PHILOSOPHICAL TRANSACTIONS.

VII. *Memoir on the Rotation of Crops, and on the Quantity of Inorganic Matters abstracted from the Soil by various Plants under different circumstances.*

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Contents.

Introduction.

In laying before this Society an account of certain experiments which I have undertaken with the view of elucidating the principles upon which the advantage of a rotation of crops in husbandry depends, it may be proper that I should in the first instance state the circumstances under which they were commenced, as well as those which led me during the course of them to deviate in some respects from my original plan of proceeding.

During the prosecution of a set of researches which embraced a period of more than ten years, it might naturally be expected, that the views at first entertained would become modified, and that arrangements deemed sufficient for carrying out the original plan should appear unsatisfactory, in proportion as glimpses of other truths, than those which enlightened us at the outset, began to open upon the field of our inquiry.

Thus, when first I determined to apply a portion of the ground at my disposal to experiments having reference to the rotation of crops, the scientific world was ge-

nerally impressed in favour of a theory which the celebrated De Candolle had so ingeniously and eloquently maintained; namely, that a soil became unfitted for supporting a second crop of any given plant, in consequence of the deleterious influence exerted upon it by juices excreted from the former one.

My original object therefore was,—first, to detect, if possible, the chemical nature of these supposed excretions; and secondly, to demonstrate their poisonous influence, by taking account of the expected diminution in the amount of the crop exposed to them, beyond that of another in which all the circumstances were the same, excepting the presence of the excretions in question.

To accomplish these two objects, it seemed sufficient to set apart a number of plots of ground uniform as to the quality and richness of its soil, planting one-half of the number year after year with the same species of crop until the land no longer produced it, and the other moiety with crops of the same description, succeeding one another in such a manner, that no one plot should receive the same twice during the period of the continuance of these experiments, or at least within a short interval of one another.

By weighing the produce of each plot, reduced to the same uniform condition of dryness, when it had arrived at maturity, I hoped to obtain data for computing, how much of the expected diminution might be referred to the exhaustion of the ground, and how much to the effect of excretions which the preceding crop had given out.

The influence of seasons indeed is in all these cases one of the most important elements in the calculation, yet by taking the average of a number of years, it was hoped that this source of error might be eliminated, and that whilst the mean of the crop obtained during the latter half of the period, as compared with that of the former half, might suggest the rate of exhaustion brought about by the annual demand made upon the resources of the soil, the difference between the *permanent* and the *shifting* crop in each instance might tend to show, in what degree the excretory function of each plant contributed to the result.

Assuming, therefore, on the faith of the then existing authorities, that soil would soon become deficient in the food which was required for the plants grown in it, and moreover that, even if not exhausted, it would become unsuitable to their growth, by being contaminated with the excretions from preceding crops, I conceived it unnecessary either to undertake an analysis of the soil itself at the commencement of my labours, or to inquire into the chemical constitution of the crops which I had obtained in the course of them.

Supposing, as was then too hastily assumed, that the composition of each vegetable was uniform, and had been already determined with sufficient precision, it should follow, that the amount of produce ought in itself to be an index of the quantity of inorganic matter abstracted from the soil, and that the number of crops obtained before the soil became effete would indicate the relative richness of the latter in those ingredients which were essential to the growth of the plant in question.

As I proceeded however in my experiments, I began to find, that both the postulates on which I had built were unsound, for neither was I able to detect any foreign organic matter in the soil, referable to the excretions of the crop which had grown in it*, nor did I find that uniform difference between the shifting and the permanent crop, to the disadvantage of the latter, which I should have expected upon the principles of DE CANDOLLE's theory.

Moreover, the researches of BRACONNOT, which have since been made known to the world, tended still further to throw doubt upon the truth of the facts on which the doctrine of excretion reposed, and when no longer swayed by the authority of the distinguished author of the theory in question, I perceived more clearly the difficulty of reconciling it with many facts or opinions that seemed current amongst agriculturists—such, for instance, as the growth of repeated crops of the most exhausting plants in certain rich alluvial, or newly settled countries; the continuance of a plant in a state of nature for ages in the same locality; and lastly, the views of LIEBIG, which went to prove, that the food of plants, so far as their organic constituents are concerned, is derived in all instances from the elements of air and of water.

No sooner, therefore, had I become suspicious as to the truth of the opinion which I had previously entertained as to the excretions from the roots of plants being capable of explaining the falling off of a crop after repetition, than I felt desirous of shaping my inquiries in such a manner as to ascertain, if possible, which of the other two conceivable explanations might deserve a preference; whether, for instance, the falling off of the crop was attributable to a failure in the soil of organic matters fitted for its nutrition, or of those inorganic materials which it equally required.

* The soils that seemed to me most likely to afford indications of the presence of root excretions were those which had reared crops of poppies and of tobacco for several years in succession, the former plant containing, in morphia and meconic acid, products readily recognizable by chemical tests, and the latter one sufficiently so in nicotine.

I accordingly digested sifted portions of the soils, amounting in each instance to 5 lbs., in water for several hours.

The water drained off was evaporated, and then filtered.

The clear solution was first treated with sugar of lead, and the precipitate which fell was collected, and then dissolved in water acidulated with sulphuric acid. Had any meconic acid existed in combination with the lead, it would have been thus separated, the metal being precipitated along with the sulphuric acid with which it forms an insoluble salt.

None of the tests, however, usually employed for detecting meconic acid produced any effect,—chloride of iron dissolved in alcohol causing no red colour, and ammonio-sulphate of copper not being rendered green.

The liquor remaining after the introduction of the sugar of lead might have contained morphia held in solution by acetic acid. To detect it, the lead was in the first place thrown down by sulphuretted hydrogen, after removing which, the remaining solution, after being concentrated, was treated with ammonia, which produced a flocculent precipitate.

This, however, proved destitute of morphia, for neither was there any blue colour as produced by chloride of iron, nor any redness by nitric acid.

My attempts to detect nicotine in the soil in which tobacco had been grown proved equally ineffectual.

To determine this, it seemed necessary to appreciate, if possible, first, what materials the soil might have contained, both before the experiments commenced, and after their termination; and secondly, what might be the constitution of the plants themselves both in the permanent and the shifting crop, as compared with the normal condition of the same.

But as the experiments which I had instituted extended to no less than sixteen different species, my object being to select at least one out of each natural family, which contained amongst the plants included under it any of those usually cultivated for farm or garden purposes in this country, it seemed necessary to limit that part of the inquiry which involved the necessity of ash analysis to a portion only of the series, and accordingly, in the autumn of 1844, I selected from the crops grown in that year the following as the subjects of chemical examination, namely, Barley, Potatoes, Turnips, Flax, Hemp, and Beans.

Of each of these six plants, the shifting and permanent crops, after having been weighed in the usual manner, in order to estimate their relative amount, were reduced to ashes, so that the proportion of inorganic to organic matter might in the first instance be determined.

In consequence of the largeness of the bulk, iron vessels were necessarily employed for burning away the volatilizable parts, and hence a portion of peroxide of iron was always introduced into the ashes, which, being indefinite in quantity, rendered it necessary for me, in the subsequent analyses, to regard the whole of that ingredient as extraneous, and to reject it from the calculation. The same course was also pursued with respect to a certain variable amount of sand and charcoal always present in the ash, the former derived evidently from the soil, the latter from the carbonaceous matter of the vegetable, which could not be entirely removed by the combustion.

Of each of these six plants it appeared necessary to analyse at least three specimens—the first taken from the permanent crop, the second from the shifting one, the third from a piece of ground, not belonging to the spot at which the experiments were carried on, and under ordinary treatment, but corresponding as nearly as possible in natural character to the soil of the experimental garden.

Thus this part alone of the inquiry involved at least eighteen distinct analyses, an amount of labour, which, as I soon found, my other occupations precluded me from undertaking, and which I was glad to delegate to other hands.

I therefore esteemed myself fortunate in being able to secure the services of Mr. THOMAS WAY, a gentleman, who had for the last two years officiated as Assistant to Professor GRAHAM of University College, London, and who was recommended to me by that distinguished chemist as well-qualified for the task.

On him, therefore, the merit, as well as the responsibility, of this part of the inquiry must mainly devolve; all that I can lay claim to in this part of the subject as my own, is the having considered, in conjunction with him, the method of analysis which

he ultimately adopted, and having made such preliminary trials on one of the crops which he afterwards analysed, as tended to satisfy me, that on those points in which the plan differs from that proposed by Dr. WILL, our method deserves the preference, on the score of convenience, if not with respect to accuracy.

In a case of this kind, experience alone can determine the degree of confidence which is due to the results obtained, but I ought not to withhold my own individual testimony to their fidelity, from having witnessed the manner in which they were conducted by Mr. WAY, his perfect familiarity with the processes which he pursued, and the scrupulous care taken by him in repeating every step in the investigation, which presented anomalous results, or appeared from any cause open to suspicion.

But to complete my design, an analysis of the soil, as well as of the crops which grew in it, was requisite, and to this subject therefore my attention was next directed.

Now, when we consider the nature of a soil in an agricultural point of view, or in reference to its suitableness for the growth of various kinds of vegetables, two questions naturally come before us; namely, what amount of ingredients capable of being assimilated in the course of time by the crops does it contain; and secondly, what is the amount of those which are present, in a condition actually available for their purposes, at the precise moment when the examination is undertaken.

Both the above points are obviously quite distinct from that of the total amount of ingredients actually existing in the soil, and hence some might be disposed to add to the labour of the two preceding investigations, that of ascertaining the whole of its constituents, whether in a state to be affected by the ordinary agents of decomposition, or not.

The latter question, however, seems to me to possess, with reference to the agriculturist, only a speculative interest, and when introduced into a Report intended for his use, may be more liable to mislead than to instruct, unless due caution be taken to point out to him, how much of each ingredient is to be regarded as inert, and how much of it as applicable to the future or present uses of the plant.

Let us take the case of a natural soil, composed of certain kinds of disintegrated lava, or even of granite, in which it is evident, that an actual analysis, conducted by means of fusion with barytes, or lead, or by those other processes which chemists employ for decomposing compounds of a refractory nature, would detect the presence of a large per-centage of alkali, not improbably of a certain amount of phosphate of lime, and in short would indicate an exuberant supply of all those ingredients which plants require for their support. Nevertheless a soil of this description, in consequence of the close union of the elementary matters of which it consists, and of the compactness of its mechanical texture, might be as barren, and as incapable of imparting food to plants, as an artificial soil composed of pounded glass is known to be, notwithstanding the large proportion of alkali which it contains.

Thus I have myself observed*, that the soil which covers the serpentine rock of Cornwall, a mineral consisting of—

Silica	43·07
Magnesia	40·37
Alumina	0·25
Lime	0·50
Oxide of iron	1·17
Water	12·45—HISINGER,

contains so minute a proportion of magnesia, that in an analysis of a small sample I altogether overlooked its presence, in so great a degree does the mechanical texture of the rock, and the state of combination subsisting between its ingredients, preserve it from the decomposing action of the elements which tend to set loose its treasures.

Now it seems obvious, that whatever cannot be extracted from a soil by digestion in muriatic acid during four or five successive hours, must be in such a state of combination as will render it wholly incapable of imparting anything to a plant, for such a period of time at least as can enter into the calculations of the agriculturist; and moreover, that all which muriatic acid extracts, but which water impregnated with carbonic acid fails in dissolving, ought to be regarded as at present contributing nothing, although it may ultimately become available to its purposes.

I have therefore thought proper to distinguish between the actually available resources of the soil, and those ultimately applicable to the uses of the plant, designating the former as its *dormant*, and the latter as its *active* ingredients.

The portion dissolved after digestion in muriatic acid will contain both the dormant and the active; that taken up by water impregnated with carbonic acid will consist merely of the latter; the difference in amount between the two will therefore indicate the dormant portion of its contents.

The dormant and active portions may both be comprehended under the designation of its available constituents, whilst those which, from their state of combination in the mass, can never be expected to contribute to the growth of plants, may be denominated the passive ones.

Every soil, which is capable of yielding an abundant crop of any kind of plant after fallowing, must be assumed to possess in itself an adequate supply of all the ingredients necessary for its support in an available condition, but it is plain that these could not have existed in an active one, or such an interval of rest would not have been required for rendering them efficient.

Accordingly it is quite possible, that after ten years cropping, the soil of the experimental garden might still retain plenty of alkaline salts and phosphates, although what was ready to be applied to the uses of the plant had for the most part been absorbed by the crops previously obtained.

* Lecture on the Application of Science to Agriculture, from the Journal of the Royal Agricultural Society of England, vol. iii. part 1.

With a view then to this part of the inquiry, I proposed to estimate, first, the amount of ingredients severally present in the soil which might sooner or later become available for the purposes of vegetation; and secondly, that of those principles which were in a state to be applied immediately to those uses. It would also have been instructive, to determine, by a comparative analysis of the soil, in the state in which it was before, and after the experiments had been instituted, the loss which had been occasioned by the crops in both these particulars; but as, from the reasons assigned, I had neglected to examine the identical soil of the experimental garden before the researches commenced, I was obliged to content myself with obtaining an approximation to its probable constitution, by selecting for examination that taken from a portion of the garden, which was immediately contiguous, but which had recently been manured, and had borne good crops.

Here also I was assisted by Mr. Way, who undertook the more laborious part of the inquiry, namely, that of determining the entire amount of the available constituents present in certain of the soils, leaving to me the task of ascertaining merely the nature of those which could be extracted by water.

The investigation therefore divides itself naturally into three heads; the first respecting the actual amount of the permanent and shifting crops each year obtained; the second, the chemical constitution of the ashes resulting from those which had been burnt for the purpose of examination; and the third, the nature of the actual as well as of the available ingredients of the soil in which the crops had been reared.

PART I.

On the quantity of produce obtained from the several plots of ground, each year throughout the period during which the experiments were continued.

The following plants were made the subjects of experiment:—

Spurge	*Euphorbia lathyris*	from 1835 to 1838
Potatoes	*Solanum tuberosum*	from 1834 to 1844
Barley	*Hordeum sativum*	from 1835 to 1844
Turnips	*Brassica rapa*	from 1834 to 1844
Hemp	*Cannabis sativa*	from 1835 to 1844
Flax	*Linum usitatissimum*	from 1835 to 1844
Beans	*Vicia faba*	from 1835 to 1844
Tobacco	*Nicotiana Tabacum*	from 1834 to 1844
Poppies	*Papaver somniferum*	from 1834 to 1844
Buckwheat	*Polygonum fagopyrum*	from 1835 to 1844
Clover	*Trifolium pratense*	from 1834 to 1844
Oats	*Avena sativa*	from 1839 to 1844
Beet	*Beta vulgaris*	from 1839 to 1844
Mint	*Mentha viridis*	from 1835 to 1844
Endive	*Cichorium endivia*	from 1835 to 1844
Parsley	*Apium petroselinum*	from 1835 to 1844

As the experiments were carried on from 1834 to 1844 inclusive, it may be satisfactory to state in the first instance such of the meteorological characters of these years as may be gathered from the Register kept at the Radcliffe Observatory, relative to the mean temperature, or from my own observations made at the Botanic Garden, Oxford, as to the amount of rain.

Year.	Inches of Rain.	Where observed.	Variation + or − (above or below) the mean of the period.	Mean temperature of the year.	Variation + or − (above or below) the mean of the period.
1834.	21·899	Obs.	− 2·845	52·8	+2·282
1835.	26·182	Obs.	+ 1·438	51·5	+0·982
1836.	24·339	Obs.	− 0·365	49·9	−0·618
1837.	21·900	B.G.	− 2·844	50·0	−0·518
1838.	20·080	B.G.	− 4·664	49·9	−0·618
1839.	32·720	B.G.	+ 7·976	51·2	−0·318
1840.	18·530	B.G.	− 6·214	49·9	−0·618
1841.	35·275	B.G.	+10·531	49·8	−0·718
1842.	23·490	B.G.	− 1·254	50·8	+0·282
1843.	25·150	B.G.	+ 0·406	50·3	−0·218
1844.	22·621	B.G.	− 2·123	49·6	−0·918
Total in eleven years.	272·186	....	....	555·7	
Average of eleven years.	24·744	....	....	50·518	

The plots of ground set apart for the experiments were not exactly equal in point of size, but their square contents being known, it was easy to reduce the crops to one standard, and that of 100 square feet was selected as the most convenient.

In reporting to the Society the results, I shall therefore always suppose that reduction as being made, and shall set down what ought to have been the produce, supposing each plot to have measured exactly 100 square feet. In this statement I will begin with the only case in the whole series to which De Candolle's theory of excretions appears at all applicable; namely, that in which the plant experimented on was a species of Spurge, the *Euphorbia lathyris*.

In 1835 a luxuriant crop of this weed was obtained, amounting to about 18 lbs., but the next year the produce had dwindled almost to nothing, and in 1837, in which fresh plants were introduced, an equal failure took place.

Nor did any new plants start up in 1838, so that in 1839 the plot was sown with flax, barley, and beans, of all of which I obtained a tolerable yield.

This experiment therefore might be appealed to in support of De Candolle's views, as it would appear, that excretions had been emitted from the roots of the Euphorbia, which proved injurious to plants of the same species as those from which they had proceeded, but which exerted no such poisonous influence upon others not allied to them in organization; or, if it be objected, that during the course of 1838 the excretions might have become so far decomposed as to lose their poisonous cha-

racter, still the failure of the second and third crops of Euphorbia would seem attributable to some deleterious influence exerted by the excretions of the antecedent crop, rather than to the ground having become exhausted, inasmuch as the latter, without being in the meanwhile enriched with manure, proved its ability to produce tolerable crops of other vegetables.

The acrid nature of the juices of the Euphorbia may possibly explain, why this plant should constitute an apparent exception to the rest, for it will be seen, that in all the other cases, the diminution in the amount of produce, consequent upon the continuation of the crop from year to year, was only such as might be supposed to result from a falling off in some one of those ingredients which were necessary for its development, and was not of a nature to indicate the existence of anything poisonous in the soil in which it grew*.

I shall therefore now proceed to state the amount of produce obtained during the several years from each of the remaining plants above enumerated, distinguishing the crop which was repeated year after year in the same plot of ground as the *permanent* one, and that which was grown successively in different parts of the garden as the *shifting* one.

1. *Solanum tuberosum.*—Ground not manured since 1833.

Year.	Permanent crop. Weighed without having been dried, but merely cleaned from dirt.	Shifting crop.
1836.	Plot No. 1.—After a crop of Turnips. Tubers . . . 89·50	After a crop of *Papaver somniferum.* Tubers . . 84·00
1837.	Tubers . . . 59·5	After a crop of *Cannabis sativa.* Tubers . . 108·0
1838.	Tubers . . . 68·0	After a crop of *Cannabis sativa.* Tubers . . 68·5
1839.	Tubers . . . 59·0	After a crop of *Polygonum fagopyrum.* Tubers . . 132·0

1840. In this year it occurred to me, that it might be interesting to determine what difference, as to the amount of produce, would be produced by planting in one instance tubers from the crop obtained the year before in the same plot, and by employing in another those raised in some different locality.

