steam-boiler; being mere accidental deposits on the surface, the result of the escape and evaporation of the agents, water and carbonic acid, which held them in solution in the sap of the plants and in the water of the soil.

In the same manner may we explain the influence of a dry season in increasing the fertility of the surface of the soil; the soil solution, on the evaporation of the water, leaving its dissolved salts and other ingredients upon the surface; so that seasons of long drought are usually followed by others of great productiveness when there is sufficient moisture.

The larger ash per centage of sample C is mainly due to this cause; the leaves not having fallen, which yield a very large proportion of ash.

The ashes of samples D and E, grown on the old land in the very dry season, while not differing much in their general weight-proportion to the dried plants, show more lime and less alkalies than that of the hemp grown on the richer land. For some reason not immediately apparent, perhaps because of a previous buckwheat crop, they gave rather more than the average quantity of earthy phosphates.

In the usual mode of management of the hemp crop the leaves mostly fall on the ground on which it is grown. A large proportion of them drop before the hemp is cut, more fall when it is spread on the ground to dry after cutting, and when it is taken up to be stacked. It would be well, doubtless, to beat off, in this process, all the leaves that can thus be separated, so that they may be more regularly distributed over the soil than if thrashed off when stacking it. It is also the general practice now to cut the hemp as nearly as possible to the surface of the ground, and leave the roots, with a few inches of the stem attached, to rot in the soil.

In order to ascertain the relative fertilizing influence of the leaves and roots, three hemp plants were collected, July 25th, 1864, in *the dry season*, from the rich field above described. These, one male and two female plants, were about six to seven feet high. The leaves, stems, and roots, carefully separated and thoroughly air-dried, weighed as follows:

The leaves weighed 23.916 grammes, equal to about 30. per cent. of the whole plant.
The roots " 7.433 " " 9.3 " "
The stems " 48.430 " " 60.7 " "

These were separately incinerated and their ashes analyzed, with the following results:

TABLE II. OF THE RELATIVE ASH INGREDIENTS OF THE LEAVES, ROOTS, AND STEMS OF THE HEMP, CARBONIC ACID EXCLUDED.

	THE LEAVES.		THE STEMS.		THE ROOTS.	
	In 100 p'ts of ash.	In 100 p'ts of dried leaves.	In 100 p'ts of ash.	In 100 p'ts of dried stems.	In 100 p'ts of ash.	In 100 p'ts of dried roots.
Lime	48.819	4.992	23.371	0.949	20.368	0.713
Magnesia	5.726	.585	5.803	.194	8.297	.291
Potash	27.955	2.858	49.599	1.659	52.233	1.829
Soda	.236	.024				
Phosphoric acid	9.264	.947	13.374	.447	15.164	.531
Sulphuric acid	2.209	.226	1.215	.040	1.344	.047
Chlorine	.171	.017	.576	.019	.405	.014
Silica	5.620	.575	1.062	.035	2.189	.077
Per cent. of phosphates	19.160	1.959	28.158	0.942	26.885	0.949
Per cent. of ash	....	10.225	....	3.346	....	3.502

By examination of the above table it is to be seen, that the leaves of the flowering hemp contain more of the essential mineral ingredients of the soil than all the other parts of the plant; constituting, as they do, about 30 per cent. of the whole plant in the air-dried state, and yielding 10.225 per cent. of their weight of ash, the carbonic acid being excluded; while the stems and roots, which together form the remaining 70 per cent. of the weight of the plant, give an average of less than 3.5 per cent. of ash.

