LI. *On the Amount of Sulphur and Phosphorus in various Agricultural Crops.* By HENRY CLIFTON SORBY, Esq.*

HAVING thought it highly probable that in the ordinary method of estimating the amount of sulphur and phosphorus in plants, viz. by burning them and analysing their ashes, there might be in many cases a loss from portions being rendered volatile by contact with combustible matter at a high temperature, I was induced to commence a series of analyses, employing a method against which there was no such objection, and, as will be seen, the quantities really present in various plants are much greater than has been hitherto anticipated. Having obtained a proper specimen, one portion of known weight was dried at 212° F. and weighed, and another in precisely the same condition was employed for the analysis, the amount which I generally used varying with the dryness of the substance from 200 grs. to 500 grs., which was cut into pieces if necessary, and introduced into a flask, and carefully heated with pure nitric acid, a little water being added if the substance was a dry one. No large quantity of the acid is required, and a gentle heat is kept up until the whole is digested down into a yellowish pulpy mass; water is then added, the whole boiled, and when cold filtered and washed, there being invariably a quantity of white fibrous substance left undissolved. To the yellowish solution thus obtained nitrate of baryta was next added, and though at first perhaps no precipitate was formed, sulphate of baryta was gradually deposited, and after standing for a day or so, the precipitate was collected on a filter, washed, dried, ignited and weighed, from which the amount of sulphur was calculated. It is well to ascertain whether it is pure sulphate of baryta, by adding to it after weighing a little hydrochloric acid, since sometimes there was present a little carbonate, which of course produces effervescence, and when that is the case, which seldom occurred to any but the most trifling extent, the amount is easily ascertained and a proper deduction made, to obtain the true weight of the sulphate alone.

To the solution filtered as above, I next added acetate of lead in moderate quantity, and then caustic ammonia in slight excess, filtered and washed the precipitate. When dry this precipitate was carefully calcined in a porcelain crucible over a lamp, at as low a temperature as convenient, stirring with a glass rod until the whole was converted into a mixture of metallic lead, oxide and phosphate of lead. These were then dissolved in nitric acid, and ammonia added until a consider-

* Communicated by the Chemical Society; having been read Dec. 7, 1846.

able precipitate of subnitrate was formed, when on adding acetic acid the whole of the phosphate alone was left insoluble, which, after standing awhile, was collected on a filter, washed, dried, ignited and weighed, and the amount of phosphorus obtained by calculation. That this method is correct, and that the phosphate which is thus obtained is $\text{Pb}_3\text{P O}_8$, I have proved by experiment.

It must be borne in mind that the amounts given below are those of sulphur and phosphorus, I having thought it right to give them as such, and not as sulphuric and phosphoric acids, since most certainly they do not exist invariably as such or as their salts in plants, and I therefore see no reason why they should not be given as elements, like the amounts of carbon, nitrogen, oxygen and hydrogen as usually given in such analyses.

The plants analysed, with only three exceptions, viz. the rye, mangel-wurzel, and hops, were obtained from the fields in which they were growing by myself, and hence I can vouch for their freedom from impurities, and have no doubt the others were as much so as possible.

Table of the Amounts of Sulphur and Phosphorus in various Agricultural Crops, calculated in 100 parts, dried at 212°F . until the weight remained constant.

Name of Plant, &c.	Sulphur.	Phosphorus.
Four species of grass (<i>Poa palustris</i> and <i>trivialis</i> , } <i>Festuca pratensis</i> , <i>Cynosurus cristatus</i>)	·165	·164
Rye grass (<i>Lolium perenne</i>)	·310	·183
Italian rye grass	·329	·145
Red clover (<i>Trifolium pratense</i>)	·107	·149
Ditto	·087	·131
Very fine white clover (<i>T. repens</i>)	·099	·183
Ordinary ditto	·151	·139
Very fine trefoil (<i>Medicago lupulina</i>)	·136	·052
Lucern (<i>M. sativa</i>)	·274	·046
Ditto	·452	·215
Ditto	·293	·353
Lints (<i>Vicia sativa</i>)	·178	·183
Kidney potatoes (<i>Solanum tuberosum</i>)	·094	·213
Ditto, tops	·389	·357
Ditto, fruit	·071	·597
American native potatoes	·082	·212
Ditto, tops	·206	·483
Carrot (<i>Daucus carota</i>)	·092	·255
Ditto, tops	·745	·382
Mangel-wurzel (<i>Beta altissima</i>)	·058	·190
Ditto, tops	·502	·293
Early yellow-top turnip (<i>Brassica rapa</i>)	·351	·352
Ditto	·421	·346
Ditto, tops	·758	·360
Ditto	·615	·380