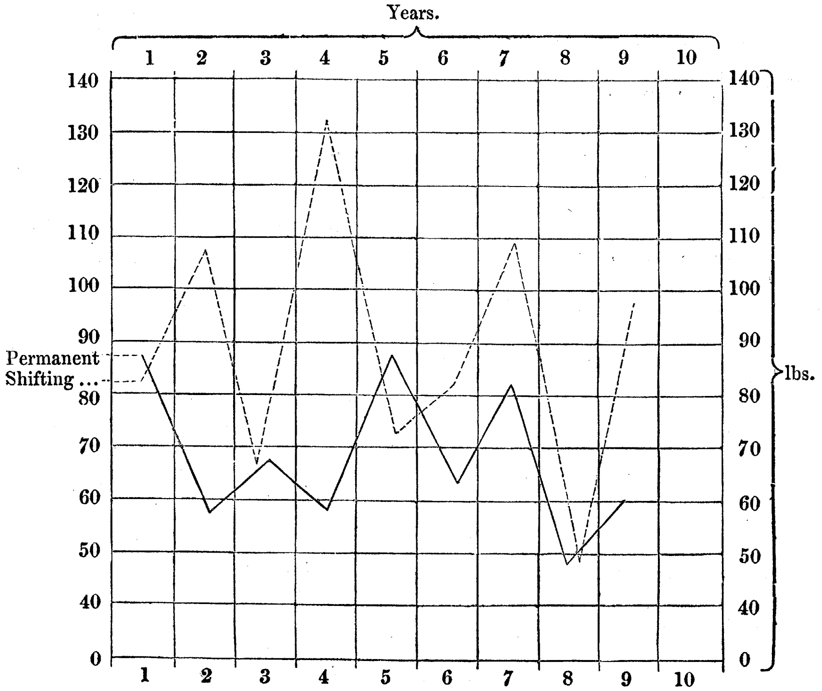
The difference in quantity will be seen not to be very considerable.

* It can hardly, I think, be denied, that juices are excreted from the roots, as well as taken up by them; the only question is, are these excretions injurious to the plants of the same species which grew in the soil afterwards, and if they are, are they favourable to the growth of others? The first of these positions may be countenanced by the facts detailed in the text, but the latter is little, if at all, corroborated by them.

Year.	Permanent crop. No. 1.—Tubers from the same plot planted.	Permanent crop. No. 3.—Tubers from a different locality planted.	Shifting crop.
1840.	Tubers . . 88½	After *Euphorbia lathyris*, which had failed. Tubers . . 90	After *Linum usitatissimum*. Tubers . . 72
1841.	Tubers . . 64	Tubers . . 87½	After *Linum usitatissimum*. Tubers . . 81½
1842.	Tubers . . 82·5	Tubers . . 94·0	After *Vicia Faba*. Tubers . . 110
1843.	Tubers . . 48·6	Tubers . . 38·6	After *Vicia sativa*. Tubers . . 48·4
1844.	Tubers . . 61·0	Tubers . . 57¾	After *Hordeum sativum*. Tubers . . 98·0
	Average of nine years. Tubers . . 68·9 Average of the first five years. Tubers . . 72·9	. . . . Average of five years. Tubers . . 74·77	Average of nine years. Tubers . . 89·1 Average of the first five years. Tubers . . 92·8

The following diagram may convey a clearer idea of the differences in the amount of the crops, and the relation between the permanent and shifting one.

POTATOES.



It is worth remarking, that the average of the shifting crops of potatoes corresponded very nearly to the amount obtained in the year 1844, from a bed of similar size, in a portion of the garden contiguous to that on which my experiments had been carried on, and which had been recently manured, the produce in this instance being 96·0 lbs., whilst the average of nine years in the other case was 89·1 lbs., and moreover that the produce of the last year, in which the crop succeeded one of barley, was not less than 98 lbs., thus apparently showing, that after so long a period of cropping, there was still a sufficient supply in the soil of those ingredients which were requisite for the due development of the plant.

An examination of samples of potatoes from the crop of 1844 proved, that the shifting crop contained more starch, and more of the woody fibre and other organic matters which belong to this vegetable, than either of the permanent ones; and that of the latter, the one grown in soil which had borne potatoes only five years, approached in these respects more nearly to the shifting, than that taken from the soil which had been cropped during ten years. The proportion of water in the two cases was not very different, but with respect to the inorganic matters, it was found that the remark held good.

Here the shifting crop yielded in a given amount of tubers the least, and the permanent crop the largest quantity of ash, as if the deficiency of organic matter had been made up by an increased quantity of that which was derived from inorganic sources. The nature of this latter portion will be stated when I proceed to detail the analyses performed by Mr. Way.

On examining a specimen of a good mealy description of potatoe taken from a garden in the neighbourhood of Oxford, the soil of which was similar to that of the experimental garden, I found the proportion of starch much the same as in the shifting crop, but the quantity of water greater.

The following is a tabular view of the results:—

	Starch.	Fibrous matter.	Other solid matters.	Water.
	per cent.			
Good mealy kind of potatoe from a garden near Oxford . .	13·00	5·90	5·6	75·5
Shifting crop in experimental garden	13·67	9·76	5·7	71·9
Permanent crop of five years' standing.	10·54	11·32	4·5	73·7
Permanent crop of nine years' standing	9·11	9·76	8·8	72·4

2. *Hordeum sativum.*

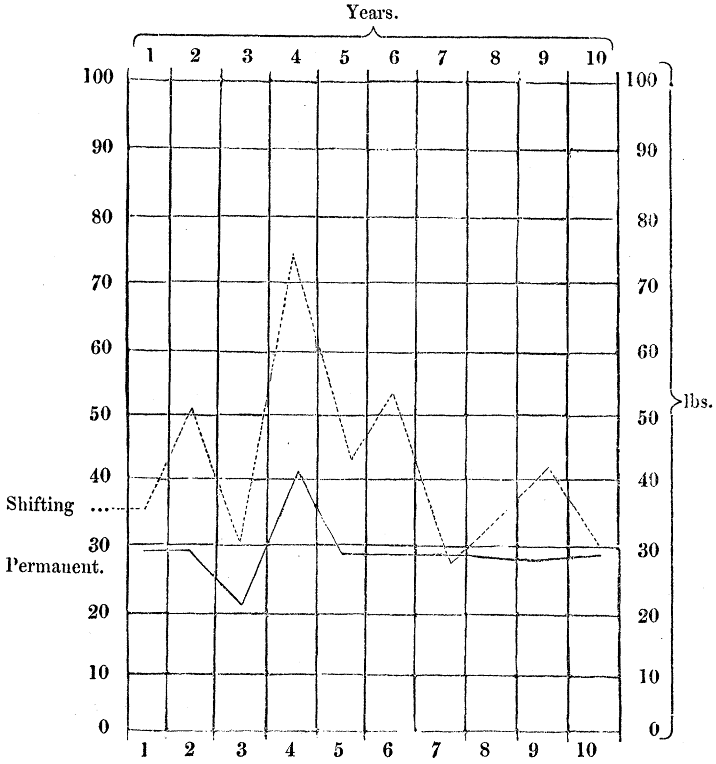
The next crop I shall notice is Barley, in which it will be perceived that, allowing for differences of seasons, the produce obtained during ten successive years was tolerably uniform, there being however a considerable balance in favour of the shifting over the permanent crop.

The following are the results:—

Year.	Permanent crop. Produce in a dried state.	Shifting crop. Produce in a dried state.
	No. 4.	After *Linum usitatissimum.*
1835.	29·0	35·5
		After *Apium petroselinum.*
1836.	29·0	51·0
		After *Linum usitatissimum.*
1837.	21·5	30·0
		After *Cichorium endivia.*
1838.	42·5	75·0
		After *Brassica Rapa.*
1839.	28·0	41·0
		After *Brassica Rapa.*
1840.	28·75	54·5
		After *Vicia Faba.*
1841.	28·0	27·4
		After *Solanum tuberosum.*
1842.	27·5	34·2
		After *Papaver somniferum.*
1843.	26·5	42·5
		After *Cannabis sativa.*
1844.	28·7	30·0
	Average of ten years . . . 28·9	Average of ten years . . . 42·1
	Average of first five years . 30·0	Average of first five years . 46·5
	Average of last five years . 27·8	Average of last five years . 37·7
	Maximum in one year . . 42·5	Maximum in one year . . 75·0
	Minimum in one year . . 21·5	Minimum in one year . . 30·0

The following Table will show the curve of their growth :—

BARLEY.



The quantity of barley produced in a contiguous piece of ground recently manured, was 39·4 lbs., being more than the average of the shifting crops, but about equal to the produce obtained the first year from the permanent one.

3. *Brassica Rapa.*

Next in the series are Turnips, in which the difference between the average of the shifting and permanent crop is very remarkable, namely as 176 to 100.

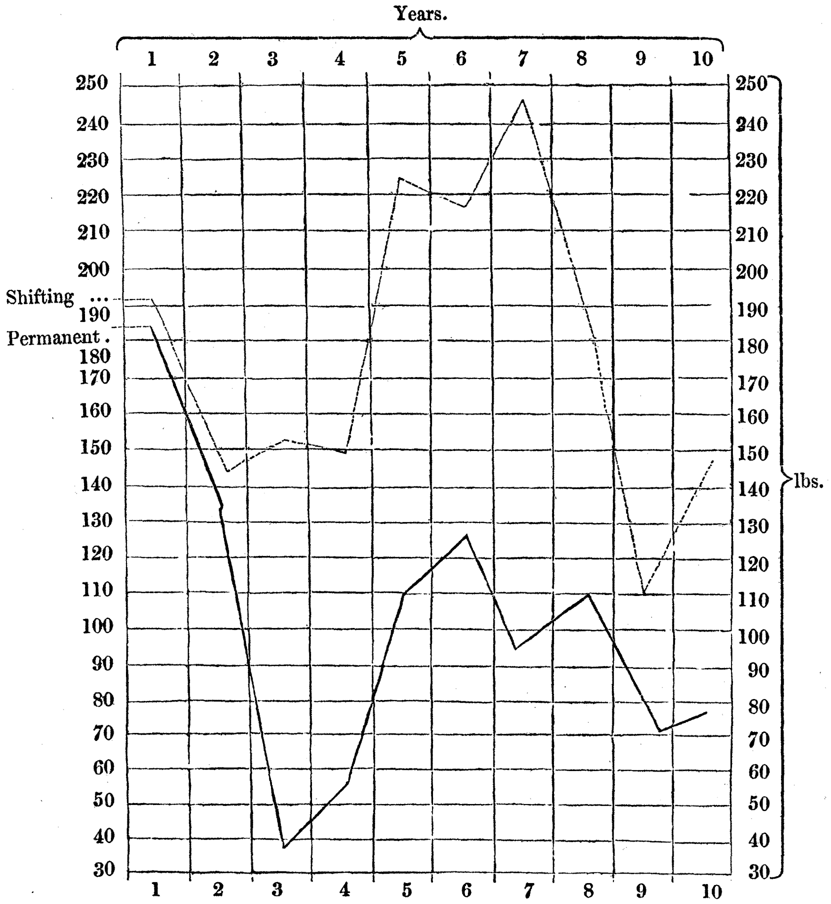
Nevertheless it will be seen, that even the latter did not sink below a certain amount when the seasons were tolerably favourable.

The following are the results:—

Year.	Permanent crop. Produce in a green state.	Shifting crop.
	No. 2.	
1834.	125·0	
1835.	185·0	192·0
1836.	133·0	After *Linum usitatissimum.* 144·0
1837.	37·2	After *Vicia Faba.* 154·0
1838.	56·0	After *Linum usitatissimum.* 150·0
1839.	110·0	After *Cichorium endivia.* 226·0
1840.	128·0	After *Nicotiana rustica.* 217·0
1841.	98·0	After *Papaver somniferum.* 245·0
1842.	111·0	After *Avena sativa.* 179·0
1843.	73·5	After *Solanum tuberosum.* 110·0
1844.	77·0	After *Helianthus annuus.* 148·0
	Average of ten years . . 100·8	Average of ten years . . 176·5
	Average of first five years 104·0	Average of first five years . 173·0
	Average of last five years . 97·5	Average of last five years . 176·5
	Maximum in one year . . 185·0	Maximum in one year . . 245·0
	Minimum in one year . . 37·2	Minimum in one year . . 110·0

The following diagram will show the variations in their yearly produce :—

TURNIPS.



In the contiguous bed recently manured the produce was 152 lbs., a quantity about ntermediate between the average of the shifting and permanent crops.

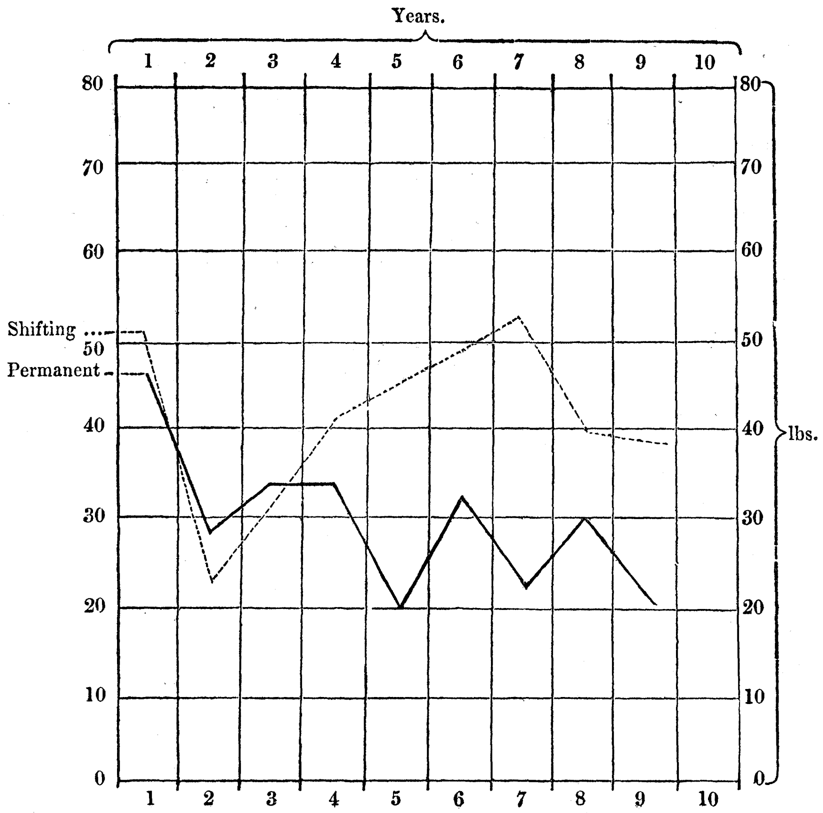
4. *Cannabis sativa.*

The next crop I shall notice, Hemp, presents a very uniform rate of produce during he whole period, nevertheless the shifting crop, which however was not grown during he years 1840 and 1841, presents a much larger produce than the permanent one, ıs will be seen by the following Table.

Year.	Permanent crop. Dried in the sun.	Shifting crop. Dried in the sun.
	No. 17.	After *Trifolium pratense*.
1836.	46·5	52·5
		After *Brassica Rapa*.
1837.	27·75	22·5
		After *Brassica Rapa*.
1838.	34·0	32·5
		After *Hordeum sativum*.
1839.	34·0	42·5
1840.	20·5	None.
1841.	33·3	None.
		After *Beta vulgaris*.
1842.	23·7	53·0
		After *Polygonum fagopyrum*.
1843.	30·0	39·5
		After *Brassica Rapa*.
1844.	21·5	37·6
	Average of nine years . . 30·13	
	Average of first five years 32·55	
	Average of last four years 27·12	Average of four years . . 30·0
	Maximum in one year . 46·50	Maximum in one year . . 52·5
	Minimum in one year . . 20·50	Minimum in one year . . 22·5

The following diagram will show the variations in the yearly produce:—

HEMP.



In the contiguous bed recently manured the crop weighed 45·4 lbs., somewhat more than the average of the shifting, and considerably exceeding that of the permanent beds.

5. *Linum usitatissimum.*

Flax presents a gradual, though not an uniform, rate of deterioration, the shifting crop always standing in advance of the permanent one.

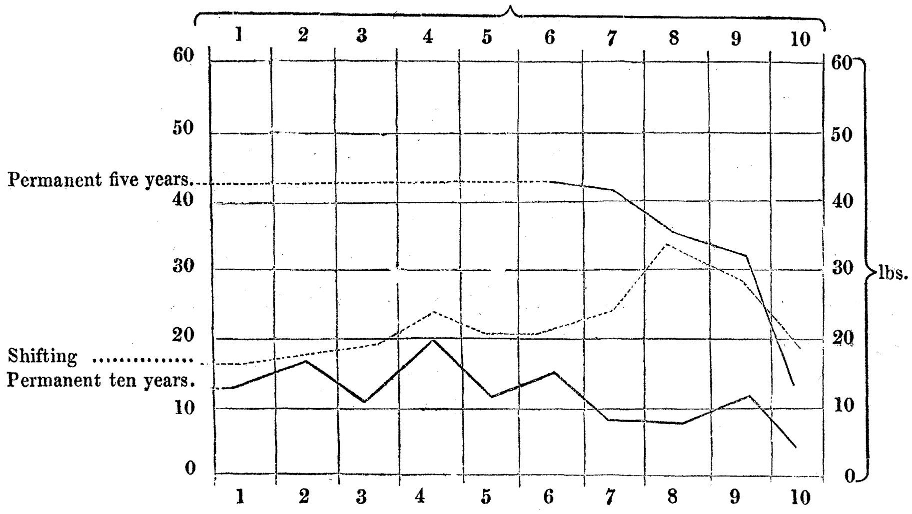
In this instance I tried the same experiment as in the case of the potatoes, namely, that of sowing one bed with seed from the last year's crop, and the second with seed obtained from some other source. The latter produced much the most abundant crop, but I am now inclined to attribute its superiority chiefly to its succeeding a crop of Valerian, a plant which probably draws little from the soil, and which consequently having grown in it for five successive years, had given time to the materials of the earth to undergo decomposition, so that an accumulation of nutritious principles may have taken place in it, nearly as would have been the case if it had been left entirely fallow.

The following are the results obtained :—

Year.	Permanent crop of ten years' standing. Crop dried.	Permanent crop of five years, fresh seed. Crop dried.	Shifting crop. Crop dried.
	No. 19.		
1835.	12·9		15·8
1836.	16·7	. . . .	After *Polygonum fagopyrum.* 17·0
1837.	12·0	. . . .	After *Solanum tuberosum.* 19·8
1838.	20·0	. . . .	After *Solanum tuberosum.* 25·5
1839.	13·75	. . . .	After *Valeriana Phu.* 21·75
1840.	16·5	Nos. 13 and 14. After *Valeriana Phu.* 43·5	After *Polygonum fagopyrum.* 21·5
1841.	9·0	41·0	After *Vicia sativa.* 25·0
1842.	8·4	34·0	After *Brassica Rapa.* 34·0
1843.	11·7	31·0	After *Vicia Faba.* 29·6
1844.	5·2	11·5	After *Solanum tuberosum.* 17·8
	Average of ten years . . . 12·6	Average of five years . . . 32·5	Average of ten years . . . 22·7
	Average of first five years 15·0	. . . .	Average of first five years 19·9
	Average of last five years 10·4	. . . .	Average of last five years 25·5
	Maximum in one year . . 20·0	Maximum in one year . . 43·5	Maximum in one year . . 34·0
	Minimum in one year . . 5·0	Minimum in one year . . 11·5	Minimum in one year . . 15·8

The following diagram will show the curve of their growth :—

FLAX.



