

*X.—Experimental Investigations on the Value of Iron Sulphate  
as a Manure for Certain Crops.*

By A. B. GRIFFITHS, Ph.D., F.C.S. (London and Paris), Medallist in  
Chemistry and Botany, &c.

I HAVE already published some researches\* on the growth of *single* plants by the aid of iron sulphate, and having been engaged lately in certain investigations to ascertain, if possible, to what extent this mineral compound is useful as a manure when applied to field crops, I have now the honour of laying before the Chemical Society the results of my investigations on this important subject. Two plots of well-drained land in the neighbourhood of Bromsgrove, Worcestershire, were chosen. The analysis of the soil (which was collected by the Lawes and Gilbert method) gave the following results:—

	I.	II.
Silica and insoluble matter ....	80·75	80·74
Organic matter .....	4·92	4·90
Ferric oxide ( $\text{Fe}_2\text{O}_3$ ).....	3·93	3·96
Alumina ( $\text{Al}_2\text{O}_3$ ).....	2·92	2·89
Magnesia ( $\text{MgO}$ ).....	0·50	0·49
Lime carbonate ( $\text{CaCO}_3$ ).....	3·25	3·28
Lime sulphate ( $\text{CaSO}_4$ ) .....	0·26	0·27
Potash ( $\text{K}_2\text{O}$ ) and soda ( $\text{Na}_2\text{O}$ )	0·36	0·35
Phosphoric oxide ( $\text{P}_2\text{O}_5$ ) .....	0·38	0·42
Moisture .....	2·73	2·70
	100·00	100·00

One plot of land was treated with the crystallised ferrous sulphate of commerce (the quantity applied being half a hundredweight to the

\* “Researches on the Growth of Plants under Special Conditions” (*Chem. News*, **47**, 27, and *Chem. Soc. J.*, Abstracts, 1883, 496). “Chemico-Microscopical Researches on the Cell-Contents of Certain Plants” (*Chem. Soc. J.*, Trans., 1883, 195; and *The Journal of the Royal Microscopical Society*, August 1883, 536).

acre), and the other was left in its normal condition. Both plots of land are exposed to the same amount of sunshine and rainfall. On each plot of land I planted on the same day a certain number of bean seeds. These were allowed to grow until ready for gathering, when they were gathered and weighed, then allowed to dry and weighed again, with the following results:—

	Plot of land (manured with $\text{FeSO}_4$ ).		Plot of land (normal).	
	(1.) Weight when gathered.	(2.) Weight when dry.	(1.) Weight when gathered.	(2.) Weight when dry.
Total weight of crop (grain + straw).....	6783 lbs.	5882 lbs.	5210 lbs.	4487 lbs.

The plants grown by the aid of the iron manure yielded 56 bushels of grain, while the plants grown without this mineral manure yielded only 35 bushels of grain; so there is a marked difference in the weights of the produce of the two pieces of land. In fact, the iron manure has been of great benefit in aiding the growth of this plant.

A certain number of the plants grown on each plot of land were separately reduced with the greatest possible care to ashes. The plants were burnt (as described in my former paper) on a platinum sheet made in the shape of a muffle, and heated at a low temperature in a gas furnace. The ashes yielded on analysis the following results:—

(A.) *Analysis of Ash of Entire Plant.*

	Plants grown <i>with</i> iron manure.		Plants grown <i>without</i> iron manure.	
	I.	II.	I.	II.
IRON OXIDE ( $\text{Fe}_2\text{O}_3$ ) .....	4·221	4·230	1·063	1·052
Potash ( $\text{K}_2\text{O}$ ).....	18·400	18·395	20·791	20·710
Soda ( $\text{Na}_2\text{O}$ ).....	16·013	16·211	17·512	17·509
Lime ( $\text{CaO}$ ).....	6·654	6·599	7·204	7·220
Magnesia ( $\text{MgO}$ ).....	7·981	7·899	8·795	8·760
Silica ( $\text{SiO}_2$ ).....	1·946	1·953	2·773	2·721
PHOSPHORIC OXIDE ( $\text{P}_2\text{O}_5$ ) .....	41·902	41·899	37·941	37·920
Sulphuric oxide ( $\text{SO}_3$ ) .....	1·001	1·022	1·400	1·462
Sodium chloride.....	1·781	1·792	2·510	2·490
	99·959	100·000	99·989	99·844

(B.) The next table gives the analysis of the ashes of the *pois* minus the seeds:—

	Grown with iron manure.	Grown without iron manure.
IRON OXIDE ( $\text{Fe}_2\text{O}_3$ ).....	2·021	0·911
Potash ( $\text{K}_2\text{O}$ ).....	41·369	42·506
Soda ( $\text{Na}_2\text{O}$ ).....	2·900	3·604
Lime ( $\text{CaO}$ ).....	6·909	6·022
Magnesia ( $\text{MgO}$ ).....	7·103	7·400
Silica ( $\text{SiO}_2$ ).....	0·542	0·504
PHOSPHORIC OXIDE ( $\text{P}_2\text{O}_5$ ).....	36·061	34·240
Sulphuric oxide ( $\text{SO}_3$ ).....	2·652	3·615
Chlorine.....	0·433	1·191
	99·990	99·993