Nor is this great excess of the ash proportion in the leaves due entirely to the influence of the greater evaporation which takes place on their surfaces, causing a deposit or incrustation of lime and magnesia salts and silica of the nature of stalagmites; for we see that whilst the amount of *silica* in the leaves is nearly fourteen times greater than that in the stems, and more than seven times greater than in the roots; the *lime* more than five times as great as that in the stems, and seven times more than in the roots; the *magnesia* three times more than that in the stems, and twice as much as that in the roots; the *phosphoric acid* and *phosphates* and the *alkalies* are in nearly double proportion in the leaves also, and the sulphuric acid five times greater in them than in the stems, and about four times greater than in the roots. So that whilst the leaves, when in their fully matured state or when they naturally fall, may possibly contain scarcely any but the less soluble salts which may be left in their tissues on the evaporation of the carbonated water which held them in solution in the sap, they contain, when in the growing, active condition, like all other green herbage, a very large proportion of salts of potash, and of all the mineral elements of plant nourishment, and hence may greatly enrich the soil on which they decay. It is obviously to the interest of the hemp farmer, therefore, so to manage as to spread them as regularly as possible over his hemp ground.

The dried hemp plants are allowed to remain in the stack until the cool season of early winter, when they are generally spread out evenly upon the same ground on which they had been grown, to undergo the process of dew-rotting. The hemp is permitted to remain on the ground until, by the action of the atmospheric waters and other agencies, it has become so far decomposed that all its soluble parts and soft tissues are removed and washed into the soil beneath or dissipated in the air, and the tough hemp fibre can be easily separated from the more woody portion of the stems. It is then taken up, "braked" out, and the clean merchantable hemp fibre separated from the "hemp-herds," or "*hemp shives*"—the broken fragments of the woody parts of the stems—which are usually burnt up by the hemp-brakers on the spots where they fall near their hemp-brakes.

In order to study the changes which occur in the mineral constituents of the hemp during this process of dew-rotting, samples of dew-rotted hemp plants, ready for the brake, were gathered, in December, from the two lots of the experimental field above mentioned, of the crop of the dry season of 1874. These were thoroughly air-dried, incinerated, and their ash submitted to analysis, with the following results:

TABLE III. OF THE ASH ANALYSES OF DEW-ROTTED HEMP PLANTS, CARBONIC ACID, &c., EXCLUDED.

	(D) SAMPLE FROM LOT 3. PLASTERED. (SEE D.)		(E) SAMPLE FROM LOT 4. NOT PLASTERED. (SEE E.)	
	In 100 parts of ash.	In 100 parts of dried hemp plants.	In 100 parts of ash.	In 100 parts of dried hemp plants.
Lime	68.846	1.235	63.651	0.942
Magnesia	8.335	.149	8.343	.124
Potash	5.716	.102	5.682	.084
Soda	.429	.008	.760	.012
Phosphoric acid	13.979	.251	15.713	.233
Sulphuric acid	.965	.017	1.552	.023
Chlorine	.050	.001	.042	.001
Silica	1.680	.030	4.257	.063
Per centage of earthy phosphates	27.144	.487	29.920	.443
Per cent. of ash to the dried rotted hemp	.....	1.793	.....	1.480

On comparing these results with those given in tables I. A. and I. B., in the columns D and E, where the results of the analyses of the ashes of this same growth of hemp are given in the *unrotted* state, it will be seen that a great diminution has taken place in the amount and proportions of the ash and its several ingredients.

To exhibit this diminution of the ash ingredients, which takes place in the ordinary process of dew-rotting, we place the averages from table I. B. and the above table side by side in

TABLE IV. COMPARATIVE VIEW OF THE ASH OF THE UNROTTED AND THE DEW-ROTTED HEMP PLANTS, CARBONIC ACID BEING EXCLUDED.

	Average of D and E. Unrotted hemp plants.	Average of D and E. Dew-rotted hemp plants.	Proportions removed by dew-rotting.
Lime	2.036	1.089	About one half.
Magnesia	.415	.136	Nearly two thirds.
Potash	.995	.093	More than nine tenths.
Soda	.019	.010	About one half.
Phosphoric acid	.524	.242	More than one half.
Sulphuric acid	.061	.020	About two thirds.
Chlorine	.011	.001	Ten elevenths.
Silica	.138	.047	Nearly two thirds.
Per cent. of earthy phosphates	1.166	.465	More than one half.
Per cent. of ash to the dried plants	4.165	1.636	More than one half.