The contiguous manured crop weighed 22·2, rather less than the average of the shifting crops.

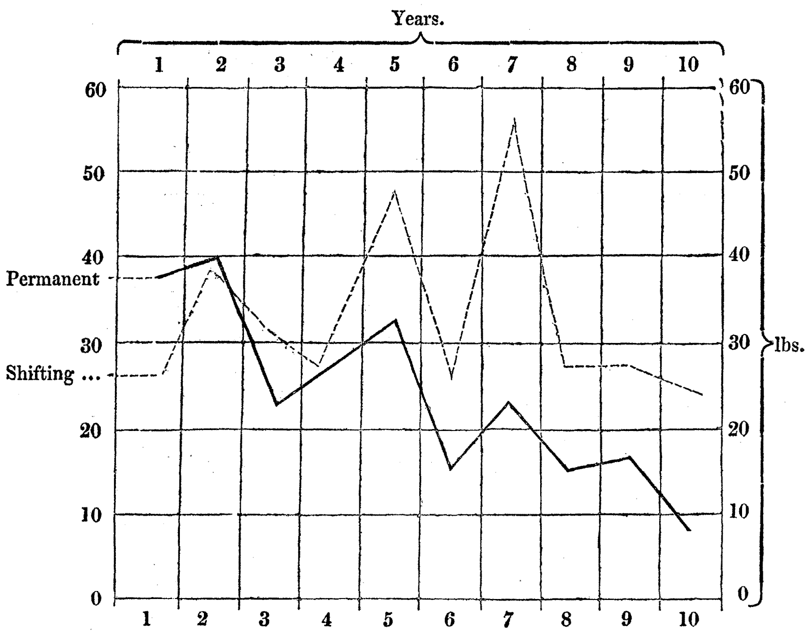
6. *Vicia Faba.*

Beans showed a considerable falling off in the case of the permanent crop, but not in the shifting, the following being the results obtained:—

Year.	Permanent crop. Produce in a dried state.	Shifting crop. Produce in a dried state.
	No. 23.	
1835.	38·0	27·7
1836.	40·0	After *Linum usitatissimum.* 39·0
1837.	23·5	After *Euphorbia lathyris.* 31·2
1838.	28·4	After *Nicotiana rustica.* 28·5
1839.	34·0	After *Nicotiana rustica.* 48·0
1840.	16·5	After *Papaver somniferum.* 26·5
1841.	24·5	After *Polygonum fagopyrum.* 56·0
1842.	15·8	After *Papaver somniferum.* 28·0
1843.	17·1	After *Avena sativa.* 28·0
1844.	9·2	After *Nicotiana rustica.* 24·0
	Average of ten years . . . 24·7	Average of ten years . . 33·6
	Average of first five years . 32·8	Average of first five years . 34·8
	Average of last five years . 16·6	Average of last five years . 32·5
	Maximum in one year . . 40·0	Maximum in one year . . 56·0
	Minimum in one year . . 9·2	Minimum in one year . . 24·0

The following represents the curve of their growth :—

BEANS.



In the contiguous manured bed the crop was only 27·1 lbs., not greatly exceeding the average of the permanent, and falling considerably short of that of the shifting crops.

7. *Nicotiana rustica.*

Tobacco is one of the plants which most strikingly illustrates the dependence of the crop upon manuring; the first year the produce being 178 lbs., whilst it sunk in six years' time to 17 lbs. The whole of this diminution, however, must not be set down to the deficiency of inorganic matter, since in subsequent years the produce became greater, although it never recovered its former rate.

In this instance the permanent presents a higher average than the shifting crop, but this seems attributable to the circumstance that in the latter instance the soil had been previously drawn upon by a crop of beans, whilst in the former it had been recently manured.

The following are the results :—

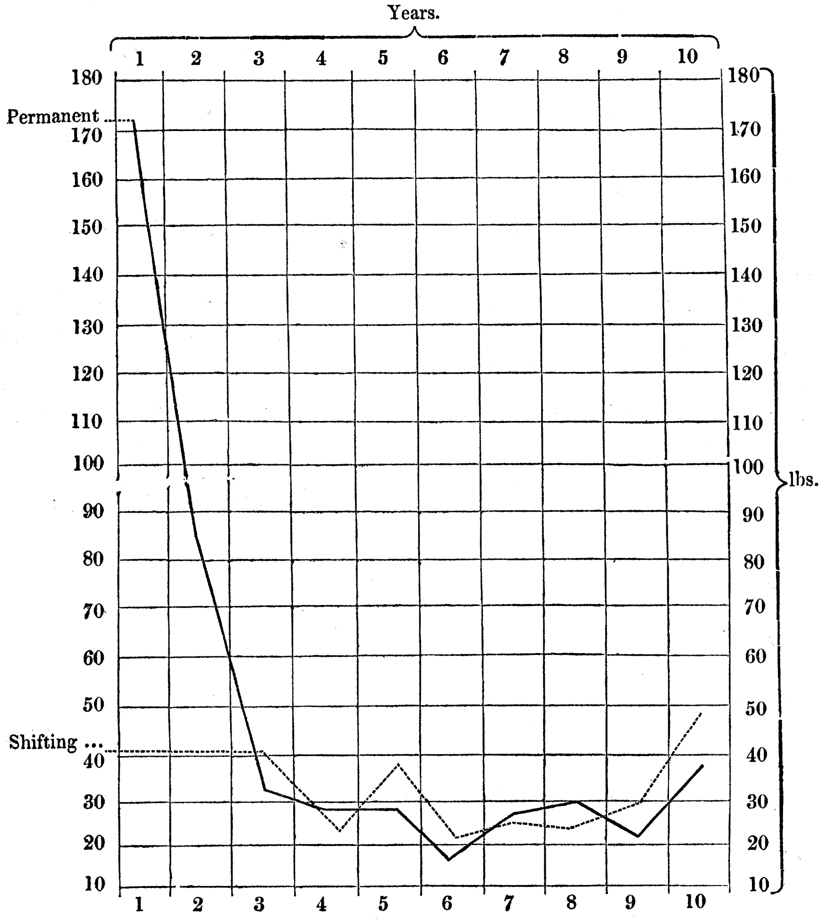
Year.	Permanent crop. Produce nearly dry.	Shifting crop. Produce nearly dry.
1834.	No. 9*a*. 172·0	None.
1835.	83·0	None.
1836.	33·0	After *Apium petroselinum.* 42·0
1837.	29·0	After *Papaver somniferum.* 25·0
1838.	29·0	After *Euphorbia lathyris.* 38·0

Nicotiana rustica (Continued).

Year.	Permanent crop. Produce nearly dry.	Shifting crop. Produce nearly dry.
	No. 9*a*.	After *Linum usitatissimum*.
1839.	17·25	22·5
		After *Cichorium endivia*.
1840.	27·0	25·0
		After *Apium petroselinum*.
1841.	30·0	24·0
		After *Helianthus annuus*.
1842.	22·5	30·0
		After *Brassica Rapa*.
1843.	37·8	49·0
	Average of ten years . . . 48·0	Average of eight years . . 32·0
	Average of first five years . 69·2	Average of first four years . 32·0
	Average of last five years . 26·9	Average of last four years . 32·0
	Maximum in one year . . 172·0	Maximum in one year . . 49·0
	Minimum in one year . . 17·2	Minimum in one year . . 22·5

The following diagram shows the variations of the crops :—

TOBACCO.



8. *Papaver somniferum.*

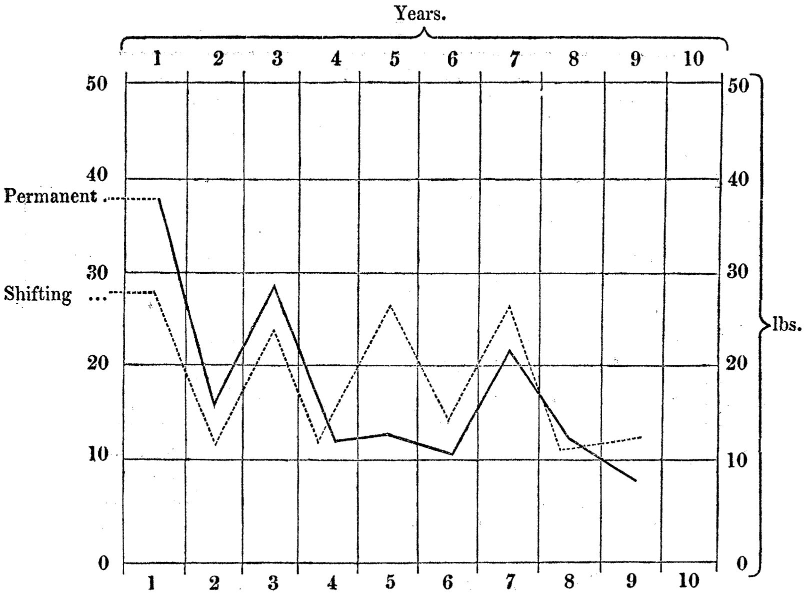
Poppies, although considered an exhausting crop, are said to be frequently grown for years in succession without any apparent decrease, but the results of my experiments serve to show, that this will not happen unless they are occasionally manured. It is remarkable how near in this instance the average of the shifting and permanent crops approaches each other.

The following Table shows the results:—

Year.	Permanent crop. Dried in the sun.		Shifting crop. Dried in the sun.	
	No. 5.		After *Euphorbia lathyris.*	
1836.	38·0		27·0	
			After *Cichorium endivia.*	
1837.	15·5		11·0	
			After *Polygonum fagopyrum.*	
1838.	29·0		24·0	
			After *Solanum tuberosum.*	
1839.	13·0		13·0	
			After *Vicia Faba.*	
1840.	14·0		26·5	
			After *Brassica Rapa.*	
1841.	11·0		15·2	
			After *Vicia sativa.*	
1842.	22·0		26·5	
			After *Hordeum sativum.*	
1843.	13·4		12·0	
			After *Avena sativa.*	
1844.	8·65		13·5	
	Average of nine years . .	18·2	Average of nine years . .	18·7
	Average of first five years .	21·9	Average of first five years .	20·3
	Average of last four years .	13·7	Average of last four years .	16·8
	Maximum in one year . .	38·0	Maximum in one year . .	27·0
	Minimum in one year . .	11·0	Minimum in one year . .	11·0

The annexed diagram shows the variations in the yearly produce:

POPPIES.

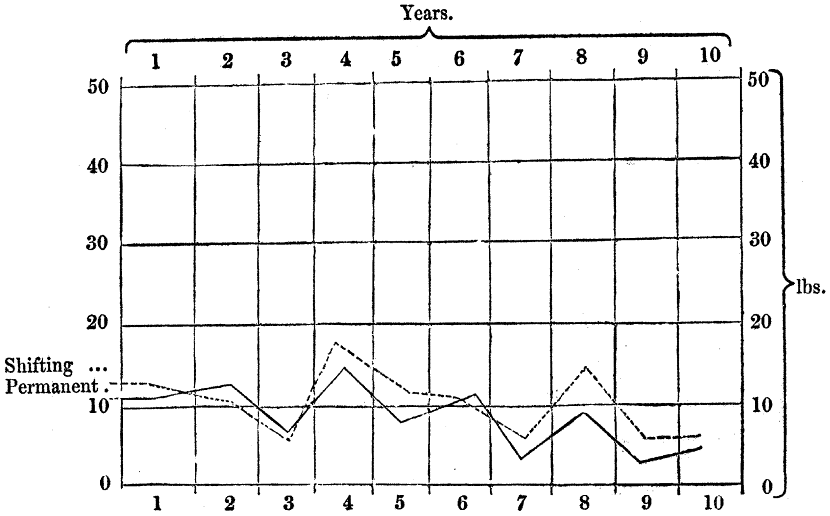


9. *Polygonum fagopyrum.*

Buckwheat, not being an exhausting crop, does not vary more than can be explained by differences of seasons and other contingent causes, the results being as follow :—

Year.	Permanent crop. Produce in a dried state.	Shifting crop. Produce in a dried state.
	No. 25.	
1835.	12·8	14·8
1836.	14·0	After *Mentha viridis.* 11·5
1837.	6·0	After *Valeriana Phu.* 5·7
1838.	16·0	After *Papaver somniferum.* 18·0
1839.	9·25	After *Vicia Faba.* 12·5
1840.	11·5	After *Hordeum sativum.* 11·5
1841.	3·2	After *Nicotiana rustica.* 5·5
1842.	9·6	After *Nicotiana rustica.* 14·1
1843.	3·8	After *Beta vulgaris.* 6·15
1844.	5·1	After *Beta vulgaris.* 6·6
	Average of ten years . . . 9·1	Average of ten years . . . 10·6
	Average of first five years . 11·6	Average of first five years . 12·5
	Average of last five years . 8·7	Average of last five years . 8·7
	Maximum in one year . . 16·0	Maximum in one year . . 18·0
	Minimum in one year . . 3·2	Minimum in one year . . 5·7

BUCKWHEAT.



10. *Trifolium pratense.*

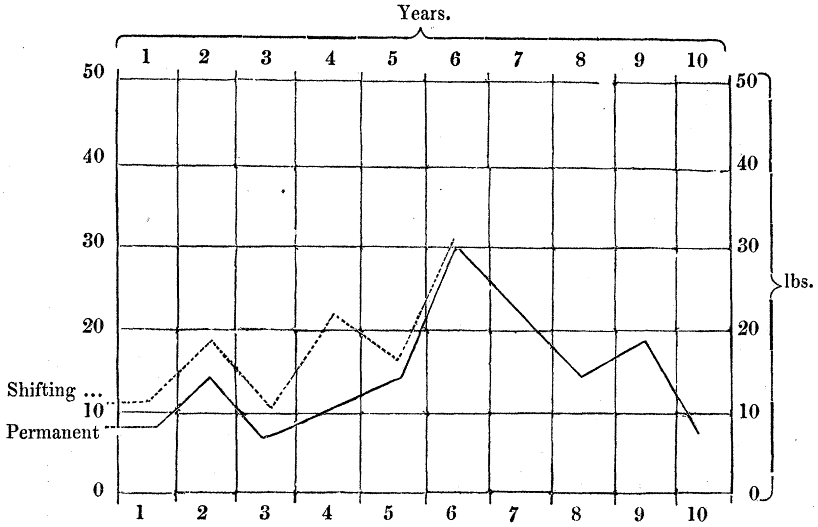
Red clover being a biennial, it was necessary to retain the shifting crop in the same bed for two years; and as the produce of the second year was in general larger than that of the first, the results can best be compared by stating the sum of each two years' growth.

Year.	Permanent crop. Produce of two years.	Shifting crop. Produce of two years.
	No. 12.	
1835. 1836.	8·5 14·2 } 22·7	11·3 17·0 } 28·3
		After *Mentha viridis.*
1837. 1838.	7·5 10·4 } 17·9	12·5 22·6 } 35·1
		After *Euphorbia lathyris.*
1839. 1840.	14·0 30·0 } 44·0	17·0 31·0 } 48·0
1841. 1842.	22·3 15·2 } 37·5	
1843. 1844.	18·8 7·5 } 26·3	

During the last four years it was not found convenient to introduce a shifting crop of clover.

The following curve represents the variations of the crop in the two cases.

CLOVER.



11. *Avena sativa.*

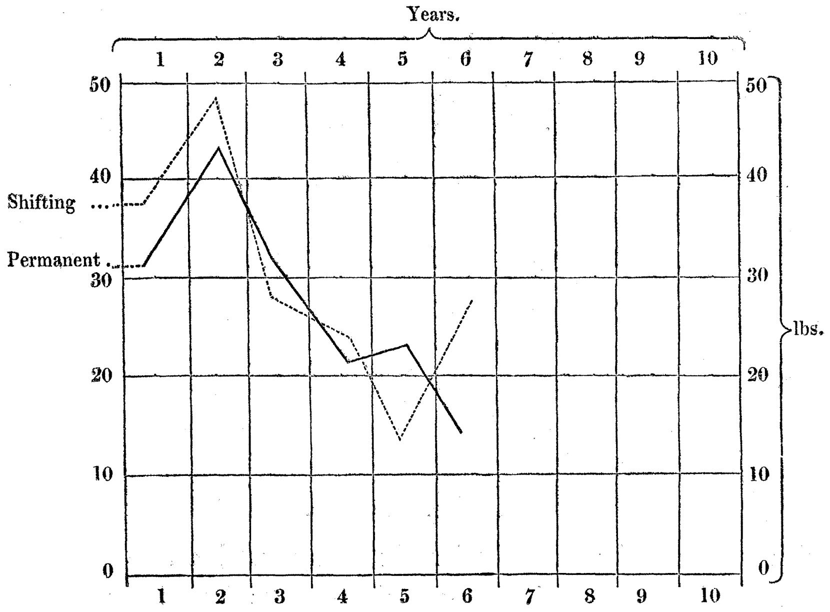
My trials with oats continued only for six years, and on ground already drawn upon by four crops since the period at which manure had been applied; the plot selected for the permanent crop having borne successively flax, beans, turnips, and hemp; that on which the corresponding crop in 1839 was raised, parsley, mint, and clover.

The produce therefore of the first year was in both cases moderate, and nearly uniform, but subsequently there was a greater diminution in the permanent than in the shifting crop, as will appear from the following Table:—

Year.	Permanent crop.	Shifting crop.
1839.	No. 20. 31·0	After *Trifolium pratense.* 37·5
1840.	44·0	After *Trifolium pratense.* 49·0
1841.	31·7	After *Beta vulgaris.* 53·0 | After *Trifolium pratense.* 28·5
1842.	22·5	After *Polygonum fagopyrum.* 24·4
1843.	24·4	After *Helianthus annuus.* 14·7
1844.	14·6	After *Vicia sativa.* 28·3
	Average of six years . . . 28·0 Maximum in one year . . 44·0 Minimum in one year . . 14·6	Average of six years . . . 32·4 Maximum in one year . . 49·0 Minimum in one year . . 14·7

The following curve will show the variations in the yearly produce.

Oats.