(C.) In this table I give the analyses of the ashes of the *seeds* from plants grown with and without the aid of the iron manure:—

	With iron manure.	Without iron manure.
IRON OXIDE ( $\text{Fe}_2\text{O}_3$ ).....	0·572	0·576
Potash ( $\text{K}_2\text{O}$ ).....	42·491	42·489
Soda ( $\text{Na}_2\text{O}$ ).....	1·361	1·370
Lime ( $\text{CaO}$ ).....	4·700	4·702
Magnesia ( $\text{MgO}$ ).....	7·101	7·099
Silica ( $\text{SiO}_2$ ).....	0·840	0·837
PHOSPHORIC OXIDE ( $\text{P}_2\text{O}_5$ ).....	38·810	38·820
Sulphuric oxide ( $\text{SO}_3$ ).....	2·512	2·520
Chlorine.....	1·613	1·586
	100·000	99·999

From these analyses (which were conducted with the greatest possible care) it will be seen—

1st. That by manuring the land with half a hundredweight of ferrous sulphate to the acre, the harvest was increased. The land which was manured yielded an increase of 1573 lbs. in the total weight of the crop when gathered; 1395 lbs. when dry (straw); and an increase of 21 bushels of grain over the crops grown without the iron manure.

2nd. When the ashes of the entire bean plants are submitted to analysis, it is found that the plants grown with an iron manure contain a much larger percentage of ferric oxide in their ash than the plants grown without an iron manure; and looking at Tables A and B, it is seen that the phosphoric oxide in the ashes increases as

the ferric oxide increases. Thus it will be seen that the composition of the ash of the bean plant is greatly influenced by the manure applied to the soil; but in Table C, which is the result of analyses of the seeds produced by plants grown with an iron manure, and seeds produced by plants grown in a soil without any added iron manure, the feature to be noticed is that the percentage numbers agree most closely in each case; thus giving additional support to the general law that the composition of the ash of the seed or embryo is very constant. From these experimental researches, I think I am safe in saying that for *certain* plants an iron manure in the form of a soluble sulphate is beneficial to their growth.

There is a precaution in the use of ferrous sulphate as a manure I may mention in passing. Last summer an entire crop of young cabbage-plants was almost killed by having the land manured with farmyard manure along with ferrous sulphate. I investigated the matter with the following results: that the carbonaceous matters of the farmyard manure reduced the sulphate to sulphide of iron; and acids acted upon this sulphide liberating sulphuretted hydrogen, which was the cause of the mischief to the little crop.

#### APPENDIX.

##### *Observations on the Influence of Certain Rays of the Spectrum on the Growth of Plants growing in an Iron Manure.*

In seven small flower-pots, each filled with the same kind of soil, treated with a known weight of iron sulphate, I sowed some mustard seeds. When the little plants had made their appearance above the soil, I exposed them for some hours each day to the coloured lights of the spectrum. No. 1 was exposed to the red part of the spectrum, No. 2 to the orange, and so on; after so many hours' exposure, they were removed to a dark place. This operation was performed for several weeks, each pot being exposed to its own part of the spectrum daily, until the plants had grown to a considerable size. The plants in each pot were then reduced to ashes and submitted to analysis, the following percentage of ferric oxide being found:—

						Per cent. $\text{Fe}_2\text{O}_3$ in ash.
Pot No. 1		exposed to red part of spectrum			gave	.... 0.92
2	orange					.... 1.43
3	yellow					.... 2.51
4	green					.... 1.90
5	blue					.... 0.71
6	indigo					.... 0.20
7	violet					.... 0.15

The same number of seeds were placed in each flower-pot, and the plants, as they grew, were watered from time to time with a weak solution of ferrous sulphate (always of the same strength).

These experiments therefore show that the most active rays for absorption coincide with those of assimilation, and at the same time prove that the iron acts to a certain extent as a food for the chlorophyll granules, these being the active agents for the process of assimilation; and from the researches of Drs. Draper and Pfeffer and those of Cloez and Gratiolet, it is evident that the most favourable rays of white light are those lying between the yellow and green; for in their experiments the greatest amount of oxygen was evolved in this part; and therefore the largest amount of carbon is retained by this process of assimilation when the plants are exposed to this part of the spectrum. I think my researches as above described confirm their conclusions in another way; for I get the largest amount of  $\text{Fe}_2\text{O}_3$  in the ashes of the plants exposed to the yellow or yellow-green part of the spectrum, or between Fraunhofer's lines D and E. From the above it will be seen that the rays near the least refrangible part of the spectrum are the most active in aiding the growth of plants; that there is a connection between chlorophyll and iron; and that if the iron be given within certain limits to a plant, it acts as a food of great value, most probably nourishing the chlorophyll granule; for I have found monoclinic crystals (as shown in my paper read before the Chemical Society on March 1st last) of ferrous sulphate near to the chlorophyll granules.

---