Name of Plant, &c.	Sulphur.	Phosphorus.
Swede turnip (<i>Brassica oleracea</i>)	·435	·172
Ditto, tops	·458	·250
Rape (<i>B. oleifera</i>)	·448	·233
Drum-head cabbage (<i>B. campestris</i>)	·431	·267
Wheat plant entire (<i>Triticum vulgare</i>) when just gone out of flower	·151	·248
Ditto	·170	·140
Ear of wheat when the grain was formed, but milky...	·075	·271
Straw from the above	·240	·132
Ear of wheat when ripe	·090	·336
Straw from the above	·213	·043
Red wheat	·070	·363
Ditto, straw	·293	·079
White wheat from the same field as the above red	·054	·366
Ditto, straw	·207	·112
Wheat (another sample)	·051	·410
Ditto, chaff	·091	·252
Very fine barley (<i>Hordeum distichum</i>)	·066	·498
Ditto, straw	·390	·087
Rather poor barley	·040	·367
Ditto, straw	·191	·065
Barley plant when in flower	·313	·236
Oat plant (<i>Avena sativa</i>) when just coming into flower	·226	·194
Ditto in flower	·189	·189
Green oats	·125	·317
Straw of ditto	·329	·128
Black tartarian oats	·080	·381
Straw of ditto	·271	·110
White oats	·090	·334
Straw of ditto	·401	·153
White oats (another sample)	·074	·382
Straw of ditto	·195	·057
Rye ears (<i>Secale cereale</i>) when young	·073	·076
Straw of ditto	·099	·153
Rye	·051	·160
Bean plant (<i>Vicia faba</i>) in flower	·045	·258
Beans	·071	·600
Ditto, straw	·148	·233
Peas (<i>Pisum sativum</i>)	·158	·206
Ditto, straw	·214	·076
Fine hops (<i>Humulus lupulus</i>)	·127	·574
Bind of ditto	·091	·138

From the above analyses it will be seen how very much the amounts vary in some cases, whereas in others they are pretty constant. This variation may probably be occasioned by that of the amount of phosphates and sulphates in the soils. I have observed as a general rule, that the finer the quality of the specimen the larger the proportions of sulphur and phosphorus present; though in the case of lucern, in which the phosphorus varies as much as in any crop of which I have analysed a sufficient number of specimens to be able to give an opinion, all the samples were growing luxuriantly. It may be presumed that when the amounts vary so much,

without apparently affecting the growth of the plant, the particular constituent so varying is not of such importance for the plant as when more constant.

It will be observed that in many plants different parts require different constituents, which indeed is well known; as for instance in the case of wheat it is probable that an abundance of sulphates in the soil would produce fine straw, and of phosphates, fine grain, and the converse, other necessary constituents being present.

It may also, perhaps, be inferred from these analyses that when grain is growing and ripening the amount of phosphorus increases in greater proportion than the total weight, and diminishes in the straw, the grain abstracting that constituent from it. Similar inferences may perhaps be derived from the above, many of which are given for such purposes.

The table given below is a practical application of these analyses, being intended to show the quantities of gypsum and bone-phosphate of lime represented by the sulphur and phosphorus which are removed annually from an acre of land by the respective crops; being also that which should be added to already fertile land to maintain it in that condition. No allowance for what would be removed by drainage is made, as that is too uncertain in its quantity, and cannot in many cases be at all material, or else uncultivated natural lands would long ago have become sterile. The quantities so removed are no doubt compensated for by the disintegration of the substrata, and the superficial removal of exhausted soil by washing.

In such a calculation as this, however, it is affectation to pretend to great exactness, the elements which unavoidably enter into it being so variable. The quantities on which I have calculated are the greatest which are shown in the analyses, unless where the variations are given, when I have taken the extremes, and the weight of crop per acre is what I learn to be a medium between the very best and average crops; but I am most willing to confess that I am not myself practically acquainted with this part of my subject, and hence cannot answer for their absolute correctness, but have obtained them from the best authorities accessible to me. The necessary alterations, however, are easily made by any one for himself, from the data I have given, but I think they cannot be far wrong. The quantities are pounds of gypsum and bone-phosphate of lime removed from one acre.