12. *Beta vulgaris.*

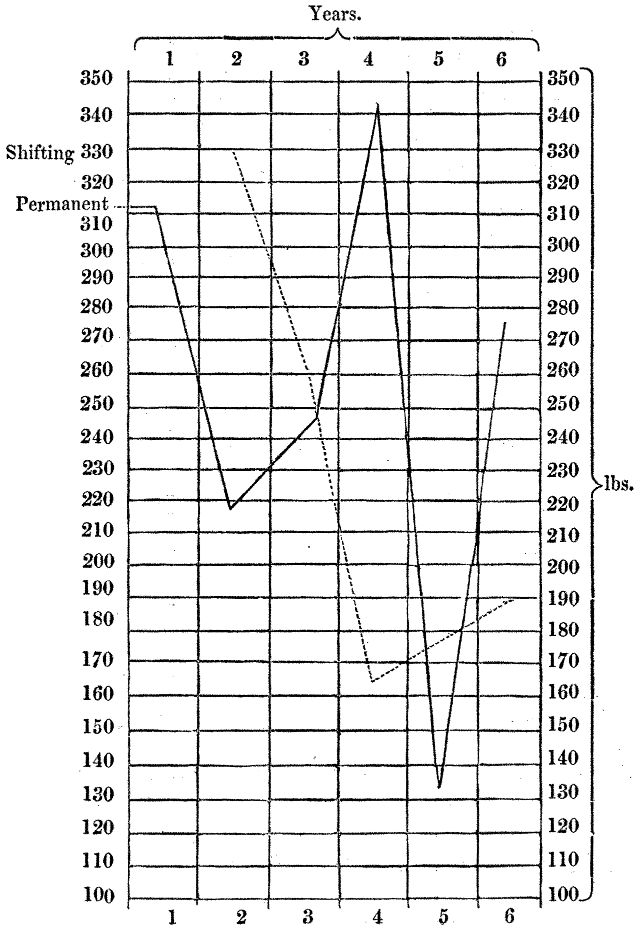
In the case also of the beet, the length of time during which the ground was cropped seems insufficient to lead to any decisive results, especially as the matters extracted from the soil by this plant are, compared to its bulk, inconsiderable.

The average of the shifting and permanent crops, it will be seen, does not vary materially, and what difference there is, seems in favour of the latter.

Year.	Permanent crop. Weighed in a green state.	Shifting crop. Weighed in a green state.
1839.	No. 11 *b.*—After *Papaver somniferum.* 312·0	None.
1840.	217·0	After *Cannabis sativa.* 330·0
1841.	250·0	After *Hordeum sativum.* 264·0
1842.	344·0	After *Avena sativa.* 173·0
1843.	135·0	187·0
1844.	278·0	200·0

The following diagram will show the variations in the annual produce:—

BEET.



13. *Cichorium endivia.* 14. *Mentha viridis.* 15. *Apium petroselinum.*

The three remaining crops, of Endive, Mint, and Parsley, were introduced into the series, from a wish to have one representative at least of the principal of those natural families, which supply us, with either plants useful for field or garden purposes, or with any of the commoner weeds which intrude themselves into our fields, it being conceived, that some interesting and useful results might be obtained, by watching the effect of their root excretions on plants of the same or of a different tribe.

Had it not been with a view to this theory, I should hardly have thought it worth while to experiment upon plants, which appear to draw comparatively so little from the soil, as the three now alluded to.

The following, however, were the results obtained:—

Cichorium endivia.

Year.	Permanent crop. Dried in the sun.	Shifting crop. Dried in the sun.
1834.	No. 15. 73·5	None.
1835.	No. 16. 68·5	After *Polygonum fagopyrum.* 68·0
1836.	No. 15 and 16. 44·4	After *Nicotiana rustica.* 49·0
1837.	33·3	After *Hordeum sativum.* 34·0
1838.	50·0	After *Vicia Faba.* 46·2
1839.	48·5	After *Hordeum sativum.* 38·0
1840.	22·0	None.
1841.	58·5	None.
1842.	67·0	None.
1843.	50·0	None.
1844.	72·0	None.
	Average of ten years . . . 51·5 Average of first five years . 53·9 Average of last five years . 49·2 Maximum in one year . . 73·0 Minimum in one year . . 22·0	Average of five years . . 47·0 Maximum of one year . . 68·0 Minimum of one year . . 34·0

Mentha viridis.

Year.	Permanent crop. Produce in a dry state.	Shifting crop. Produce in a dry state.
	No. 21.	
1835.	21·9	17·0
		After *Apium petroselinum.*
1836.	53·0	26·0
		After *Apium petroselinum.*
1837.	38·0	9·25
1838.	18·3	36·8
1839.	26·75	None.
1840.	24·5	None.
1841.	16·8	None.
1842.	18·7	None.
1843.	12·8	None.
1844.	16·5	None.
	Average of ten years . . . 24·7 Average of first five years . 31·5 Average of last five years . 17·8 Maximum in one year . . 53·0 Minimum in one year . . 12·8	

Apium petroselinum.

Year.	Permanent crop. Produce in a dried state.	Shifting crop.
	No. 27.	
1835.	64·25	74·0
		After *Vicia Faba.*
1836.	115·0	208·0
		After *Polygonum fagopyrum.*
1837.	52·0	61·0
		After *Polygonum fagopyrum.*
1838.	58·0	68·5
		After *Mentha viridis.*
1839.	13·0	32·5
		After *Mentha viridis.*
1840.	59·0	83·0
1841.	22·7	None.
1842.	9·4	None.
1843.	12·0	None.
1844.	33·0	None.
	Average of ten years . . 39·75 Average of first six years . 60·2 Average of last four years . 19·3 Maximum in one year . . 115·0 Minimum in one year . . 9·4	Average of six years . . . 87·8 Maximum in one year . . 208·0 Minimum in one year . . . 32·0

Tabular View of Experiments on the Rotation of Crops.

Name of the crop.		Whether planted in the same, or in different plots of ground.	No. of years during which the experiments were continued.	Amount of produce the first year.	Amount of produce the last year.	Highest amount of produce obtained during the whole period.	Year in which the highest amount of produce was obtained.	Smallest amount of produce obtained during the whole period.	Year in which the smallest amount of produce was obtained.	Average of the first five years.	Average of the whole period.	Crop obtained in 1844 from an equal space of ground previously well-manured.	General remarks.
				Tubers.	Tubers.	Tubers.		Tubers.		Tubers.	Tubers.	Tubers.	
Potatoes (*Solanum tuberosum*)	1.	in the same	9	89·50	61·0	89·50	1st year, viz. 1836	48·6	8th year, viz. 1843	72·9	68·9	88·5	Merely cleaned from dust before weighing.
	2.	in different	9	84·0	78·0	132·0	4th year, 1839, after Buckwheat.	48·4	8th year, 1843, after Vetches	92·8	89·1		
	3.	in the same	5	96·0	57·75	96·0	1st year, 1840	58·6	4th year, 1843	74·77			
Flax (*Linum usitatissimum*)	1.	in the same	10	12·9	5·2	20·0	4th year, 1838	5·2	10th year, 1844	15·0	12·6	20·5	Dried in the sun before weighing.
	2.	in different	10	15·8	17·8	34·0	8th year, 1842, after Turnips	15·8	1st year, 1835	19·9	22·7		
	3.	in the same	5	43·5	11·5	43·5	1st year, 1840	11·5	5th year, 1844	32·5			
Beans (*Vicia Faba*)	1.	in the same	10	38·0	9·2	40·0	2nd year, 1836	9·2	10th year, 1844	32·8	24·7	25·0	Dried in the sun before weighing.
	2.	in different	10	27·7	24·0	56·0	7th year, 1841, after Buckwheat.	24·0	10th year, 1844, after Tobacco	34·8	33·6		
Barley (*Hordeum vulgare*)	1.	in the same	10	29·0	28·7	42·5	4th year, 1838	21·5	3rd year, 1837	30·0	28·9	36·4	Dried in the sun before weighing.
	2.	in different	10	35·5	30·5	75·0	4th year, 1838, after Endive	27·4	7th year, 1841, after Beans	46·5	42·1		
Turnips (*Brassica Rapa*)	1.	in the same	10	185·0	77·0	185·0	1st year, 1835	37·2	3rd year, 1837	104·0	100·8	140·0	In a green state when weighed.
	2.	in different	10	192 0	148·0	245·0	7th year, 1841, after Poppies	110·0	9th year, 1843, after Potatoes	173·0	176·5		
Hemp (*Cannabis sativa*)	1.	in the same	9	46·5	21·5	46·5	1st year, 1836	20·5	5th year, 1840	32·55	30·13	42·0	Dried in the sun before weighing.
	2.	in different	7	52·5	37·6	53·0	7th year, 1842, after Beet	22·5	2nd year, 1837, after Turnips		40·0		
Spurge (*Euphorbia lathyris*)	1.	in the same	3	17·2	0·								Dried before weighing.
Poppy (*Papaver somniferum*)	1.	in the same	9	38·0	8·65	38·0	1st year, 1836	8·65	9th year, 1844	21·9	18·2		Dried in the sun before weighing.
	2.	in different	9	27·0	13·5	27·0	1st year, 1836, after Spurge	11·0	3rd year, 1837, after Endive	20·3	18·7		
Clover (*Trifolium pratense*)	1.	in the same	10	8·5	7·6	30·0	7th year, 1840	7·5	11th year, 1844	10·9	14·8		Dried in the sun before weighing.
	2.	in different	6	11·3	31·0	31·0	6th year, 1840, after Spurge	11·3	1st year, 1835, after Larkspur		16·9		
Endive (*Cichorium endivia*)	1.	in the same	10	68·5	72·0	72·0	1st year, 1834	22·0	7th year, 1840	53·9	51·5		Dried in the sun before weighing.
	2.	in different	5	68·0	38·0	68·0	2nd year, 1835, after Buckwheat.	34·0	4th year, 1837, after Barley.		47·0		
Mint (*Mentha viridis*)	1.	in the same	10	21·9	16·5	53·0	2nd year, 1836	12·0	9th year, 1843	31·5	24·7		Dried in the sun before weighing.
	2.	in different	4	17·0	36·8	36·8	4th year, 1838	9·25	3rd year, 1837		22·5		
Buckwheat (*Polygonum fagopyrum*)	1.	in the same	10	12·8	5·1	16·0	4th year, 1838	3·2	7th year, 1841	11·6	9·1		Dried in the sun before weighing.
	2.	in different	10	14·8	6·6	18·0	4th year, 1838, after Poppies	5·5	3rd year, 1837, after Valerian	12·5	10·6		
Parsley (*Petroselinum sativum*)	1.	in the same	10	68·25	33·0	115·0	2nd year, 1836	9·4	8th year, 1842	61·25	39·75		In a green state when weighed.
	2.	in different	6	74·0	83·0	208·0	2nd year, 1836, after Beans	32·5	5th year, 1839, after Mint		87·8		
Tobacco (*Nicotiana rustica*)	1.	in the same	10	172·0	37·8	172·0	1st year, 1834	17·25	6th year, 1839	69·2	48·0		Dried in the sun before weighing.
	2.	in different	8	42·0	49·0	49·0	10th year, 1844, after Turnips	22·5	6th year, 1839, after Flax		32·0*		
Oats (*Avena sativa*)	1.	in the same	6	31·0	14·6	44·0	2nd year, 1840	14·6	6th year, 1844		28·0		Dried in the sun before weighing.
	2.	in different	6	37·5	14·7	53·0	2nd year, 1840, after Clover	14·7	5th year, 1843, after Sunflower		32·4		
Beet (*Beta vulgaris*)	1.	in the same	6	312·0	135·0	344·0	4th year, 1842	135·0	5th year, 1843		256·0		In a green state when weighed.
	2.	in different	5	330·0	200·0	330·0	1st year, 1840, after Hemp	173·0	3rd year, 1842, after Oats		231·0		
Tares (*Vicia sativa*)	1.	in different	4	14·0	10·0	20·0	4th year, 1842	9·0	5th year, 1843		13·25		Dried in the sun before weighing.
Sunflower (*Helianthus annuus*)	1.	in different	4	40·0	165·0								Dried in the sun before weighing.

* The average is here lower than in the former, because two crops of a different kind had been previously taken off the ground before the first crop of Tobacco was sown. Hence this is so much inferior to the first crop of the preceding column.

It appears then that out of the whole series, there are only four cases in which the average amount of the permanent crop was equal or superior to that of the shifting one.

In the first of these, the Tobacco, the fact may be accounted for, from the condition of the ground being more favourable to the permanent than to the shifting crop on the year of its introduction, the former being obtained from soil which had been recently manured, the latter from what had been partially exhausted by preceding crops.

The second, the Beet, was scarcely continued for a sufficient length of time to lead to any certain conclusions.

The two others, namely, the Endive and Mint, present results so nearly agreeing in the amount of their permanent and shifting crops, that the slight disparity may be fairly referred to contingent circumstances, and an uniformity in the products obtained may in consequence be inferred.

Setting aside then the above four cases as exceptional, the general tenor of the experiments would seem to indicate a *manifest* advantage on the side of the shifting crops, varying from 1 to 75 per cent., but more generally approaching to the latter.

Yet it by no means follows that this difference is to be attributed to the influence of root excretions. Were such the cause, we ought to perceive a more regular, as well as a more rapid, diminution in the permanent crop than is indicated in these Tables; we should not find, for instance, the crop of potatoes equalling in the fifth year the produce of the first; the Turnips, after sinking to 37·0 lbs. in the third year, rising in the sixth to 128 lbs.; not to allude to other similar instances of oscillation.

If De Candolle's theory too could be carried out, we might have expected to find a more manifest improvement in the shifting crop occasionally occurring, owing to the excretions of the family of plants which had preceded it proving congenial to its constitution.

But if nothing positively injurious be imparted to the soil by the crop, the gradual falling off in the amount of the latter can only be attributed to the deficiency, either of organic, or of inorganic matter fitted for its development, in the soil in which it was reared.

Of the two continental writers on chemical agriculture whose works have excited the greatest interest in this country, the one would seem to favour the former, the other the latter explanation, although it may be more correct to consider them, as viewing the subject under two different aspects, rather than as laying down principles irreconcileable one with the other.

Liebig, for instance, although he regards the presence of certain inorganic matters as the only condition *essential* to the existence of a plant, does not deny, that its growth may be accelerated in proportion to the ready access to it of ammonia and carbonic acid, and these, it is evident, would be supplied more abundantly by the presence in the soil of organic matter in a readily decomposable condition.

Nor, on the other hand, would Boussingault deny the necessity for a supply of the

inorganic principles, which form, as it were, the skeleton of each plant, although he attributes the peculiar benefit derived from fallow crops to their power of generating the organic matter which is required by the cereals that are to succeed them.

In order to determine then in what degree the falling off of the permanent crop arose from the one or the other of these causes, it seemed necessary to obtain an analysis of the plants derived from this and from the shifting crop corresponding, and to compare the composition of both with that of a standard specimen of the same plant determined by the method pursued with respect to the two former; and it would have been also satisfactory, not only to ascertain, whether the soil itself originally contained such a store of all the principles existing in the crop, as might be sufficient to meet the demand made upon it for that purpose during the whole decennial period, but also whether its present composition was such, as actually indicated a deficiency in any of the principles which entered into the constitution of the plants grown in it.

It is evident that the former branch of the inquiry would have been superfluous, if I could have depended on two things:—

1st. That the analyses given by Sprengel and others, of the plants to which the inquiry related, were trustworthy; and

2ndly. That the composition of the same vegetable was at all times uniform both as to the quality and quantity of its ingredients.

But with respect to the former point, I found, on turning to the analyses given of the ashes of the same plants by different authorities, many marked discrepancies, and that those of Sprengel, which are the most numerous of any we could appeal to, were regarded as inaccurate by other chemists of higher distinction.

Nor, even if they had represented truly the composition of the plants which were actually examined by that analyst, could we be sure, that they would apply to those of the same species, grown in a different country, and under altered circumstances, more particularly as the recent researches of Liebig, Will, Fresenius and others, appeared to indicate, that certain ingredients admit of being substituted for others, according to laws as yet not fully made out.

For all these reasons then, it became necessary for my purpose to obtain a correct analysis, both of the crops, and of the soil; and I was the more reconciled to the expenditure of labour involved in this undertaking, when I reflected, that the results obtained were likely not only to lead to an explanation of the cause of the utility of a rotation of crops, but also to throw some incidental light upon certain other points connected with the chemistry of agriculture, which did not appear to be sufficiently elucidated; such for instance, as the degree of variation of which a plant may admit in the quality and quantity of its inorganic ingredients, or in other words, its power of substituting one principle for another, and likewise as to the state of combination, in which the alkalies, phosphates, &c. exist with the other constituents of the soil, when in a condition to be assimilated by a plant.

I shall, therefore, next proceed to state the results of the analyses of the several crops which were made in my laboratory by Mr. Way.

PART II.

On the chemical composition of certain crops cultivated in the Botanic Garden, and on the amount of inorganic principles abstracted by them from the soil during the period the experiments were continued.

It is only within a few years that the importance of ash analyses has been understood, and we were consequently much at a loss for accurate instructions as to the best method of conducting it.

A valuable paper has however recently appeared in the Memoirs of the Chemical Society of London (Part IX.), by Will and Fresenius, which in a great degree supplies this deficiency, and which we therefore determined to adopt as the basis of our scheme of operations.

One part of it, however, relating to the determination of the phosphoric acid, was soon found extremely troublesome in practice, and too tedious to be resorted to in an inquiry which involved the necessity of so large a number of analyses. In this part therefore of the process, Mr. Way suggested a method, which, as it recommended itself from its greater simplicity, and appeared to answer well in practice, he has adopted in all the cases, of which mention will hereafter be made.

But although the plan of analysis pursued presents in other respects but little of novelty, yet as certain modifications of the scheme of the German chemists have been here and there introduced, and as some of the manipulations may admit of being more clearly explained than in the paper alluded to, it will not be amiss to set down, as briefly as possible, all the principal steps pursued for the determination of the several ingredients existing in the ash.

In a few instances, as in the Cerealia, where the ashes abounded in silicates, complete solution in acids could not be effected, until the whole had undergone, either a previous fusion with carbonate of barytes, or evaporation with caustic potass, the former substance being employed for that portion of the ash which was to be examined for alkalies, the latter for the one set apart to ascertain the other ingredients.

But where the whole of the ash proved soluble in muriatic acid, no such preliminary process was required, and we were able to proceed directly to dissolve it in this menstruum.

A certain amount, however, of sand derived from the soil in which they had grown, and of charcoal, from the organic matter of the plant which had not been burnt off, was always present, and these of course would not be acted upon by this acid.

There was also in every instance a variable quantity of peroxide of iron proceeding manifestly from the vessels in which the combustion had been carried on, the quantity

to be burnt being too considerable to allow of its calcination in any of the platina vessels which I chanced to possess.

The ashes, therefore, of which 200 grains were usually taken, had first to be treated with pure muriatic acid, and the latter to be driven off by heat, so that the silica of the ash might be rendered insoluble.

Water and muriatic acid were then added to the dry mass, and the portion which did not dissolve was separated by filtration. Its weight, after being washed, represented the amount of silica in the ash, together with that of the extraneous sand and charcoal intermixed with it. The former was separated by digestion in pure dilute alkaline ley, and its quantity determined, in the first place indirectly, by the loss of weight sustained by the insoluble portion after its removal, and in the second more accurately, by the direct process of separating it from its solution in the alkali by treatment with an acid, and subsequent evaporation to dryness, after which, water having been added in sufficient quantity to redissolve the alkaline salt, the silica was collected on a filter, and then dried and ignited previously to weighing it.

The solution in dilute muriatic acid was made up to some definite quantity, so that it might be divided into four exactly equal portions, of which one was kept in reserve in case of any accident happening to the remainder, whilst the three others, which we will call A, B and C, were examined for the different ingredients present, as for instance,—

A. For the peroxide of iron.
B. For the phosphoric acid.
C. For the alkalies.

In most of the parts of vegetables, especially in their seeds, and in the tubers and bulbs which afford nutriment to animals, the amount of phosphoric acid may be expected to exceed that necessary for combining with the iron present. A reagent then which throws down phosphate of iron, affords us in these cases a ready means of estimating the whole amount of that metal, from the weight of phosphate obtained, and Will assures us* that 100 grains of the latter precipitate consists of 43·92 phosphoric acid, and 56·08 peroxide of iron.

