

XIII.—*On the Use of Ferrous Sulphate in Agriculture.*

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IN continuation of my experiments on the use of ferrous sulphate as a manure, I have this year observed its effect on wheat crops with the following results :—

*Conditions of Growth of the Crops.*

- I. Two plots of land (exposed to the same rainfall and sunshine) were chosen, both plots being well-drained land.
- II. The soils were of the same chemical and mechanical composition.
- III. One of the plots was manured with  $\frac{1}{2}$  cwt. of ordinary commercial iron sulphate to the acre.
- IV. Each plot of land was of the same size, and the same quantity of seed was applied to each. The quality of the seed was the same, being the produce of my last year's crop.

At the end of the season, the following weights were obtained:—

*Wheat Crop.*

	Plot of land manured <i>with</i> iron sulphate.		Plot of land, normal ( <i>i.e.</i> , <i>without</i> iron sulphate).	
	(1.) Weight when gathered.	(2.) Weight when dry.	(1.) Weight when gathered.	(2.) Weight when dry.
Total weight of crop (grain + straw)...	6425 lbs.	5304 lbs.	6460 lbs.	5316 lbs.

The crop of wheat grown by the aid of iron sulphate yielded  $32\frac{1}{2}$  bushels of grain; and the crop grown *without* iron sulphate yielded 30 bushels of grain. From the above results (although there is an increase of  $2\frac{1}{2}$  bushels of grain produced by the crop on the iron-manured land), I am rather inclined to the opinion I gave in a former paper (*Chem. Soc. J.*, Trans., 1885, 46--55) that an iron manure is *not* as valuable as a plant-food for cereals as for root and leguminous crops.

On submitting the ashes of the plants from each plot of land to careful analysis, I obtained results which do not differ materially from those of last year.

Table I is an analysis of the ash of the entire wheat plants—

TABLE I.—*The Entire Wheat Plants.*

	Grown with iron manure.	Grown without iron manure.
<i>Iron oxide</i> , $\text{Fe}_2\text{O}_3$ .....	2·60	2·19
Potash, $\text{K}_2\text{O}$ .....	12·12	11·67
Soda, $\text{Na}_2\text{O}$ .....	2·22	2·59
Lime, $\text{CaO}$ .....	3·53	3·60
Magnesia, $\text{MgO}$ .....	5·51	5·53
Silica, $\text{SiO}_2$ .....	64·90	64·99
<i>Phosphoric oxide</i> , $\text{P}_2\text{O}_5$ .....	4·59	4·49
Sulphuric oxide, $\text{SO}_3$ .....	4·02	4·05
Chlorine .....	0·50	0·89
	99·99	100·00

The ash of the leaves gave the following percentage of ferric oxide :—

TABLE II.—*The Leaves of the Wheat Plants.*

	Grown with iron manure.	Grown without iron manure.
<i>Iron oxide</i> , $\text{Fe}_2\text{O}_3$ .....	3·92	1·54

From the above analysis the percentage of iron oxide in the plants grown with iron sulphate was about half a per cent. over those grown on the normal plot of land. The percentage of ferric oxide in the leaves of the crops is larger in those grown on the iron-manure land by  $2\frac{1}{4}$  per cent.

Besides my own experiments on cereal crops, Mr. George W. Edgson, of Etton, near Peterborough (an agriculturist of great experience), has applied iron sulphate to several acres of wheat-crops this year (1885). He tells me that this wheat-crop was better than any he has had for very many years, and he "*never saw such clean straw*" in his life, being perfectly free from wheat mildew.

I had the pleasure of seeing these crops last summer, and may remark that they looked the healthiest and finest in the neighbourhood. I have made analyses of the ashes from Mr. Edgson's wheat-crops grown with iron sulphate. The following is the percentage of ferric and phosphoric oxides contained in the ashes :—

TABLE III.—*The Entire Plant* (Mr. Edgson's Crop).