When we also take into consideration the fact that the dried hemp plants lose at least one third of their weight in the dew-rotting, we can judge how large a proportion of the essential mineral ingredients are restored to the soil in this process.

The above table also shows us that the more soluble ingredients, such as the alkalies, &c., are removed from the plants in the larger proportions.

These analyses and comparisons enable us clearly to understand why the culture of hemp, when judiciously managed, especially when it is spread out and dew-rotted on the same surface on which it was grown, is so little exhausting to the soil, as compared with the method in which the water-rotting process is used.

In order to ascertain how much of the essential elements of the soil are carried off in the merchantable product—the hemp fibre as ordinarily sold—analyses were made of some of this, both in the usual condition as it is to be found in our hemp factories, and after it had been well washed with water to remove from it as much of its adhering dirt and soluble matter as possible.

Two samples of the "hemp-herds," or refuse woody portions of the stems, separated in the operation of braking, were also incinerated, in the air-dried state, and the ashes submitted to chemical analysis. The results are given in the following table:

TABLE V. COMPARISON OF THE ASH INGREDIENTS OF DEW-ROTTED HEMP FIBRE AND HEMP HERDS, CARBONIC ACID EXCLUDED.

	HEMP FIBRE, UNWASHED.		HEMP FIBRE, WASHED.		HEMP-HERDS, 1873. MOIST SEASON.		HEMP-HERDS, 1874. DRY SEASON.	
	In 100 pt's of ash.	In 100 p'ts of dried hemp.	In 100 p'ts of ash.	In 100 p'ts of hemp.	In 100 p'ts of ash.	In 100 p'ts of dried herds.	In 100 p'ts of ash.	In 100 p'ts of dried herds.
Lime	59 960	0.984	68.694	0.722	51.998	0.446	62.992	0.676
Magnesia	8.612	.141	6.222	.065	8.426	.072	8.966	.097
Potash	7.351	.121	3.789	.040	19.615	.168	8.670	.093
Soda	.712	.012	.801	.008	.915	.008	.754	.008
Phosphoric acid	15.852	.260	15.335	.161	14.401	.124	12.215	.131
Sulphuric acid	1.710	.029	.487	.005	2.016	.017	2.138	.023
Chlorine	.092	.002	.048	.001	a trace.	a trace.	a trace.	a trace.
Silica	5.621	.092	4.624	.049	2 629	.022	4.465	.048
Per cent. of earthy phosphates	31.567	.518	29.486	.310	29 275	.251	24.807	.267
Per cent. of ash to the air-dried material	.....	1.642	.....	1.051	.....	.859	.....	1.076

The hemp fibre, which was analyzed in the ordinary unwashed condition, was obtained from a factory in Lexington. It was of the crop of 1874, dark colored, and containing, perhaps, more than the average quantity of dirt or fine soil adhering to it. Washing with cold water removed some but not all of this adhering dirt, as well as much of the soluble matters contained in it, reducing the per centage of the ashy residue more than one third. Had it been thoroughly cleaned and bleached the ash per centage would have been still more considerably reduced. All the nitrogenous matters, holding phosphates in a comparatively soluble condition, all the alkaline salts, would thus be dissolved out, and very little else than silica, with a small proportion of the earthy carbonates, would be left in the clean hemp fibre; so that exhaustion of the soil from its production would be quite insignificant.

Calculating on the data of the above tables, we find that an average crop of hemp of 800 pounds to the acre removes from the soil only a little more than thirteen pounds of ash ingredients, or, when in the washed condition, less than eight pounds and a half, while it is well known that a crop of wheat of twenty bushels takes nearly twenty pounds in the grain alone; a crop of fifty bushels of corn removes more than thirty pounds in the grain alone, and a crop of tobacco of one thousand pounds, more than one hundred and seventy-six pounds.