When therefore, to the muriatic solution A, containing a slight excess of acid, acetate of ammonia is added, the muriatic acid, which had held the phosphate of iron in solution, is seized upon by the ammonia of the former salt, and the phosphate of iron, being insoluble in the liberated acetic acid, is precipitated.

We thus obtain a means of readily estimating the amount of peroxide of iron, but not of determining that of phosphoric acid, because there may be still a portion of the latter remaining in the liquid in combination with other bases, the phosphate of lime and of magnesia being soluble in free acetic acid, and the alkaline phosphates being so even in water.

In order therefore to estimate the amount of phosphoric acid, an expedient was

* Memoirs of the Chemical Society, part 9.

adopted, by which the presence of sufficient iron to carry down the whole of the phosphoric acid might be secured.

For this purpose a certain known weight of clean iron wire was dissolved in a mixture of nitric and muriatic acids, care being taken that no loss should occur from the violence of the action occasioned.

The solution thus prepared will then contain a definite amount of peroxide of iron, which, when introduced into the liquid containing the ash, will seize upon all the phosphoric acid, not already combined with iron, which it may contain.

Accordingly, after adding it to the latter, from which the phosphate of iron originally present had been previously thrown down by acetate of ammonia, we recover the whole of the metal, whether in combination with phosphoric acid or not, by applying again this same reagent, provided only the solution be rendered neutral by ammonia, and raised to a boiling temperature.

In the case supposed, therefore, the precipitate will indicate the whole of the phosphoric acid existing in the fluid, after the phosphate of iron originally present had been thrown down, together with the peroxide of iron which results from the iron introduced into it in union with chlorine.

Accordingly the quantity of phosphoric acid remaining after the first operation may be estimated, by deducting the weight of peroxide of iron, which is known, from that of the entire precipitate collected.

In practice however it was found most convenient to determine the amount of phosphoric acid, by taking another measured portion of the solution, viz. B, and adding to it in the first instance the known weight of iron. We are thus enabled, by following the steps above pointed out, to throw down, all the iron originally present in combination with phosphoric acid, all the phosphoric acid which may have existed in combination with other bases, and the whole of the peroxide of iron, whether proceeding from the ash, or introduced from without.

The amount of the former portion of the iron will have been ascertained by the examination of the solution A, whilst that of the latter can be readily calculated, as we know the weight of the iron introduced; by deducting therefore the sum of these two, which represents the total amount of peroxide of iron, from the entire weight of the precipitate, we obtain that of the phosphoric acid present in the ash.

This modification of the process saves some trouble, as it obviates the necessity of reducing the bulk of the solution remaining after the separation of the phosphate of iron precipitated from A. in the first process, which, owing to the number of washings necessary, becomes inconveniently large.

I felt curious to ascertain whether the phosphoric acid obtained by the above method was combined with two or with three atoms of base, as Will and Fresenius state, that the Cerealia generally present it in the former predicament, the Leguminosæ in the latter.

Our experiments on this point do not appear to confirm such a conclusion, showing

rather, that the proportion of base to acid has some reference to the quantity of alkali present, and is therefore dependent in a certain degree upon the manner in which the previous calcination had been conducted.

Supposing a plant to be rich in alkali, and to contain but little silex, it would seem natural to expect, that the phosphoric acid would be united with three atoms of bases.

When, on the contrary, the proportion of silica was large, a strong heat would cause more of it to unite with the alkali, and hence there might be only enough of the latter remaining to form a bibasic combination with phosphoric acid. Yet even here, if a slighter heat had been applied, it might happen that a tribasic compound would be produced.

Thus we found, that in all the three crops of potatoes the phosphate gave a yellow precipitate with nitrate of silver, and the same was also the case in the turnips; but in only one sample of beans, viz. the shifting crop, and in one of barley, which was also the shifting one, did the same hold good.

On the other hand, in two other samples of ash from the barley, and in two samples of that from the beans, the phosphoric acid seemed, from the precipitate afforded by nitrate of silver, to be united with two atoms only of base.

It is easy to determine the amount of lime and of magnesia from either of the liquids already operated upon, oxalate of ammonia being added to separate the former, and, after neutralizing with ammonia the acid solution, phosphate of soda throwing down the magnesia.

In these respects the common methods were adhered to.

The solution C. was reserved for the determination of the alkalies.

For this purpose it is necessary to get rid of all the earths and metallic oxides which may be present, which is accomplished by adding barytic water so long as a precipitation takes place. That reagent of course throws down the whole of the sulphuric and phosphoric acids, the peroxide of iron, most of the magnesia, and most of the lime*.

The filtered solution may however contain a little magnesia and lime, and probably much barytes.

To remove these, carbonate of ammonia is added in excess, and the precipitate which is thrown down removed by filtration, after being allowed to stand until it becomes heavy and granular.

If this be duly performed, the remaining solution can contain only muriate of ammonia and chlorides of the fixed alkalies.

The former is removed by heat, and the dry chlorides then remaining will repre-

* As the entire precipitate, excepting what consists of sulphate of barytes, is soluble in muriatic acid, we may estimate the amount of sulphuric acid present, by treating it with the former acid, removing all that is soluble in water by filtration, and lastly weighing the dried residue, from which the weight of sulphuric acid may be readily deduced.

sent the weight of the alkaline salts originally present in the ash. Having ascertained this, the dry residue is dissolved in a small quantity of water, chloride of platinum added, and the whole evaporated nearly to dryness. It is then treated with dilute alcohol, which takes up the double chloride of platinum and sodium*, together with any excess of the reagent that may have been added. The undissolved residue is the double chloride of platina and potass, from which the amount of the chloride of potassium may be calculated. The difference between the weight of the latter and of the whole salt gives that of the chloride of sodium proceeding from the ash.

The carbonic acid present was best ascertained by operating on a separate portion of the ash, and the common method of determining it by the loss of weight consequent upon the addition of a stronger acid was adopted, with the precautions usually taken†.

The chlorine also was determined in the usual manner by nitrate of silver, a separate portion of the ash being employed for that purpose.

In the analyses given, it has been usual to consider it as in combination either with sodium or with potassium. That this was the case, seemed probable from the curious relation generally found to subsist between the quantity of chlorine and of sodium detected, which in many instances approximated so nearly, that we were led to conclude, that the chlorine in these instances merely implied a corresponding amount of chloride of sodium existing in the ash. That the correspondence should not have been exact, may be more readily explained, when we consider that the only generally practicable mode of estimating soda is an indirect one, and therefore liable to some degree of uncertainty.

In the few instances where the amount of chlorine was more than proportionate to that of the sodium, it was thought consistent with analogy to regard that portion of the former which was in excess, as held in combination with the vegetable alkali, or as representing an equivalent weight of chloride of potassium.

This mode of stating the results may appear objectionable, as blending theory with fact, but my reason for adopting it is, that it points at an important general conclusion, which it is hoped future inquiries will either negative or confirm, namely that the base of the soda found in plants commonly enters them in a state of combination with chlorine, being derived from the common salt, taken up, but not decomposed, by the organs of the plant.

Such an inference indeed cannot be adopted by those who receive the analyses given by SPRENGEL as correct, for in many of these large quantities of soda are stated

* This double chloride is readily decomposed, if first rubbed up with mercury, which flies off along with the chlorine in the form of calomel, when heated.

† It seems a defect in the analyses reported by SPRENGEL, that this ingredient is never mentioned in them; for although it may not be present as such in the crop, yet its amount in the ash probably represents that of the organic acids existing in the plant previously to its being burnt, and hence the proportion which it bears in different samples of the same species to the phosphoric and other mineral acids, may tend to indicate the relation subsisting between the amount of organic and of inorganic matter, arising from the mode of culture or other circumstances.

as having been detected; but, without presuming to bring forward the analyses made in my laboratory as in themselves sufficient to justify the public in rejecting the former as inaccurate, I may be permitted to observe, that it is much more easy to conceive that the amount of soda present may have been *overrated*, than that it should have been estimated *below* its real amount, supposing anything like an equality of skill and attention on the part of the operator.

To overrate it, we need only attribute to him some degree of negligence, either in not converting by means of chloride of platinum the whole amount of chloride of potassium into the sparingly soluble double chloride, or in not determining its entire quantity; to estimate it too low, we must imagine, what is far less probable, a portion of the readily soluble compound of chlorine with sodium, or the equally soluble double salt which the latter forms with platinum, to remain attached to the chloride of potassium and platinum, and thus to add to its weight.

Our results may also appear to militate against the conclusions of a much higher authority than SPRENGEL, I mean Professor LIEBIG, who has lately represented that one alkali may be substituted for another in the organization of a plant, and that a species, which in inland spots assimilates a certain amount of potass, takes into its frame an equivalent proportion of soda in maritime districts, where the latter alkali abounds.

With the slender data before me, it would be the height of presumption to impugn the generalisations of this distinguished philosopher, but it will be seen from the analyses given below, that no difference in the nature of the alkaline ingredients could be detected between barley, taken from the neighbourhood of the sea, whether from the eastern or western coasts of this country, and from the more central region of Oxfordshire.

Two ingredients mentioned by SPRENGEL as existing in the ashes of plants were searched for in a few of those to which this paper refers, but without success. These were alumina and manganese, the former so universally present in the soil, that it may readily find admission into the ashes of the plants, unless the greatest care be taken to clean off every particle of dirt entangled by their roots; the latter, as LIEBIG thinks, an accidental ingredient, being taken up by many plants in considerable quantities where the soil contains much of it, but altogether wanting in the same vegetables cultivated elsewhere.

In order to ascertain the presence of alumina, the ash was dissolved in muriatic acid, the solution evaporated to dryness, in order to separate the silica, and then re-dissolved in muriatic acid diluted with water.

An excess of ammonia was afterwards added to the filtered liquor, and the precipitate which fell, after having been well-washed, was boiled with a pure solution of potass. The portion dissolved was then filtered, neutralized with muriatic acid, and treated a second time with ammonia. If any precipitate had been thrown down, the presumption would have been that it consisted of alumina, and the appropriate tests would have been applied to confirm the conjecture; but in the only instance in which

we could positively assure ourselves that no admixture of the soil had got in, namely, in the grain of barley from Ensham, nothing was thrown down by the last application of ammonia, and in one sample of ash from flax (viz. the standard crop), only a mere trace was discoverable.

Considering indeed that the soluble salts of alumina are poisonous to plants, and that the earth itself is confessedly present in very variable, sometimes very minute, quantities, I am inclined to doubt whether it be in reality a constituent of their ashes at all.

With respect to manganese, two methods were adopted for ascertaining its presence.

The first, that of boiling the muriatic solution with carbonate of lime, and then, after filtering it, adding hydrosulphuret of ammonia.

The second, the blow-pipe test, fusing a little of the muriatic salt with borax, when a very minute quantity of manganese would produce its characteristic colour in the bead of glass produced.

By neither of these methods were any indications of manganese obtained.

I next proceed to state the results of the analyses made in my laboratory by Mr. Way, of six kinds of crops grown in the experimental garden, together with those obtained from certain standard crops of the same species, grown in another part of the garden, or in other places in the vicinity of Oxford, under more natural circumstances.

My original object being merely that of ascertaining the quality and quantity of the inorganic matters abstracted from the soil in these instances, the crop of barley, flax, hemp and beans, was burnt altogether without any separation of their respective parts having been previously made, and it was only in the case of the potatoes and the turnips that a distinct portion of the plant was selected for analysis, namely, the tubers in the former, and the bulbs in the latter.

Barley.

Permanent crop, after ten years' repetition.

100 grains of the dried crop, including both the straw and grain, left of ash 8·7 grains.

100 grains of this ash contained as follows:—

Sand and charcoal, extraneous	22·36
Peroxide of iron, chiefly extraneous	2·12
	24·48
Silica of the plant	24·60
Phosphoric acid	7·31
Sulphuric acid	2·12
Carbonic acid	1·94
Chloride of sodium	4·73
Potass	17·33
Magnesia	4·68
Lime	13·91
Total	101·14

Barley.

Grown in the same part of the garden as the last, for ten years unmanured, distinguished as the *shifting crop*.

100 grains of the dried crop, including as before both the straw and the grain, left of ash 6·25 grains.

100 grains of this ash contained as follows:—

Sand and charcoal, extraneous	21·91
Peroxide of iron, chiefly extraneous	2·30
	24·21
Silica of the plant	36·47
Phosphoric acid	9·30
Sulphuric acid	2·35
Carbonic acid	1·44
Chloride of sodium	1·43
Potass	16·58
Magnesia	3·58
Lime	7·72
	103·08

Barley.

Grown in a distinct part of the garden. Soil similar, but recently manured, distinguished as the *standard crop*.

100 grains of the dried crop, including as before the straw and grain, gave of ash 7·15 grains.

100 grains of this ash contained as follows:—

Sand and charcoal, extraneous	16·60
Peroxide of iron, chiefly extraneous	2·30
	18·90
Silica of the plant	37·27
Phosphoric acid	7·67
Sulphuric acid	4·37
Carbonic acid	1·51
Chloride of sodium	1·84
Potass	13·86
Magnesia	3·96
Lime	11·81
	101·19

It would appear then from the above analyses, that the principal difference between the permanent crop and the two others consisted in the larger amount of soluble silica, which, together with the greater proportion of ash, may have arisen from the straw predominating in quantity over the grain.

It next appeared to me desirable, both by way of testing the accuracy of these results, and likewise of ascertaining whether the third sample of barley analysed might really be adopted as a fair representative of a standard crop, to examine separately the grain and straw taken from a crop of average quality grown in the neighbourhood of Oxford.

Mr. Druce of Ensham accordingly supplied me with a sample of barley from his farm, of which the following analysis was made by Mr. Way.

1000 parts of the crop of barley from a field near Ensham, situated on the Oxford clay, consisted of—

Grain	575
Aulm	37
Straw	388
	1000

Of the Grain.—100 parts yielded of ash 2·04 parts, 100 grains of which consisted of—

					Excluding extraneous matter.
Charcoal*, extraneous .	24·51	Silica	24·51	or	33·2
Peroxide of iron, extraneous	2·30	Phosphoric acid .	22·97	or	31·2
	26·81	Sulphuric acid . .	2·48	or	3·4
Ingredients of the grain .	73·86, viz.—	Carbonic acid . .			
Total . . .	100·69	Chloride of sodium	1·48	or	2·3
		Potass	14·10	or	19·1
		Magnesia . . .	5·63	or	7·6
		Lime	2·71	or	3·6
			73·86		100·4

Of the Straw.—100 parts yielded 4·2 of ash, of which 100 parts contained—

					Excluding extraneous matter.
Sand and charcoal, extraneous	4·20	Silica	44·72	or	47·20
Peroxide of iron, extraneous .	4·74	Phosphoric acid .	1·68	or	1·80
	8·94	Sulphuric acid .	4·38	or	4·60
Ingredients of the straw. .	94·62, viz.—	Carbonic acid .	1·21	or	1·27
Total	103·56	Chloride of sodium	7·85	or	8·25
		Soda	0·98	or	1·06
		Potass	22·98	or	24·40
		Magnesia . . .	1·67	or	1·70
		Lime	9·15	or	9·65
			103·56		99·93

* In this instance the extraneous matter not dissolved by muriatic acid proved to consist almost wholly of

Of the Aulm.—100 parts yielded 13·7 of ash, of which 100 parts contained—

Charcoal and sand, extraneous	6·22
Peroxide of iron, extraneous	1·53
	7·75
Ingredients of the aulm . .	90·58, viz.—
Total	98·33

			Excluding extraneous matter.
Silica	80·96	or	89·50
Phosphoric acid .	1·20	or	1·30
Sulphuric acid .	0·89	or	0·90
Carbonic acid .	a trace		0·00
Chloride of sodium	0·73	or	0·80
Soda	0·22	or	0·24
Potass	1·23	or	1·30
Magnesia . . .	0·90	or	0·99
Lime	4·50	or	5·00
	98·33		100·03

According to these data the crop of barley will consist as follows :—

	Parts.		Parts.		Parts.	Total.
Grain	57500	Straw	38800	Aulm	568	96868.
Yielding of ash .	1170	Yielding of ash .	1629	Yielding of ash .	77·5	3406·5
Of which the extraneous matter amounted to	313	Of which the extraneous matter amounted to	141	Of which the extraneous matter amounted to	5·5	459·5
Real ash . .	857	Real ash . .	1488	Real ash. .	72·0	2417·0
The latter consisting of		Consisting of		Consisting of		
Silica	287	Silica	705	Silica	64·50	1056·50
Phosphoric acid .	270	Phosphoric acid .	26	Phosphoric acid .	0·13	296·13
Sulphuric acid . .	29	Sulphuric acid . .	70	Sulphuric acid .	0·65	99·65
Carbonic acid . .	00	Carbonic acid . .	18	Carbonic acid .	0·00	18·00
Chloride of sodium	17	Chloride of sodium	122	Chloride of sodium	0·57	139·57
Soda	00	Soda	15	Soda	0·14	15·14
Potass.	164	Potass	361	Potass	0·93	525·93
Magnesia. . . .	65	Magnesia . . .	25	Magnesia . . .	0·65	90·65
Lime	31	Lime	143	Lime	3·60	177·60
	863		1485		71·17	2419·17

Now according to this calculation, 100 parts of the mixed ash ought to contain the subjoined quantities of the ingredients below-mentioned, and by comparing these with the composition given of the ashes obtained from the three crops grown in the Botanic Garden, which I have deduced from the analysis before given, after deducting in each instance the matters regarded as extraneous, it will be seen that there is a near correspondence.

charcoal, for after the first analysis had been completed, another portion of the ash was fused with potass, after which the silica obtained agreed within 0·2 with that procured in the first instance by the usual process.

I am the more anxious to state this, as it will be seen from the statement given in a subsequent page, that there is a great discrepancy between the per-centage of silica given in Mr. Way's analysis and that reported by Sprengel, a discrepancy which, without this explanation, might be attributed to a want of care on his part in not dissolving the whole of the silica.

100 grains of real ash contain,—

DRUCE's Barley and Barley-straw.		Botanic Garden.		
		Permanent.	Shifting.	Standard.
Silica	43·6	32·3	46·1	45·0
Phosphoric acid	12·2	9·5	11·8	9·2
Sulphuric acid	4·1	2·7	2·9	5·2
Carbonic acid	0·7	2·5	1·7	1·8
Chloride of sodium	5·7	6·1	1·7	2·1
Soda	0·6	0·0	0·0	0·0
Potass	21·7	22·6	20·9	16·8
Magnesia	3·7	6·0	4·4	4·7
Lime	7·3	18·2	9·7	14·3
Total	99·6	99·9	99·2	99·1
Or Acids	17·00	14·7	16·4	16·2
Bases	32·70	46·8	35·0	35·8

These results are interesting on two accounts; first, as they show what the composition of barley is when cultivated under natural circumstances, or within what limits its variation from a normal condition may be circumscribed; secondly, as they confirm the general exactness of the preceding analyses, by the correspondence which is seen to exist between the composition of the shifting crop, as ascertained by experiment, and that of the sample obtained from Mr. DRUCE's brought out by the above method of computation.