<i>Iron oxide, Fe<sub>2</sub>O<sub>3</sub> .....</i>	3·45
<i>Phosphoric oxide, P<sub>2</sub>O<sub>5</sub> .....</i>	5·88

TABLE IV.—*The Ash of the Leaves.*

<i>Iron oxide, Fe<sub>2</sub>O<sub>3</sub> .....</i>	3·99
<i>Phosphoric oxide, P<sub>2</sub>O<sub>5</sub> .....</i>	4·97

From the above analyses, it is evident that there is a greater *increase* of ferric oxide than is normally found in the ashes of wheat-crops, and the phosphoric oxide is also increased. It appears that in this case the iron manure has been beneficial—increasing the growth and yield of the wheat-crop. Yet, as far as my own experiments with cereal crops go, I have seen no remarkable increase due to an iron manure. These facts evidently show that some soils are deficient in iron, or, to use the words of M. Ville,\* “it may be that more efficacious compounds of iron and manganese exist than those which the soil contains naturally, and whose presence in manures would be followed by an increased yield.”

#### *Grass Land.*

Mr. Edgson has also used iron sulphate to grass land. A large plot of grass land of his was “infested” with the ordinary moss, and was extremely poor in quality and quantity. After having applied a top-dressing of iron sulphate to this land, the grass turned black after the first rainfall, but in a fortnight became a bright-green colour, and perfectly healthy, and the moss was destroyed. The grass grew well throughout the summer. The bright-green appearance never altered in the least, although the summer was rather a dry one, and other plots of grass land which had received occasional dressings of nitrate of soda were “parched up,” more or less, for want of rain.

I have submitted the ashes of the grasses and mosses to analysis, with the following results:—

\* “On Artificial Manures,” Mr. Crookes' Translation, 2nd Edition, p. 39.

TABLE V.—*Ash of Mosses.*

	Ash of plants <i>before</i> addition of $\text{FeSO}_4$ to the land.	Ash of plants <i>after</i> addition of $\text{FeSO}_4$ to the land.
<i>Iron oxide</i> , $\text{Fe}_2\text{O}_3$ .....	6·62	11·56
<i>Alumina</i> , $\text{Al}_2\text{O}_3$ .....	10·79	10·25
<i>Potash</i> , $\text{K}_2\text{O}$ .....	2·48	3·24
<i>Soda</i> , $\text{Na}_2\text{O}$ .....	3·40	2·10
<i>Lime</i> , $\text{CaO}$ .....	11·28	10·89
<i>Magnesia</i> , $\text{MgO}$ .....	3·23	3·62
<i>Silica</i> , $\text{SiO}_2$ .....	45·10	41·59
<i>Phosphoric oxide</i> , $\text{P}_2\text{O}_5$ .....	3·73	4·03
<i>Sulphuric oxide</i> , $\text{SO}_3$ .....	12·74	11·97
<i>Chlorine</i> .....	0·61	0·74
	99·98	99·99

TABLE VI.—*Ash of Grasses.*

	Grass from land <i>not</i> manured with iron sulphate.	Grass from land manured <i>with</i> iron sulphate.
<i>Iron oxide</i> , $\text{Fe}_2\text{O}_3$ .....	0·45	2·46
<i>Potash</i> , $\text{K}_2\text{O}$ .....	24·92	23·12
<i>Soda</i> , $\text{Na}_2\text{O}$ .....	6·21	6·10
<i>Lime</i> , $\text{CaO}$ .....	15·00	14·26
<i>Magnesia</i> , $\text{MgO}$ .....	5·46	4·98
<i>Silica</i> , $\text{SiO}_2$ .....	29·06	29·61
<i>Phosphoric oxide</i> , $\text{P}_2\text{O}_5$ .....	5·52	7·21
<i>Sulphuric oxide</i> , $\text{SO}_3$ .....	8·46	7·43
<i>Chlorine</i> .....	4·92	4·82
	100·00	99·99

It will be seen from the above analyses (Table VI) that grass manured with iron sulphate gives larger amounts of ferric and phosphoric oxides in the ash than the grass before the addition of iron sulphate—hence the healthy appearance (during a rather dry summer) may be due to this circumstance; an iron manure being beneficial for the growth of grass. The analysis of the ashes of the *moss-plants*, after the addition of iron sulphate, shows that the percentage of ferric oxide is 11·56. In a former paper (*Chem. News*, 50, 193, "Physiological Experiments with Iron Sulphate on Plants"), I found that all the plants I had examined died when they had absorbed iron salts to the extent of yielding 10 *per cent.* of ferric oxide after incineration. Hence the reason the mosses were destroyed (by the iron

sulphate), being plants naturally requiring a large amount of moisture.