When we compare the relative proportions of the ingredients of these several ashes, the result is still more to the advantage of the hemp crop, as is to be seen in the following table:

TABLE VI. OF THE PROPORTIONS OF MINERAL INGREDIENTS REMOVED FROM THE SOIL IN CERTAIN AVERAGE CROPS.

	In 800 lbs unwashed hemp.	In 800 lbs of washed hemp.	In 20 bus'ls of wheat *	In 50 bus'ls of corn.*	In 1,000 lbs tobacco, including the stalks.*	In 2,400 lbs of ordinary hemp-h'ds.
Lime, in pounds	7.872	5.776	1.63	0.22	68.00	10.704
Magnesia, "	1.128	.520	2.43	3.61	8.67	1.728
Potash, "	.968	.320	5.45	8.06	69.73	4.032
Soda, "	.096	.064	.13	6.22	6.80	.192
Phosphoric acid, "	2.080	1.288	9.12	11.85	8.13	2.976
Sulphuric acid, "	.232	.040	.08	not est.	8.40	.408
Chlorine, "	.016	.008	.35	not est.	1.06	a trace.
Silica, "	.736	.392	.41	.71	5.86	.528
Total ash	13.128	8.408	19.60	30.67	176.65	20.568
Total earthy phosphates	4.144	2.480	. . . .	. . . .	. . . .	6.024

* From volume IV, Reports of Kentucky Geological Survey (old series), page 321.

We see that while an average crop of hemp takes only an amount of potash from the acre varying from less than one pound to less than one third of a pound, the wheat crop takes nearly five and a half pounds, the corn crop more than eight, in the grain alone, and the tobacco crop nearly seventy pounds; and while the hemp crop carries off only from one and a quarter to two pounds of phosphoric acid, the wheat will take more than nine, the corn more than eleven, in the grain alone, and the tobacco more than eight pounds. We notice also that the removal of the hemp-herds (which are believed by some of our practical farmers to bear a proportion in weight to the hemp fibre of three to one) will take from the land greatly more of its essential ingredients than the hemp fibre itself; for while the merchantable hemp holds less than a pound of potash and two pounds of phosphoric acid in its composition, the equivalent quantity of hemp-herds holds more than four pounds of potash and nearly three pounds of phosphoric acid.

As we have stated, it is the common practice of our farmers to permit the hemp-herds to be burned up in the heaps where they fall near the hemp-brakes. Some erroneously believe, indeed, that they would exert an injurious or poisonous influence on the land if spread over it; but it is evident that this practice tends more rapidly to reduce the fertility of the hemp field than the sale of the hemp fibre; and that it would be beneficial to adopt some plan of reducing the hemp-herds to the condition of vegetable mould, and to spread it over the surface, where it would not only tend to keep up the proportion of humus, but would re-supply much of the essential mineral elements in a soluble or available form. If it is found that the recently scattered hemp-herds seriously interfere with the cultivation or growth of the next succeeding hemp crop, it would doubtless pay to haul them into heaps to rot, or to spread them over some other field, which might be in preparation for hemp in a system of rotation adapted to this culture.

The common practice in our region has been to cultivate the rich new land in hemp continuously until it no longer yields a profitable product, and then to resort to other newly-cleared woodland pasture, or open blue grass fields, to renew the process. Sometimes land comparatively old in cultivation has been used for hemp, after it has been rested and has increased its humus during two or three years in clover, or for a longer time in open blue grass pasture; but as yet no regular system has been adopted by which the abundant humus and ready supply of soluble mineral ingredients of the soil, necessary to this luxuriant vegetation, can be secured or maintained. As the hemp product carries but little of these away from the land, leaving most of them behind, after a temporary use of them during its season of growth, the maintenance of the productiveness of the hemp soil seems an easy problem to solve, where the land is well drained and naturally of a suitable composition and consistence, as is our blue grass land. But the capability of the production of hemp, even in this fertile soil, appears to be limited, and its humus and other soluble essential ingredients, on the abundance of which this crop is so greatly dependent, seem gradually to undergo diminution in the ordinary system of culture.