As the analyses of the ash, both in the case of the straw and of the grain, were performed by Mr. WAY, whilst the proportion between the grain and straw, as well as that subsisting in each instance between the crop and its ash, was ascertained by myself, the statement which I have just submitted as to the real composition of the crop, calculated from these data, would hardly have presented so near an accordance with the analysis made of the entire crop which I had obtained in the Botanic Garden, had not both the one and the other been executed with considerable care.

It was far otherwise, however, when we compared our results with those of SPRENGEL, in which, amongst other striking discrepancies, we observe, that the proportion of soda stated to exist in the grain exceeds that of the potass, whilst in our analyses, only so much as was equivalent to the amount of chlorine appeared to be present*.

* Our analysis of *Hordeum vulgare.*		SPRENGEL's, of *Hordeum distichum.*		BICHON's, as quoted by WILL.	
Silica	33·2	Silica	50·2	Silica	21·99
Phosphoric acid	31·2	Phosphoric acid	8·4	Phosphoric acid	40·63
Sulphuric acid	3·4	Sulphuric acid	2·5	Sulphuric acid	0·26
Carbonic acid	0·0	Carbonic acid	0·0	Carbonic acid	0·00
Chloride of sodium	2·3	Chloride of sodium	0·0	Chloride of sodium	0·00
Potass	19·1	Potass	11·80	Potass	3·91
Soda	0·0	Soda	12·30	Soda	16·79
Magnesia	7·6	Magnesia	7·65	Magnesia	10·05
Lime	3·6	Lime	4·50	Lime	3·36
Alumina	0·0	Alumina	1·50	Alumina	0·00
	100·4		99·95		97·03

This discrepancy made me desirous of learning, whether, in accordance with the observations of WILL and FRESENIUS, any marked variation in the character of the alkaline constituent might subsist between barley cultivated in an inland county like Oxfordshire, and near the sea, and I therefore procured, through the kindness of a friend, one sample from the coast of Essex, and another from that of Cardiganshire, in South Wales.

The following were the results obtained of barley from the sea coast of Essex :—

1000 grains yielded 19 grains of ash.

100 grains of this ash contains, of—

Sand and charcoal, extraneous	23·28	
Peroxide of iron, extraneous	2·44	
	25·72	
Silica	24·89, or, excluding extraneous matter	34·0
Phosphoric acid	21·84, or, excluding extraneous matter	29·7
Sulphuric acid	1·79, or, excluding extraneous matter	2·4
Carbonic acid	0·00	0·0
Chloride of sodium	0·00, there being no chlorine in the ash.	
Soda	1·05, or, excluding extraneous matter	1·3
Potass	15·42, or, excluding extraneous matter	21·1
Magnesia	5·29, or, excluding extraneous matter	7·2
Lime	3·36, or, excluding extraneous matter	4·5
	99·36	100·2
	25·72	
Real ingredients of plant	73·64	

Barley-straw belonging to the same crop from Essex.

1000 grains yielded 49 grains of ash.

100 grains of these ashes contain, of—

Sand and charcoal, extraneous	8·59	
Peroxide of iron, extraneous	4·26	
	12·85	
Silica	41·81, or, excluding extraneous matter	48·9
Phosphoric acid	4·18, or, excluding extraneous matter	4·9
Sulphuric acid	0·67, or, excluding extraneous matter	0·8
Carbonic acid	0·00	0·0
Chloride of sodium	9·58, or, excluding extraneous matter	11·2
Soda	0·65, or, excluding extraneous matter	0·7
Potass	18·49, or, excluding extraneous matter	21·6
Magnesia	4·95, or, excluding extraneous matter	5·7
Lime	5·18, or, excluding extraneous matter	6·1
	98·36	99·9
	12·85	
Real ingredients	85·51	

The straw of the barley grown on the coast of Wales was not examined, but the ash of the grain from that quarter was found to contain, in 100 parts, 9·64 of potass, 1·32 of chloride of sodium, and only 0·84 of soda, the smaller proportion of potass being explained by the larger amount of extraneous matter present in the residuum left by it after calcination, than by the samples previously noticed.

The small proportion of soda, however, both in this, and in the former case in which the sample was obtained from the neighbourhood of the sea, seems to militate against the general conclusion deduced by WILL, from his analysis of barley taken from the interior of Germany, as compared with the same brought from the Netherlands.

POTATOES.

The crop grown in a recently manured portion of the Botanic Garden, separate from the spot set apart for the experiments, proving defective in quality, I selected as my standard a good mealy sort reared in the neighbourhood of Oxford, in the same kind of subsoil. The following will give the relative composition of this, and of the two crops obtained from the ground left for ten years unmanured, which, in the case of that styled the permanent, had borne potatoes for ten years consecutively, whilst in that styled the shifting, it had only borne them in 1844, having been occupied with the following plants on the nine years preceding, viz.—

1835. Delphinium consolida.
1836. Trifolium pratense.
1837. Nicotiana rustica.
1838. Valeriana Phu.
1839. Valeriana Phu.
1840. Linum usitatissimum.
1841. Solanum tuberosum.
1842. Papaver somniferum.
1843. Hordeum sativum.

Standard Crop.

Of the tubers, 1000 grains yielded about . . .
- 7·6 of ashes.
- 755·0 of water.
- 236·4 solid organic matter.

1000·0

Overlooking the small amount of extraneous matter intermixed, the ash will of course represent the proportion which its inorganic constituents bear to the whole quantity.

Now 100 grains of this ash consisted of—

Sand and charcoal, extraneous	5·93
Peroxide of iron, extraneous	6·85
	12·78
Silica	5·81
Phosphoric acid	9·68
Sulphuric acid	5·23
Carbonic acid	5·84
Chloride of sodium	2·06
Chloride of potassium	6·67
Potass	37·99
Magnesia	10·98
Lime	2·71
	99·75
	12·78
Real ingredients	86·97

Permanent Crop of Potatoes.

Tubers, 1000 grains yielded	12·7	of ash.
	724·0	of water.
	263·3	solid organic matter.
	1000·0	

100 grains of this ash consisted of—

Sand and charcoal, extraneous	14·40
Peroxide of iron, extraneous	3·30
	17·70
Silica	1·57
Phosphoric acid	10·68
Sulphuric acid	3·74
Carbonic acid	10·68
Chloride of sodium	2·79
Chloride of potassium	3·09
Potass	37·47
Soda	0·00
Magnesia	7·00
Lime	3·64
	98·24
	17·70
Real ingredients	80·54

Shifting Crop of Potatoes.

Of the tubers, 1000 grains yielded	10·8	of ash.
	719·0	of water.
	270·2	solid organic matter.
	1000·0	

100 grains of this ash consisted of—

Sand and charcoal	2·16
Peroxide of iron	5·15
	7·31
Silica	6·60
Phosphoric acid	15·13
Sulphuric acid	2·21
Carbonic acid	11·03
Chloride of sodium	1·87
Chloride of potassium	0·00
Potass	46·12
Soda	0·78
Magnesia	6·31
Lime	2·54
	99·88
	7·31
Real ingredients	92·57

The above analyses of potatoes, it may be observed, agree more nearly with BOUSSINGAULT than with SPRENGEL, as will appear by the following Table:—

Ingredients.	BOUSSINGAULT.	SPRENGEL.	WAY.		
			Permanent.	Shifting.	Standard.
Silica	5·6	1·0	1·95	7·150	6·67
Phosphoric acid	11·3	4·8	13·30	16·200	11·15
Sulphuric acid	7·1	6·5	4·66	2·370	6·00
Carbonic acid	13·4	0·0	13·30	11·900	6·70
Chloride of sodium	0·0	0·0	3·43	1·950	2·30
Chloride of potassium	0·0	0·0	0·00	0·000	7·60
Soda	traces.	28·5	0·00	0·840	0·00
Potass	51·5	48·2	46·60	50·00	43·80
Magnesia	5·4	3·9	8·70	6·85	12·65
Lime	1·8	4·0	4·54	2·70	3·10

The correspondence between the standard crop analysed by Mr. WAY and the one analysed by BOUSSINGAULT, is in many particulars exceedingly close; there is indeed an excess of magnesia and some little deficiency of potass, but if the potassium present in 7·6 of chloride (which is equivalent to 4·0) be represented as potass, it will amount to 4·8, which, added to 43·8, brings up the proportion of potass to 48·6, or to more than that present in the permanent crop.

TURNIPS.

The next kind of crop which we analysed was the turnips, and the following were the results obtained:—

Standard sort from the neighbourhood of Oxford, contained about 10 of water, and 1 of organic matter.

1000 grains yielded 3·18 of ashes; 100 grains of which consisted of—

Sand and charcoal	5·28
Peroxide of iron	11·91
	17·16
Silica	3·81
Phosphoric acid	12·63
Sulphuric acid	7·17
Carbonic acid	7·04
Chloride of sodium	4·83
Soda	2·57
Potass	31·62
Magnesia	3·18
Lime	11·54
	101·55
	17·16
Real ingredients	84·39

Turnips.

Shifting crop.

Sand and charcoal	4·01
Peroxide of iron	3·81
	7·82
Silica	3·30
Phosphoric acid	10·77
Sulphuric acid	9·43
Carbonic acid	8·66
Chloride of sodium	0·00
Chloride of potassium	5·40
Potass	38·46
Magnesia	5·08
Lime	10·44
	99·42
	7·82
Real ingredients	91·60

Turnips.

Permanent crop.

Sand and charcoal	3·92
Peroxide of iron	2·80
	6·72
Silica	2·67
Phosphoric acid	12·80
Sulphuric acid	11·07
Carbonic acid	9·75
Chloride of sodium	1·74
Soda	0·00
Potass	39·44
Magnesia	3·83
Lime	11·81
	99·73
	6·72
Real ingredients	93·01

Here also there is a pretty near coincidence between the analysis of Mr. Way and that of Boussingault, excepting in the amount of phosphoric acid, which corresponds nearly to that reported by Sprengel, with whom however in other respects there is but little agreement, as will appear from the following Table:—

Ingredients.	Boussingault.	Sprengel.	Way.		
			Permanent.	Shifting.	Standard.
Silica	6·4	7·8	2·87	3·60	4·5
Phosphoric acid. . . .	6·0	14·0	13·70	11·80	14·9
Sulphuric acid	10·9	7·9	11·80	10·30	8·5
Carbonic acid	0·0	0·0	10·40	9·40	8·3
Chloride of sodium. . .	0·0	0·0	1·83	0·00	5·7
Chloride of potassium . .	0·0	0·0	0·00	5·90	0·0
Soda	4·1	21·0	0·00	0·00	3·1
Potass	33·7	14·0	42·40	42·00	37·4
Magnesia	4·3	4·3	4·10	5·60	3·8
Lime	10·9	24·4	12·81	11·30	13·6

	Boussingault.	Sprengel.	Way.		
			Permanent.	Shifting.	Standard.
Potass . . .	33·7	21·0	42·40	45·74†	37·40
Soda	4·1	14·0	1·14*	0·00	6·16‡
Alkalies . .	37·8	35·0	43·54	45·74	43·56

Hemp.

Standard crop grown in the Botanic Garden apart from the portion reserved for the experiments.

100 grains of the crop left 6·1 of ashes, 100 grains of which contained of—

Charcoal and sand	7·48
Peroxide of iron	2·78
	10·26
Silica	5·58
Phosphoric acid	5·44
Sulphuric acid	1·09
Carbonic acid	19·81
Chloride of sodium	1·72
Soda	0·98
Potass	13·71
Magnesia	7·67
Lime	34·03
	100·29
	10·26
Real ingredients	90·03

* Viz. Ch. Sod. 1·83 = Soda 1·14.

† Viz. Potass . . . . 42·00
Ch. Pot. 5·9 = Potass . . . . . . 3·74
45·74

‡ Viz. Soda . . . . 3·10
Ch. Sod. . . . . 5·7=3·06
6·16

Hemp.

Shifting crop.

100 parts yielded 7·01 of ash, 100 parts of which consisted of—

Sand and charcoal	8·30
Peroxide of iron	3·78
	12·08
Silica	8·71
Phosphoric acid	5·68
Sulphuric acid	0·73
Carbonic acid	20·10
Chloride of sodium	0·63
Chloride of potassium	0·00
Soda	0·14
Potass	7·49
Magnesia	5·19
Lime	39·00
	99·75
	12·08
Real ingredients	87·67

Hemp.

Permanent crop.

100 parts yielded 6·00 of ash, 100 parts of which consisted of—

Sand and charcoal	10·40
Peroxide of iron	3·94
	14·34
Silica	8·39
Phosphoric acid	4·50
Sulphuric acid	1·09
Carbonic acid	19·78
Chloride of sodium	0·43
Soda	0·06
Potass	7·25
Magnesia	2·18
Lime	40·10
	98·12
	14·34
Real ingredients	83·78

The following will give a tabular view of the composition of the above three crops in 100 parts, after deducting the extraneous matters present in the ash.

Ingredients.	Standard.	Shifting.	Permanent.
Silica	6·13	9·95	10·00
Phosphoric acid	6·00	6·50	5·35
Sulphuric acid	2·00	0·83	1·20
Carbonic acid	21·79	23·00	23·50
Chloride of sodium	1·89	0·72	0·47
Soda	1·08	0·16	0·07
Potass	15·08	8·55	8·62
Magnesia	8·43	5·95	2·62
Lime	37·40	44·60	47·60
	99·80	100·26	100·00

Flax.

Standard crop grown in the Botanic Garden apart from the spot reserved for the experiments.

100 grains of the crop, including the ripened seeds, yielded 10·7 of ash, of which latter 100 parts contained—

Sand and charcoal	12·02
Peroxide of iron	3·42
	15·44
Silica	1·77
Phosphoric acid	6·85
Sulphuric acid	5·10
Carbonic acid	15·69
Chloride of sodium	2·43
Chloride of potassium	6·04
Soda	0·00
Potass	21·73
Magnesia	3·89
Lime	18·30
	97·24
	15·44
Real ingredients	81·80

Flax.

Shifting crop.

100 grains of the crop yielded 8·0 of ashes, 100 grains of which consisted of—

Sand and charcoal	13·15
Peroxide of iron	5·41
	8·56
Silica	1·82
Phosphoric acid	6·77
Sulphuric acid	4·18
Carbonic acid	17·38
Chloride of sodium	1·58
Soda	1·05
Potass	20·51
Magnesia	4·72
Lime	21·56
	98·13
	18·56
Real ingredients	79·57

Flax.

Permanent crop.

100 grains of the crop yielded 6·675 of ash, 100 grains of which consisted of—

Sand and charcoal	7·05
Peroxide of iron	8·01
	15·06
Silica	6·55
Phosphoric acid	6·55
Sulphuric acid	3·12
Carbonic acid	12·20
Chloride of sodium	1·14
Soda	5·87
Potass	11·05
Magnesia	4·68
Lime	33·59
	99·81
	15·06
Real ingredients	84·75

The following will show the composition of the three crops of flax, after deducting the extraneous matters present in the ash.

Ingredients.	Standard.	Shifting.	Permanent.
Silica	2·16	2·3	7·3
Phosphoric acid. . . .	8·40	8·5	7·3
Sulphuric acid	6·20	5·3	3·7
Carbonic acid	19·10	21·9	14·4
Chloride of sodium. . .	2·93	2·0	1·4
Chloride of potassium. .	7·35		
Soda	. . . .	1·3	6·9
Potass	26·50	25·8	13·0
Magnesia	4·76	5·9	5·5
Lime	22·30	27·0	40·0
	99·70	100·0	99·5

BEANS.

Standard crop grown in a part of the Botanic Garden distinct from the portion set apart for the experiments.

100 grains yielded 6·45 of ash, 100 grains of which consisted of—

Sand and charcoal	12·00
Peroxide of iron	2·33
	14·33
Silica	2·44
Phosphoric acid	7·77
Sulphuric acid	2·95
Carbonic acid	17·38
Chloride of sodium	2·58
Chloride of potassium	0·91
Soda	0·00
Potass	30·37
Magnesia	2·69
Lime	17·17
	98·57
	14·33
Real ingredients	84·26

Beans.

Shifting crop.

100 parts of crop yielded 5·7 of ashes, 100 parts of which consisted of—

Sand and charcoal	8·24
Peroxide of iron	3·77
	12·01
Soluble silica	3·97
Phosphoric acid	3·83
Sulphuric acid	2·49
Carbonic acid	18·45
Chloride of sodium	1·23
Soda	0·22
Potass	20·56
Magnesia	3·79
Lime	33·87
	88·41
	12·01
Real ingredients	76·40

Beans.

Permanent crop.

100 parts of crop yielded 4·4 of ash, 100 parts of which consisted of—

Sand and charcoal, extraneous	6·13
Peroxide of iron, extraneous	4·24
	10·37
Soluble silica	4·05
Phosphoric acid	3·29
Sulphuric acid	1·96
Carbonic acid	19·87
Chloride of sodium	1·00
Soda	7·00
Potass	12·77
Magnesia	3·63
Lime	35·76
	99·70
	10·37
Real ingredients	89·33

The following Table will show the composition of the three crops of beans, after deducting the extraneous matters present in the ash.

Ingredients.	Standard.	Shifting.	Permanent.
Soluble silica	2·90	4·48	4·50
Phosphoric acid. . . .	9·25	4·32	3·68
Sulphuric acid	3·50	2·80	2·19
Carbonic acid	20·70	20·85	22·20
Chloride of sodium. . .	3·17	1·38	1·12
Chloride of potassium. .	1·08	0·00	0·00
Soda	0·00	0·24	7·80
Potass	36·10	23·20	14·20
Magnesia.	3·20	4·28	4·06
Lime	20·30	38·20	40·00
	100·00	99·75	99·75

Having now, with reference to the six plants above-mentioned, stated, not only the amount of every year's crop, but also the composition of the last of each which had been obtained, we seem to be in a position to calculate the amount of the several inorganic ingredients contained in them, which will have been abstracted from the ground during the time the experiments were carried on.

This indeed is a question of little interest, so far as regards the acids and bases that are predominant ingredients in the soil, but in the case of the alkalies, the magnesia, and the phosphates, which exist there in more limited quantity, its determination may afford us a clew towards the main object of our inquiry, namely, the cause of the falling off of a crop after frequent repetition.

In the case of the barley, it will be seen, that the produce of the same plot of ground amounted in the course of ten years to 289·65 lbs., including straw as well as grain, and that, taking the last year's crop as the criterion, this quantity would have yielded 25·2 lbs. of ash.

For as 100—8·7—289·65—25·2.