That this gradual deterioration is not due wholly to the removal of the crop is evident from the foregoing facts and considerations. But it appears that the humus and its soluble and available constituents are decomposed and removed, under the influence of the atmospheric agencies, faster than they are renewed by the decay of the leaves and other decomposable parts of the hemp plant. The small proportions of these carried off in the merchantable hemp need, indeed, scarcely be taken into consideration in this connection.

The humus is a very decomposable and oxidable substance; the atmospheric oxygen combines continuously with its carbon and hydrogen to produce carbonic acid and water, so necessary as plant food, while the essential mineral elements of the mould thus set free, being in a soluble condition, are subject to the washing agency of water, which may diffuse them more or less through the neighboring fields, or gradually carry some of them off in the drainage. This action would be the greatest when the ground is no longer covered with a growing vegetation, which would absorb the rich soil solution and bring its valuable fixed ingredients to the surface, but is doubtless constant whenever water in sufficient quantity falls to saturate the soil or to pass through it. For although many experimenters have established the fact that the soil has a power of absorption sufficient not only to enable it to withdraw and hold certain substances dissolved in the water which passes through it, and even to decompose some chemical compounds, and to separate and hold some of the elements and replace them by others less essential, yet it is equally well established by numerous experiments that pure water, such as rain water, which passes through a fertile soil, carries off from it, in solution, a notable quantity of its essential elements, which, as already intimated, may either be lost to the locality by the drainage or diffused through the adjoining grounds, according to the well-known laws of osmose.

To maintain the high degree of active fertility necessary to successful hemp culture, even in our rich blue grass lands, seems, therefore, to require something more than the most judicious management of that crop itself; for we find that, although the removal of the hemp causes a scarcely sensible diminution of the mineral elements of the soil, the field on which it is continuously produced for a series of years becomes at length unproductive of this crop, because, doubtless, of a gradual decrease of its proportions of humus and of those soluble salts which are required by the hemp plant in such a large and ready supply as is necessary to its rank and rapid development, during its short season of growth.

As the prevalent mode of culture, if carried on indefinitely, would inevitably reduce all our hemp lands below the level of profitable production, the adoption of a new system, which would promise greater durability to hemp culture, is greatly desirable.

According to the prevalent system, the hemp ground is exposed, more or less, to the decomposing and leaching influence of the atmospheric agencies for more than six months in the year, with scarcely any growing plant upon its surface to absorb and retain the dissolved fertilizing materials or the nutritive gases which are produced in it by decomposition. These, therefore, may pass off in the drainage or become lost to the field by the continuous process of diffusion.

The growth of the hemp begins early in May; it is ended, by the cutting of the crop, late in August. During these four months it is probable the active vegetation absorbs and retains the dissolved essential elements of the soil, so that waste of them by oxidation, diffusion, or drainage, is little or nothing. The drying of the cut hemp spread on the ground is a short process, and the subsequent influence of the roots of the hemp left in the ground is merely mechanical, and does not prevent oxidation of the humus or the leaching out or diffusion of its soluble materials; neither does the hemp, when spread out to dew-rot, prevent this action of the atmosphere or the water, although it may give much soluble fertilizing matters to the soil; and very few weeds of any kind spring up in the hemp field to take up and retain for future use these valuable gaseous and soluble substances which pervade the soil, and are escaping, mostly in solution, in all the water which passes through it.

The obvious remedy for this loss is to keep the surface of the ground, as much as possible, covered with an active vegetation which would absorb and retain upon the surface these fleeting elements of fertility, and keep up, in its subsequent decay, the large proportion of humus which is necessary to a heavy hemp production.