Now 25·2 lbs. of ash would contain nearly as follows, according to the analyses given above:—

Sand and charcoal, Peroxide of iron } extraneous . . .	6·25
Silica	6·30
Phosphoric acid	1·84
Sulphuric acid	0·53
Carbonic acid	0·47
Chloride of sodium	1·18
Potass	4·36
Magnesia	1·15
Lime.	3·52
	25·60

On the other hand, the shifting crops of barley, which in ten years amounted to 421 lbs., and which, taking as our criterion the amount of ash yielded the last year (1844), had drawn from the land 26·31 lbs. of inorganic matter (the sand, charcoal, and peroxide of iron, drawn from other sources having been deducted), would have abstracted from the soil in ten years, as follows:—

Sand and charcoal, Peroxide of iron } extraneous	6·175
Silica	9·300
Phosphoric acid	2·370
Sulphuric acid	0·600
Carbonic acid	0·366
Chloride of sodium	0·364
Potass	4·220
Magnesia	0·915
Lime	1·960
	26·270

Proceeding now to the second case, that of the potatoes, we find the amount of the produce, in the case of the permanent crop, in nine years to have been 620·8 lbs., yielding 7·37 of ashes, of which, however, about 1·37 were extraneous. Consequently during that period the inorganic constituents, abstracted from the soil, and contained in 6 lbs. of real ash, would be as follows:—

Silica	0·11
Phosphoric acid	0·80
Sulphuric acid	0·27
Carbonic acid	0·80
Chloride of sodium	0·20
Chloride of potassium	0·23
Potass	2·80
Magnesia	0·52
Lime	0·27
	6·00

On the other hand, we find, in the case of the shifting crop, the average of nine years' produce to be 89·1, or nearly 802 lbs. for the whole period, yielding of ashes about . . . . . 7·3 lbs.
from which must be deducted, as extraneous matter, about . . . . . 0·7

Leaving for real ash . . . . 6·6

and containing the following constituents:—

Silica	0·472
Phosphoric acid	1·070
Sulphuric acid	0·157
Carbonic acid	0·785
Chloride of sodium	0·130
Potass	3·300
Soda	0·055
Magnesia	0·452
Lime	0·178
	6·599

In the case of the next crop, the turnips, I have not sufficient data to determine with exactness the amount of inorganic ingredients extracted from the soil, having omitted to weigh the bulbs, from which the ash, in the case both of the permanent and shifting crops, was derived.

I find, however, that 1000 parts of a good sample from the neighbourhood of Oxford yielded 3·15 of ash, of which about 0·55 was extraneous, so that 2·6 grains will represent the amount of inorganic constituents really present.

The bulbs obtained from the permanent crop in ten years amounted to about 1008 lbs.; so that the inorganic constituents extracted from the soil in this instance may be reckoned at about 2·62 lbs.

Now 2·62 lbs. of inorganic matter would, according to the previous data, consist of the following ingredients, viz.

	lbs.
Silica	0·075
Phosphoric acid	0·360
Sulphuric acid	0·310
Carbonic acid	0·273
Chloride of sodium	0·050
Potass	1·110
Soda	0·000
Magnesia	0·110
Lime	0·332
	2·620

The shifting crop of turnips in the same period yielded of bulbs 1765 lbs., which, according to the same calculation, would have produced 4·58 of real ash.

For as 1008—262—1765—4·58.

Now 4·58 lbs. of ash would contain the following proportions of inorganic constituents, viz.

Silica	0·165
Phosphoric acid	0·540
Sulphuric acid	0·470
Carbonic acid	0·430
Chloride of potassium	0·270
Potass	1·930
Magnesia	0·255
Lime	0·520
	4·580

The next crop I shall consider is hemp, of which the permanent crop, according to the statements given in the first part of this paper, would have amounted in nine years to 271·25 lbs., or 30·13 lbs. per annum, yielding of ash 16·27 lbs.

For as 100—6·0—271·25—16·27.

Now 16·27 lbs. of ash would contain of extraneous matter about 2·27

leaving 14·00 of inorganic principles belonging to the plant, which would consist of—

Silica	1·30
Phosphoric acid	0·70
Sulphuric acid	0·17
Carbonic acid	3·07
Chloride of sodium	0·06
Soda	0·08
Potass	1·10
Magnesia	1·40
Lime	6·12
	14·00

Now the average of the shifting crops for seven crops was 40 lbs., and as the ash obtained was about 7 per cent. its whole amount would have been 2·8 lbs.

	lbs.
Or in seven years	(2·8×7)=19·6
Of which the extraneous matter would be about	2·3
Leaving of inorganic principles extracted from the earth in seven years	17·3
Or, if in seven years—17·3—nine years	22·17

Now 17·3 lbs. of inorganic principles consist of

Silica	1·70	2·19
Phosphoric acid	1·18	1·52
Sulphuric acid	0·14	0·18
Carbonic acid	3·96	5·10
Chloride of sodium	0·12	0·15
Soda	0·03	0·04
Potass	1·47	1·90
Magnesia	1·00	1·29
Lime	7·60	9·80
	17·20	22·17

I next proceed to the flax, which in ten years produced, as we have seen, an amount of crop equal to 126 lbs., yielding of ashes 8·4 lbs.

of which 1·26 was extraneous.

Leaving of real ash 7·14, which would consist of—

Silica	0·520
Phosphoric acid	0·520
Sulphuric acid	0·264
Carbonic acid	1·020
Chloride of sodium	0·099
Soda	0·490
Potass	0·925
Magnesia	0·390
Lime	2·850
	7·078

Now the average of ten crops of flax, cultivated in different plots of the same garden, was 22·7 lbs., yielding 1·816 of ashes, = in ten years 18·16 lbs., of which 3·36 lbs. were extraneous, leaving 14·8 lbs. of real ash, which would consist of the following ingredients:—

Silica	0·34
Phosphoric acid	1·25
Sulphuric acid	0·78
Carbonic acid	3·22
Chloride of sodium	0·30
Soda	0·20
Potass	3·80
Magnesia	0·87
Lime	4·00
	14·76

The last of the crops made the subject of examination was the beans, where the aggregate of ten years' produce, in the case of the permanent crop, was 247 lbs., which would have yielded 10·8 lbs. of ashes.

Of this, however, about 1·1 would consist of extraneous matter.

Leaving 9·7 of real ash,

consisting of the following ingredients:—

Silica	0·44
Phosphoric acid	0·36
Sulphuric acid	0·22
Carbonic acid	2·13
Chloride of sodium	0·12
Soda	0·76
Potass	1·37
Magnesia	0·40
Lime	3·90
	9·70

In the case of the shifting crop of beans the produce of ten years gives an aggregate of 336 lbs., yielding of ash 19·15 lbs.,

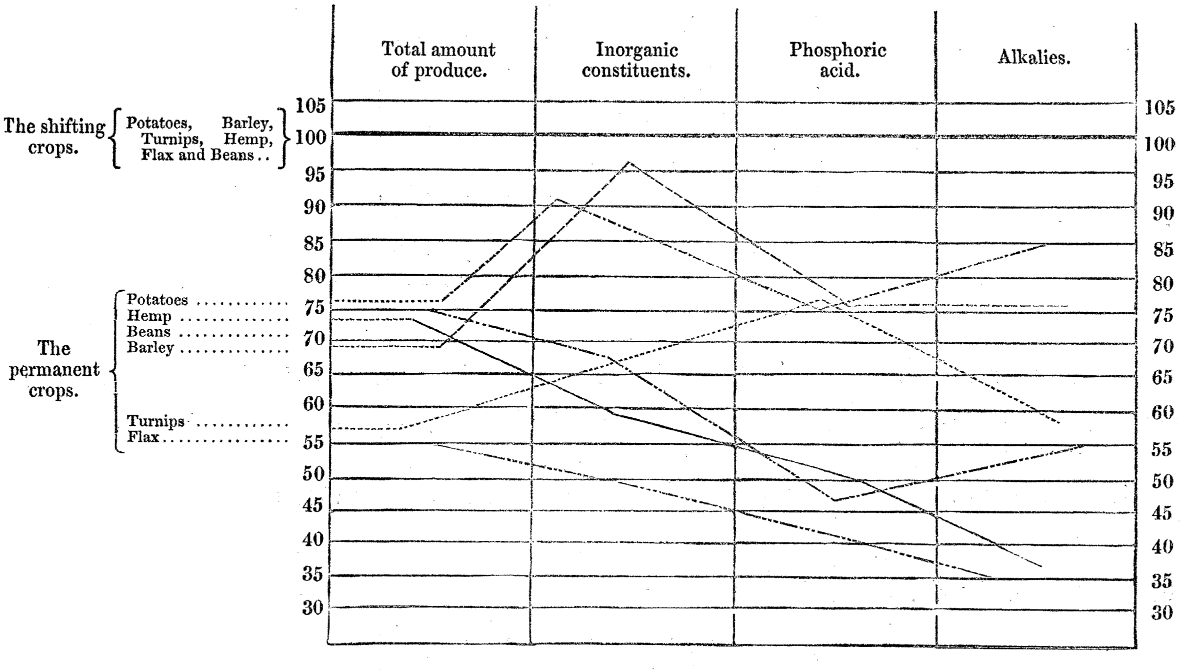
of which, however, about 2·30 was extraneous,

leaving 16·85 of real ash,

which would contain, of—

Silica	0·757
Phosphoric acid	0·723
Sulphuric acid	0·470
Carbonic acid	3·500
Chloride of sodium . .	0·235
Soda	0·044
Potass	3·900
Magnesia	0·725
Lime	6·420
	16·774

Diagram showing the relation between the Permanent and the Shifting Crops.



Before we proceed to inquire, whether the difference in the average amount of produce obtained under these two modes of cultivation arose from a deficiency of the organic, or of the inorganic materials present in the soil, it may be worth while to present a tabular view of the numerical relation subsisting between the permanent and shifting crops in each instance, with respect to the entire crop, to the entire amount of inorganic matter, and to the proportions of phosphoric acid and of alkalies present in each.

	Total amount of produce.		Inorganic constituents.		Phosphoric acid.		Alkalies.	
	Permanent.	Shifting.	Permanent.	Shifting.	Permanent.	Shifting.	Permanent.	Shifting.
Barley....	69·0	100·0	96·5	100·0	77·0	100·0	77·0	100·0
Potatoes..	77·5	100·0	91·0	100·0	75·0	100·0	85·0	100·0
Turnips ..	57·0	100·0	....	....	77·0	100·0	58·0	100·0
Hemp....	75·0	100·0	63·5	100·0	46·8	100·0	55·0	100·0
Flax.....	55·5	100·0	48·0	100·0	41·6	100·0	35·0	100·0
Beans....	73·0	100·0	58·0	100·0	50·0	100·0	36·0	100·0

The results in the two first instances would seem to lead to opposite conclusions from those suggested by the three latter, inasmuch as, whilst in the barley and the potatoes, the difference between the amount of inorganic constituents in the two cases was much less than that between the permanent and shifting crop collectively taken; in the hemp, flax and beans the contrary remark applies.

If we take the phosphoric acid, we find also that in the barley, and turnips, it stands in a higher ratio to the other constituents in the permanent, than in the shifting crop, whilst in the hemp, flax and beans, it stands in a much lower one.

A similar remark applies to the alkalies, so that no general conclusion, as it might seem, is deducible from these premises.

It appears to me, however, that the existence of a larger relative amount of phosphoric acid in the permanent than in the shifting crops of barley and of turnips, affords a stronger presumption in favour of a certain dependence of the produce on the organic matter, than the opposite result arrived at in the three other cases does of the reverse.

If the falling-off of the crop in these instances had arisen from a deficiency of certain of its inorganic principles, such for instance as the phosphates or the alkalies, at least a corresponding reduction in these latter might have been expected to have been found in the ashes of the one which proved deficient in quantity; whilst on the other hand, if the deficiency of organic matter be supposed to have checked the development of particular parts, as, for example, of the seeds, it might thereby affect the character of the ashes obtained, and thus a smaller amount be abstracted, without any actual failure, in the supply afforded by the soil to the plants that grew in it, taking place with regard to them.

I am led to this opinion, by the result of an examination, which I requested Mr. Way to institute, into the nature of the inorganic constituents present in ordinary gluten, and in starch.

The first, obtained from wheat, yielded about three parts of inorganic matter in the 1000 parts, which latter contained as much as 33 per cent. of phosphoric acid combined with lime, and a trace of magnesia, but no carbonate of lime*.

* I found also that the bran contained a larger proportion of silica than the albumen of the grain itself, and we know that the proportion of these several parts, one to the other, varies considerably in different samples of flour.

The latter, obtained from potatoes, yielded about 3·43 parts of inorganic matter in the 1000, of which only 4·77 per cent. was phosphoric acid, whilst 82·48 was carbonate of lime.

Thus, in the case of wheat, any condition of things which should check the formation of gluten, would diminish the quantity of phosphoric acid present in the ashes of this plant, even though the soil might contain an abundant supply of that ingredient; and as the formation of gluten is promoted by the presence of manures abounding in ammoniacal salts*, so it may easily happen, that this principle should be deficient where such manures are too sparingly administered.

In a similar way, a variation in the constituents of barley and other crops may be supposed to arise, not only from a larger or smaller supply of inorganic principles in the soil, in the manner that Liebig has so lucidly explained to us, but likewise from a more plentiful exhibition of those products of the decomposition of organic bodies, which favour the development of particular organs, or of certain of the proximate principles which the latter contain.

Which, however, of these two suppositions applies to the cases now under consideration, will be better seen, when we have considered the composition of the soil in which they grew, as determined by analysis.

PART III.

On the chemical composition of the soil in which the crops were grown, and on the proportion of its ingredients that were available for the purposes of vegetation.

The chief difficulty, which occurs with respect to the analysis of a soil, relates to the determination of those ingredients which, like the phosphates and the alkalies, exist in minute proportions, and which accordingly appear to have been overlooked by Davy, and others, who first applied themselves to the subject of agricultural chemistry.

It will not be necessary therefore to take up the time of this Society, by giving a detailed account of the method pursued by Mr. Way in his examination of the soils of which I wished to learn the composition; it may be sufficient to state, that after separating the several portions, one from the other, by the mechanical method pointed out by Mr. Rham, and determining the relation which the coarser bore to the finer, the latter, which alone were supposed capable of imparting any nourishment to plants, at least within a limited period, was submitted to the usual course of examination pursued by chemists.

To ascertain the phosphates however, a distinct and a much larger portion of the soil was operated upon, not less than 2000 grains being taken for the purpose, and this was digested for five hours in water acidulated with muriatic acid, the flask employed for the purpose being fitted up with a funnel attached to its neck, in the manner re-

* See Hermbstadt's experiments quoted in the third of my Lectures on Agriculture, and Sir H. Davy's Lectures on Agricultural Chemistry.

commended by Dr. URE, for the purpose of condensing the acid which might be disengaged in vapour, and restoring it to the body of the vessel*.

The liquor, after being filtered, was evaporated to dryness, so as to dispel the greater part of the acid.

The residuum was then treated with water, and an excess of ammonia was added, by which the iron, alumina, and phosphate of lime were thrown down.

The whole was then carried to dryness, and gently ignited, by which means the greater part of the iron and of the alumina is rendered insoluble in dilute acids, which take up the phosphate of lime.

The solution was then treated with ammonia so long as any precipitate was thrown down, and the latter digested with dilute alcohol mixed with sulphuric acid, by which any alumina and iron that had been precipitated were converted into soluble salts, whilst any lime in combination with phosphoric acid would remain as an insoluble sulphate, from the amount of which, when well-washed and dried, that of the phosphate present in the soil admits of being calculated.

After ammonia had thrown down the alumina, iron, and phosphate of lime, the alkalies existing in the ash would still remain in the solution.

The latter was therefore again evaporated to dryness, and the ammoniacal salts driven off.

The residue was then treated with water, boiled and filtered, after which a solution of carbonate of ammonia, to which a little pure ammonia had been added, was introduced into the liquor that came through. The remainder of the earths were thus thrown down, and nothing remained in solution except the alkalies. After the ammoniacal salts had been expelled by heat, the mixed chlorides of potassium and sodium were separated in the usual way by chloride of platinum.

Such then was the method pursued for determining the nature and proportions of those ingredients, which, if not available for the purposes of vegetation at the present time, may at least be regarded as likely to prove useful to them within no very distant period, as being separable, by dilute muriatic acid, from the mass of the earth.

The soil of that part of the garden, in which the experiments above detailed had been conducted, varied in depth from three to four feet, and rested upon a stiff clay, of which the subsoil in the valley of Oxford consists, wherever it is not overlaid by gravel.

It was chiefly made ground, brought in to elevate the level of the garden above that to which the contiguous river rises during the winter floods, and about a year antecedent to the commencement of the experiments it had been manured with stable dung.

I have already expressed my regret, that no analysis was made of it until the present year, at which time the experiments had been already brought to a close.

In a neighbouring part of the garden, which appeared to be similarly circumstanced to that which had been set apart for the experiments, except that it had been recently

* Journal of the Agricultural Society, vol. v. p. 617.

manured, the ingredients of the impalpable portion of the soil, which had passed through the meshes of a fine sieve, were found by Mr. Way to be as follows:—

Sand and clay	410·44
Organic matter	103·96
Silica	95·06
Lime	139·53
Peroxide of iron	98·33
Alumina	35·60
Carbonic acid	106·10
Sulphuric acid	1·82
Chlorine	a trace.
Magnesia	·46
Potass	2·58
Soda	1·18
Phosphate of lime	·73
	995·79
Loss	4·21
Coarse sand	890·00
Stones and pebbles	870·00
	2760·00

The soil of the garden in which the experiments had been conducted was also subjected to a similar examination, the plot which had grown a crop of barley for ten years without manure having been selected.

The following were the results:—

Sand and clay	407·00
Organic matter	75·00
Silica	109·20
Lime	144·17
Peroxide of iron	103·80
Magnesia	·85
Alumina	25·00
Sulphuric acid	1·65
Carbonic acid	125·69
Potass	2·91
Soda	·29
Phosphate of lime	·80
Chlorine	a trace.
Loss	3·64
	1000·00
Coarse sand	810·00
Stones and pebbles	660·00
	2470·00

In another of the beds which had reared a permanent crop, viz. that of potatoes, the proportion of the phosphates, alkalies, and magnesia did not appear to vary much, the analysis of 1000 grains of the finer portion sifted, affording the following results:—

Phosphate of lime . . .	0·86
Potass	1·57
Soda	0·27
Magnesia	0·82
The organic matter here was	53·00

A third of the beds in the same garden, which had borne a crop of turnips for ten years, exhibited rather a remarkable anomaly, as the phosphates exceeded in quantity considerably that present in the contiguous garden, the results being as follows:—

Potass, in 1000 parts . .	0·46
Soda	0·74
Phosphate of lime . . .	1·62
Organic matter . . .	110·80

It will be seen, that the permanent crop of turnips in ten years would have extracted from the soil only 0·36 of phosphoric acid, whilst the barley in the same time had extracted 1·84, and the potatoes 0·80; hence perhaps the difference in the quantity present in the soil.

One only of the plots of ground, which had grown a succession of different crops for ten years without manure, was examined*, and the proportion of the above ingredients found in it appeared to be as follows, viz.—

Potass in 100 grains . .	1·96
Soda	1·12
Phosphate of lime . . .	0·33
Organic matter	76·50

It will be seen from the table in the following page, that, taking as our standard the composition of the contiguous garden, of which the analysis is first reported, and in which the proportion of phosphoric acid would seem to be lower than it is in most of the plots of ground experimented upon, even after ten years' cropping without manure (judging from the few which were examined), a sufficient quantity of the above ingredient existed, to supply what would be necessary for nineteen crops of barley, of the same amount as the average of those obtained from the permanent bed, and of the same quality as that produced in 1844.

* The crops were, barley in 1844, hemp in 1843, buckwheat in 1842, tobacco in 1841, parsley in 1840 and 1839, mint in 1838 and 1837, parsley in 1836, and beans in 1835.

In the following Table the results are all reduced to one standard.

1000 grains of the soil.

Ingredients.	Contiguous garden.	Permanent bed of barley.	Permanent bed of potatoes.	Permanent bed of turnips.	Bed which had borne a succession of ten crops without manure.
Stones and pebbles	315·000	267·000			
Coarse sand	322·000	328·000			
Fine sand and clay	149·000	165·000			
Organic matter	37·600	30·400	21·400	44·8*	31·000
Silica, soluble	34·400	44·000			
Lime	50·500	58·000			
Peroxide of iron	35·500	41·800			
Alumina, soluble	12·800	10·100			
Carbonic acid	38·400	50·500			
Sulphuric acid	0·660	0·665			
Chlorine	a trace.	a trace.			
Magnesia	0·167	0·344	0·332		
Potass	0·930	1·180	0·640	0·186	0·790
Soda	0·428	0·117	0·109	0·300	0·470
Phosphate of lime	0·265	0·322	0·346	0·656	0·133
	997·650	997·428			

For one cubic foot of the soil of the garden was found to weigh eighty-two lbs., from which it follows, that an area of 100 square feet to the depth of three feet (which is less than the average depth of the soil in the garden), would contain 24,600 lbs. of soil, which at 1·0 gr. to 1 lb. of soil would give an amount of phosphoric acid equal to 3·5 lbs.

Now it has been calculated (page 230) that the quantity of phosphoric acid extracted from the soil in ten years did not exceed 1·84 lb., so that the permanent bed of barley, which contains at present 0·8 of phosphate of lime, or 0·4 of phosphoric acid, would not have possessed before the cropping more than 1·26 of phosphate, or 0·63 of phosphoric acid, in the 1000 grains.

With respect to the alkalies, we shall find by the same mode of calculation that the medical garden contains in 100 square feet—

	lbs.
Potass	6·9
Soda	2·9

And as each permanent crop of barley in the average extracted no more than of—

Potass	0·436
Soda	0·064,

(deduced from 1·18 of chloride of sodium) in 100 parts, there would be a supply of potass equal to fifteen crops of barley, and of soda equal to forty-five crops.

* Thus we perceive that a series of ten successive crops of turnips had added more organic matter to the soil than it had abstracted. See Boussingault's late work, chap. vii. on the Rotation of Crops.

Here also we have reason to believe, that the soil of the experimental garden was richer than that upon which our calculations are founded, so that the falling-off of the crop cannot be attributed to any actual deficiency either of alkali or of phosphoric acid in the soil.

The amount of magnesia in the soil was also very small, not exceeding 3·8 lbs. to the 100 square feet.

This however would have been sufficient for thirty-four crops of barley, according to the estimate given (in p. 230) of the quantity taken up by the crop in ten years.

When, however, we proceed to inquire into the quantity of these ingredients, which are at the particular moment in a condition to be taken up by the spongioles of the roots, we find the case very different.

I have already pointed out, that, with a view of imitating nature as nearly as possible, water impregnated with carbonic acid is a preferable solvent to muriatic acid, since it may be presumed, that what is not extracted from the soil by a sufficiently large amount of the former, is not in a condition to be readily assimilated by the plants that grow in it.

I therefore took sifted portions, each weighing 5 lbs., of the soil, from the part of the garden contiguous to the scene of my experiments, as well as from several of the plots which had grown either the same or different crops during ten years without the addition of manure, and having introduced them into earthen pots, with a hole at the bottom covered over with a piece of wire gauze fine enough to prevent the earth from falling through, I added to each a known quantity of distilled water which had been saturated with carbonic acid gas.

After a certain amount of the water had passed through, generally two quarts were taken and evaporated to dryness, after which the residuum was treated, in the first place with water, which took up the alkaline salts together with a little calcareous matter, and afterwards with muriatic acid, which dissolved the rest of the lime, whether in combination with carbonic or with phosphoric acid.

Having got rid of the earthy matter from the aqueous solution by means of oxalate of ammonia, the alkalies remaining were converted into sulphates, heated and weighed, after which the nature of the alkali, combined with the sulphuric acid, was determined by the usual method.

The acid solution was then treated with ammonia, and the precipitate, when well-washed and dried, was set down as phosphate of lime, iron being rarely present, and never except in minute proportions.

The following results were obtained, by operating in this manner on the soils enumerated below, and, granting that objections may be raised against the precision of the method adopted, they at least suffice to show, that the ten years' cropping had reduced very materially the amount of matter immediately available for the purposes of vegetation, however little it appear to have trenched upon the latent resources of the soil.

Table of the quantity of alkaline sulphates and earthy phosphates extracted by means of water impregnated with carbonic acid from the soils enumerated below.

Soil examined and treated with water.	Quantity of water added.	Quantity of alkaline sulphate obtained.	Nature of the alkali.	Quantity of alkaline sulphate per quart of water.	Quantity of alkaline sulphate in 1 lb. of soil.	Quantity of alkaline sulphate in 100 square feet (24,600 lbs.) of the soil.	Quantity of earthy phosphate taken up.	Quantity of earthy phosphate per quart of water.	Quantity of earthy sulphate per lb. of soil.	Quantity of earthy phosphate in 100 square feet of soil (24,600 lbs.).
	qts.	gr.		gr.	gr.	gr.	gr.	gr.	gr.	gr.
From the contiguous garden, first time	2	5·2	Potass.	2·6	....	....	0·7	0·35		
From the contiguous garden, second time ..	2	7·8	Potass.	3·9	....	....	0·7	0·35		
From the contiguous garden, third time	1	3·4	Potass.	1·7	....	....	0·05	0·05	0·29	7134
From the contiguous garden, fourth time ..	1	2·6	Potass.	1·3	3·4	83640				
From the permanent bed of Barley........	2	0·6	Soda.	0·30	0·12	2950	0·30	0·15	0·06	1470
From the permanent bed of Potatoes	2	0·7	Soda.	0·35	0·07	1700	0·25	0·125	0·05	1200
From the permanent bed of Hemp	2	0·6	Soda.	0·30	0·12	2950	Scarcely appreciable.			1470
From the permanent bed of Flax..........	2	0·5	Soda.	0·25	0·10	2450	Scarcely appreciable.			2940
From the permanent bed of Turnips	2	0·6	Soda chiefly.	0·30	0·12	2950	0·30	0·15	0·06	3180
From the permanent bed of Beans	2	0·5	Soda.	0·25	0·10	2450	0·60	0·30	0·12	4900
From the shifting bed of Barley	2	0·7	Soda chiefly.	0·37	0·07	1700	0·065	0·0325	0·013	3420
From the shifting bed of Potatoes	2	1·0	Soda chiefly.	0·50	0·20	4900	0·100	0·050	0·020	4900
From the shifting bed of Hemp	2	1·0	Soda chiefly.	0·50	0·20	4900	Scarcely appreciable.			
From the shifting bed of Flax............	2	0·3	Soda chiefly.	0·15	0·06	1470	0·7	0·35	0·14	3420
From the shifting bed of Turnips	2	3·6	Potass.	1·8	0·72	17700	0·9	0·45	0·18	4410
From the shifting bed of Beans	2	1·0	Soda.	0·50	0·20	4900	0·30	0·15	0·06	1470

Thus it is seen, that whilst the entire quantity of phosphate present in 100 square feet of the garden soil amounted to 43911 grains, or exceeded 6 lbs., and that of alkali (including both potass and soda) to 233,700 grains, exceeding 33 lbs., all that could be extracted from the same quantity of soil by water was, 7134 grains of phosphate, and an amount of alkali sufficient to produce 83,640 grains of sulphate.

It appears, moreover, that, in the soils which had been drawn upon for ten years, either by the same crop or by a succession of different ones, without the application of manure, whilst the actual amount of phosphate and of alkali was fully as great as in the other parts of the garden, the quantities extracted by water were many times less; and although it need not be supposed, that what had been withdrawn by two quarts of water constituted the whole amount of these substances which was available at the time for the purposes of vegetation, yet it seems probable, that the facility with which the above ingredients were supplied to the plants, would bear some relation to the quantities taken up by the same amount of water from the different soils.

Since, therefore, the amount of phosphates and of alkalies extracted by two quarts of water in these cases falls considerably short of the quantities of those ingredients required for an average crop of barley, such as that produced for ten years in succession in the same soil, it may be fairly concluded, that the deficiency in the produce arose in part from a less ready supply of these constituents being provided, than would have been the case in soil newly broken up, or recently manured, where, although the absolute amount of nutritious principles may not be very different, the proportion of them in a state directly applicable to the uses of the plant will be much greater.

This hypothesis however seems to me only to afford a partial explanation of the problem before us; for repeated instances occur in this paper, of two soils presenting no apparent difference in the condition of their ingredients as to solubility, and in other respects alike, which nevertheless have varied very materially in the amount and quality of their produce, according as the crop has been a permanent or a shifting one; so that in these instances, the crop had extracted different quantities of phosphates and of alkalies from two soils, both of which were capable of supplying them with these principles, with equal readiness, and in equal abundance.

This circumstance might seem to favour the idea, that the quantity and condition of the organic matter present in the soil may exercise some control over the development of the crop.

Upon the whole, then, it must, I think, be admitted, on the one hand, that the quantity of inorganic matter brought into a soluble condition would, other things remaining the same, be more considerable in proportion to the activity with which the processes of vegetation are carried on, inasmuch as those operations which result from the vitality of the plant, would facilitate that introduction of air and water into the body of the soil, by which a fresh portion of the above ingredients might be brought into a more soluble condition—owing to the separation of the clods of earth,

caused by the fibres of the roots insinuating themselves amongst them—owing to water impregnated with carbonic acid, excreted by the extremities of the roots, which may exert its solvent power upon the principles contained in the soil—and owing to an imbibition, by the plants themselves, of the water surrounding them, which would cause a general movement and circulation in the fluid contained in all the portions of the soil contiguous.

On the other hand, it would seem, that a due supply of these necessary ingredients, already prepared and available for their purposes, would itself be likely to favour the development of the parts of the vegetable, and thus to cause a larger portion of such substances to be extracted from the earth, by the more vigorous action excited within the secreting organs themselves.

These effects are so connected together, that it is difficult to pronounce which of them deserves to rank as the first link in the series.

The only inferences, therefore, I could venture at present to deduce from the facts which I have laid before the Society, are as follows:—

1st. That it is quite consistent with the general tenor of the preceding facts and observations, to maintain with BOUSSINGAULT, that the falling-off of a crop is dependent upon a deficiency of organic matter proper to promote the nutrition of the plants, as well as upon a failure of its inorganic principles; not indeed that the organic matter enters, as such, into the constitution of the vegetable, but that by its decomposition it furnishes it with a more abundant supply of carbonic acid and ammonia, which supply accelerates the development of its parts, and thus at once enables it to extract more inorganic matter from the soil, and enables the soil to supply it more copiously with the principles it requires.

Hence, perhaps, in part, the advantage of intercalating the Leguminosæ and other fallow crops, which generate a larger amount of organic matter than the Cerealia, and which thus serve to enrich the soil by what they leave behind them.

2ndly. That it by no means follows, because a soil is benefited by manuring, even though that manure may, as in the case of bones, guano, &c., derive its efficacy from the phosphates it supplies, that the soil is therefore destitute of the ingredient in question, since it may happen, that it possesses abundance of it in a dormant, though not in an immediately available condition.

In these cases, in which the agriculturist has been assured by the results of actual analysis, that there is no real dearth of the principles essential to his crops in the soil which he is cultivating, but where he has ascertained, either by the chemical mode pointed out, or by an experience of the good effects brought about by manures, that the principles in question are not in a state to become immediately applicable to the purposes of vegetation, three courses appear to be open to him:—

1st. To apply a sufficient quantity of the same materials in a state in which they can be absorbed by the plants without delay; 2ndly, to allow the ground to remain fallow, by which expedient time is allowed for a further decomposition of its mate-

rials, and for a renewed extrication of its useful ingredients, to take place; 3rdly, to produce by the various methods in daily use, such a stirring and pulverization of the ground, as may admit of a more thorough admission of air and moisture, and consequently accelerate the process of disintegration in a greater degree than would take place under natural circumstances.

Examples will occur to every one of the successful adoption of each of these three practices: of the first, in the ordinary process of manuring, and especially in the beneficial consequences resulting from the use of bones in the exhausted pastures of Cheshire and other similar localities; of the second, in the system so general in the early stages of agriculture, of allowing land to remain at rest for a certain period with a view of restoring to it its exhausted powers,—a method which would be absurd, if the alkalies, phosphates, and other of the more scanty ingredients were absolutely deficient, but which would be likely to prove efficient, if they were only locked up within the recesses of the soil, and required time to render them active; of the third, in the practice resorted to by JETHRO TULL, who boasted that he could realize an abundant crop year after year without manure, provided the ground were only stirred and broken up sufficiently,—a statement which seems confirmed, by some of the results of spade husbandry, and in a certain degree by those detailed in this paper, with respect to the permanent crops which are herein mentioned as having been made the subject of experiment.

The choice between the above three methods will of course be determined in each instance by a balance of economy, and although in general this latter consideration will incline the farmer to prefer the ordinary method of manuring, either to the sacrifice of a year's produce, as in the second method, or to the expenditure of labour required to put into practice the third, still there may be cases where it might better answer his purpose to resort to one or other of them, either as being more advantageous in itself, or more suitable to the circumstances of the case.

At any rate it may be important for him to be assured, that at the very time he is ransacking the most distant quarters of the globe for certain of the mineral ingredients required for his crops, he has lying beneath his feet in many instances an almost inexhaustible supply of the very same.

For there seems no reason to doubt, that the whole mass of rock, which constitutes the subsoil in the secondary and tertiary districts of this country, is as rich in phosphates and in alkalies, as the vegetable mould derived from its decomposition; and although the soil, in which the experiments in my garden were conducted, possessed a depth nearly three times as great as the average of those in which farm produce is generally raised, yet on the other hand, the amount of phosphates and of alkaline ingredients reported to be present in them, appears in many instances greater than that determined in the case before us.

Thus Dr. URE* gives an analysis of a soil in the parish of Hornchurch, Essex,

* Journal of the Royal Agricultural Society.

which contained four grains of phosphate of lime in 1000 grains, whereas ours scarcely exceeded one-fourth of a grain in the same quantity; and if the former be regarded as an exceptional case, I might refer to SPRENGEL, who states, that the per-centage of phosphoric acid in the soils he analysed varied from 0·024 to 0·367; and of the subsoil from about 0·007 to 0·2.

I detected many years ago phosphate of lime in several secondary limestones chiefly from the oolitic formation, and Mr. SCHWEITZER of Brighton has determined the proportion of that ingredient in the chalk near Brighton, to be not less than one grain in the 1000. We need not therefore resort to South America for bones, if means could be found for extracting this ingredient economically from the rocks of our own country.

3rdly. These facts place in rather a new light, although one, it is conceived, not less striking than before, the importance of taking care of the various excrementitious matters at our disposal, whether proceeding from animal or from vegetable sources.

Such substances indeed contain the products, which nature has, with so large a consumption of time, and by such a number of complicated operations, elaborated from the raw material contained in the soil, and has at length brought into the condition, in which they are most soluble, and therefore best fitted to be assimilated by the organs of plants.

To waste them, is therefore to undo, what has been expressly prepared for our use by a beautiful system of contrivances, and to place ourselves under the necessity of performing, by an expenditure of our own labour and capital, those very processes, which nature had already accomplished for us, without cost, by the aid of those animate or inanimate agents which she has at her disposal.

4thly. The analyses above reported may suggest caution as to the inferences which some might be disposed to deduce from certain researches lately announced, with respect to the power which a plant possesses of substituting one alkali, or one earth, for another, in the processes of vegetation.

This substitution indeed, however brought about, is a fact which hardly admits of being questioned, supported as it is by the testimony of men so eminent as SAUSSURE and as LIEBIG, and indeed many of the analyses detailed in this paper might be appealed to in corroboration of its truth.

Thus we find, that whilst the amount of bases agreed pretty nearly in the three crops of the same plant which had been analysed, the proportions between them often varied considerably. This is particularly seen in the case of the lime and magnesia, the deficiency in one of these earths being often made up by an excess in the other.

In like manner a deficiency of potass is found to be compensated by an increased amount of soda, and the same remark seems to apply to the acids.

Still we have not as yet sufficient data for determining to what extent this exchange of the usual ingredient for another can take place; whether indeed the same

organ, or the same proximate principle belonging to the plant, may admit at all of this change in its constitution taking place; or if it can, in what degree the presence of this new principle may affect the healthy development of the vegetable.

By turning to the Table which states the relative quantities of alkaline ingredients extracted from the different soils by water impregnated with carbonic acid, it will be seen, that in most of these the amount of soda predominated over that of potass, and yet the latter alkali was principally found in their ashes, an indication at least of some superior adaptation of potass to soda for the organization of plants*.

Again, it is remarkable, that whilst in several of the soils soda appeared to exist in the form of a carbonate (since the quantity of chlorine was so small that only a minute trace of it was discoverable in them), in many of the ashes of the plants, only as much soda was detected as would contain sodium equivalent to the chlorine present.

Hence it would seem to follow, that common salt, when it acts beneficially upon land, does not assist the crop by virtue of the alkali it imparts to it, but in some other way, and that it is still questionable, at least in the case of terrestrial species, whether plants have the power of decomposing chloride of sodium, and of separating its chlorine.

Lastly, the analyses contained in this paper may be of use at the present moment, by contributing to show, how much still remains to be done, before we can flatter ourselves at having attained any sure knowledge of the normal constitution of plants, and of the range of variation of which under natural circumstances it is susceptible. At a time when certain enlightened members of the Royal Agricultural Society have prevailed upon that great Body, to devote a portion of their funds to the prosecution of the chemical analysis of the ashes of vegetables, whatever tends to render more palpable the importance of such an investigation, may be of service, in aiding their meritorious efforts, to give a more scientific direction to the inquiries which such associations are intended to promote, and in vindicating the utility of the course which they have in this instance adopted.

Now the facts and observations detailed in the present paper contribute in two respects towards this object, viz. by showing that the composition of the most commonly cultivated plants is still open to much uncertainty; and 2ndly, by pointing out in what way an exact knowledge of their inorganic ingredients might aid us towards the solution of many important practical questions.

I hope, it will not be attributed to any blindness on my part to the deficiencies and imperfections which exist in this paper, if I remark, that an investigation of a similar kind to the one herein detailed, if carried out on a more adequate scale, undertaken on ground more carefully selected, conducted with a more vigilant attention to all the minute circumstances which might influence the result, and accompanied by a

* This is also shown very strikingly in a paper on the analysis of Fuci, read to the British Association at Cambridge, by Mr. SCHWEITZER, in June 1845.

regular series of analyses, both of the soil and of the crops, during the whole period of their continuance, would be of essential service in clearing up many points which yet remain open to investigation in agricultural science.

My Memoir may serve also as a kind of illustration of that method of Scientific Book-keeping, which I proposed some time ago, at once as an useful exercise for the agricultural student, and as a means of introducing greater precision in the conduct of our experiments on this subject, and which I am therefore happy in having this opportunity of rendering more generally known.