Some of our farmers, for this purpose, have very judiciously resorted to the sowing of rye after the cutting of the hemp, to be plowed in, the following spring, as early as may be necessary to kill it and allow it to rot. The rye grows with great vigor and covers the ground fully; is not injured by the hardest frost, and offers no impediment to the dew-rotting of the hemp, while its roots continually absorb the soluble and gaseous elements of plant food, to retain them and leave them in an available state, together with a new supply of humus, when it is plowed in to decay in the soil. If at the time of sowing the rye the ground is also plowed and the hemp roots covered to rot, no doubt the surface could be more benefited than if the grain is simply sown on the surface and harrowed in.

Some definite idea of the beneficial influence of the rye may be obtained by examining the results of the analyses of this plant in its immature condition, as given in the tables of Emil Wolff and Dr. Emmons, of New York. (See table in Johnson's "How Crops Grow" and "Natural History of New York.")

It would be quite a moderate estimate to say that rye, sown on the rich hemp ground in early September and plowed in early in April or late in March, would give to the land an amount of vegetable matter, in its roots and leaves, equal to three thousand five hundred pounds, in the dried condition, to the acre, which by its decay would greatly increase its vegetable mould or humus, and probably replace fully that portion which had been removed in the hemp culture. But we find, by reference to the table of Wolff, that this amount of organic matter would also give to the soil more than sixty-six pounds of potash; more than twenty-five pounds of phosphoric acid; nearly thirteen pounds of lime; more than five pounds of magnesia; more than two pounds of sulphuric acid, and equally considerable quantities of soda, chlorine, and soluble silica; in all more than one hundred and seventy pounds of essential mineral ingredients to the acre, in a state most favorable for plant food, or nearly twenty times as much as need be carried off in an average crop of merchantable clean hemp fibre. This use of the rye plant evidently commends itself to the careful and judicious hemp farmer for a full and thorough trial.

Another important question with our hemp farmers is, how best to improve our old fields to a new capability of profitable hemp culture? Such is the natural fertility of our blue grass soil, and so very favorable are the conditions to which it is subject, that this is a more easy problem than is generally supposed. Indeed, our routine farmers find by experience that a good clover rotation, or a series of years in blue grass sod, will ordinarily recuperate a field to hemp land. The soft Silurian limestone beneath it is constantly, although slowly, yielding up its stores of fertilizing elements to the atmospheric waters, which gradually dissolve it and bring them by diffusion into the soil for the use of growing plants. But the demands of the farmer upon the soil most generally exceeds this beneficent supply of fertilizers, and hence his fields decrease in productiveness in the ordinary thriftless husbandry which has been kept up by this liberality of nature, and he is already confronted with the necessity, either for the use of artificial fertilizers or the adoption of such a system of rotation of crops as will give time for the natural recuperation of his soil, without a serious diminution of his annual income. The latter alternative commends itself most in our region, and especially a rotation which includes a clover fallow of two years. The red clover growing with great vigor on our ordinary soil; producing a great amount of herbage; drawing largely from the atmospheric gases and vapors, and reaching to considerable depths in the soil for mineral fertilizers with its long tap roots; so that experience proves it to be the best known plant for the renewal of our land, in our common rotations, more especially because it can be pastured with hogs or cattle without a very serious diminution of its ameliorating influence upon the soil. When cut for hay, which is removed from the field, the case is very different, as can be understood when we see that a clover hay crop of two tons carries off with it not only the equivalent of humus which its decay on the soil would give, but also more than eighty pounds each of potash and lime, nearly twenty-three pounds of phosphoric acid, and other fertilizing mineral substances in proportion.

The ash of the dried clover and dried green hemp plant are strikingly alike in composition, as may be seen in the following table:

TABLE VII. OF THE RELATIVE PROPORTIONS OF THE ASH CONSTITUENTS OF CLOVER AND HEMP PLANTS, &c.

	In 100 parts of the dried hemp. From table I. B. (Sample C.)	In 100 parts of dried clover. (E) From Wolff's tables.*	Mineral Ingredients in an acre of clover, including the roots. (Say 5,000 lbs., dry.)
Lime	2.461	2.30	115.00 pounds.
Magnesia	.312	.80	40. "
Potash	1.472	2.30	115. "
Soda	.065	.10	5. "
Phosphoric acid	.525	.65	32.5 "
Sulphuric acid	.047	.20	10. "
Chlorine	.022	.25	12.5 "
Silica	.139	.20	10. "
Per cent. of ash	5.055	6.80	340. pounds.

* The average of fifty-six analyses.

That the clover fallow may be made very useful in the renovation of our hemp lands, by a judicious management, is manifest.

But other plants of a quicker growth may sometimes enter into an improving rotation for this crop, and no other promises better than the *buckwheat plant*, in ordinary seasons, which may afford moisture enough for its luxuriant growth.

During the present year my son, Benj. D. Peter, devoted one lot in his experimental field (see Prof. N. S. Shaler's report) to buckwheat, sown broadcast in the spring, in order to study its ameliorating influence on the soil when plowed in. The season being a very wet one, the plants grew with great luxuriance and fully covered the ground. Samples of it were gathered by me, roots and all, on June 20th, when it was in full leaf and in flower at the top; and also on August 4th, when it was about three feet high, yet in flower at the top, and had matured a good deal of seed. It had, of course, then lost most of its lower leaves. These samples were fully air-dried in the laboratory, incinerated, and the ashes fully analyzed, with the following results:

TABLE VIII. OF THE COMPOSITION OF THE ASH OF THE BUCKWHEAT PLANT, &c., CARBONIC ACID EXCLUDED.

	BUCKWHEAT IN FLOWER.		BUCKWHEAT IN SEED.	
	In 100 parts of the ash.	In 100 parts of dried plants.	In 100 parts of the ash.	In 100 parts of dried plants.
Lime	33.434	2.9'9	35.103	2.131
Magnesia	10.518	.922	12.586	.764
Potash	32.900	2.883	26.180	1.589
Soda	1.266	.111	.657	.040
Phosphoric acid	16.824	1.470	23.770	1.443
Sulphuric acid	1.378	.120	not est.	not est.
Chlorine	.431	.0:8	.350	.021
Silica	3.249	.285	1.354	.083
Per cent. of earthy phosphates	32.873	2.880	47.198	2.865
Per cent. of ash in dried plants	.....	8.762	.....	7.479
Per cent. of dried to green plants	.....	18.000	.....	29.000

This crop of green herbage was plowed under shortly after the last sample was gathered, in the hope that the matured seed would germinate and produce a second growth to be plowed under in the fall. Many did sprout, but the grass-hoppers consumed most of the young plants.

Before plowing this buckwheat under, the green growth on a yard square was weighed, and amounted to four and three quarter pounds, which is equivalent to about 22,990 pounds to the acre, equal to more than six thousand pounds, or three tons, of the dried plants, including the roots, to the acre of ground. So that, calculating on the data given in the above table, this large quantity of green herbage, with the seeds and roots included, would not only give to the surface the large amount of humus, or vegetable mould, which would result from its decomposition, but also more than ninety-five pounds of potash; more than eighty-six pounds of phosphoric acid; nearly one hundred and forty pounds of lime; nearly forty-six pounds of magnesia, and other essential ingredients in proportion; all in a state immediately available for plant nourishment.

The experience of another season may demonstrate its practical effect in an increased hemp production.

The buckwheat plant is used in other regions as a fertilizer, and may very properly be introduced here in a rotation. It is evident that future profitable hemp culture will depend greatly on the adoption of a judicious rotation of crops suited to our soil and markets. What the details of that rotation may be must be worked out by our intelligent farmers.

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