*Antiseptic Properties of Iron Sulphate and its Action on Vegetable Parasites.*

I have already published a paper on the antiseptic properties of iron sulphate (*Chem. News*, **49**, 279; also *Chem. Soc. J.*, Abstr., 1884, 1070) in connection with micro-organisms and the *Peronospora infestans* (potato disease). An aqueous solution containing as little as 0.1 gram of iron sulphate in 100 grams of water has the power of destroying the *Peronospora infestans*. After a careful microscopical study, I have found that iron sulphate attacks the cellulose walls of the hyphæ of peronospora, perforating them. That is, it may act chemically upon the cellulose—or the form of cellulose making up the external walls of this lowly organism.

I have also made a careful microscopical study of the action of iron sulphate on “wheat-mildew” in both stages of its life-history. First with the red spores (“rust”) of the barberry fungus, which produce hyphæ in the cells of the stem or leaf of a wheat-plant or similar cereals; and also with the two-celled spores of the wheat-mildew which germinate on the leaf of the barberry.

On placing the spores of “rust” and also the two-celled spores of wheat-mildew on slides under the microscope, mounted in a drop of water, then running in between the cover-slips the above solution of iron sulphate, the spores are completely destroyed. Not only the spores, but the hyphæ which they give rise to, are also destroyed by the same solution. Hence from this experiment it will be seen that iron sulphate is a useful agent, besides being a direct plant-food, for it has a remarkable action on parasitic life.

Turning to the more practical side of this investigation, I should recommend the use of a weak solution of iron sulphate to water ordinary farmyard manure before it is applied to the land; for farmyard manure may contain spores from the wheat-straw forming the litter in the farmyard. These and other spores hibernate until the spring (farmyard manure being a medium that rather favours this dormant state than otherwise), and are then ready to live their life-history again.

*Potato Crops.*

This year I have grown potato crops with iron sulphate along *with* other artificial manures, so as to make a comparison between potato crops growing with the ordinary artificial manures used for potatoes *with* and *without* the addition of iron sulphate. Three plots of well-drained land were chosen, and the soil was of good quality. All were exposed to the same climatic influences (*i.e.*, rainfall and sunshine).

The first plot of land (A) was left normal—not treated with any manure. The second plot of land (B) was manured with—

$$\begin{cases} 1 \text{ cwt. kainite,} \\ 1 \text{ cwt. nitrate soda,} \\ \frac{1}{2} \text{ cwt. iron sulphate,} \\ 2 \text{ cwt. superphosphate of lime,} \end{cases}$$

per acre. The third plot (C) was manured with the above constituents (per acre) *minus* the  $\frac{1}{2}$  cwt. of iron sulphate.

At the end of the season the following were the results obtained (7 cwt. of tubers were sown on each plot of land) :—

TABLE VII.—*Potato Crops.*

	A.	B.	C.
Tubers .....	6720 lbs.	19040 lbs.	14023 lbs.
Haulm .....	2125 „	6231 „	4917 „
Total weight of crop.	8845 lbs.	25271 lbs.	18940 lbs.

From the above, the crop grown with the addition of iron sulphate to the ordinary artificial manure, yielded  $8\frac{1}{2}$  tons of potatoes (tubers). The crop grown with the artificial manure *without* iron sulphate yielded only  $6\frac{1}{2}$  tons of tubers, while the normal plot of land only gave 3 tons. Hence an iron manure is beneficial for the growth of potato crops—largely increasing the yield and also, I may say in passing, the quality.

I have submitted the ashes of the potato crops to analysis, with the following results :—

TABLE VIII.—*Ash of Potato Tubers.*

	A. Normal plot.	B. Grown on plot manured with FeSO <sub>4</sub> and artificial manure.	C. Grown on plot with <i>only</i> artificial manure.
Iron oxide, Fe <sub>2</sub> O <sub>3</sub> .....	5·15	7·00	5·42
Potash, K <sub>2</sub> O .....	53·80	52·91	53·69
Soda, Na <sub>2</sub> O .....	0·71	1·09	1·20
Lime, CaO .....	3·02	3·14	3·19
Magnesia, MgO .....	7·94	7·25	7·23
Silica, SiO <sub>2</sub> .....	5·00	5·21	5·21
Phosphoric oxide, P <sub>2</sub> O <sub>5</sub> ..	15·63	17·94	16·24
Sulphuric oxide, SO <sub>3</sub> ....	5·21	3·34	4·00
Chlorine .....	3·50	2·12	3·81
	99·96	100·00	99·99

TABLE IX.—*Ash of Potato (Haulm).*

	A. Normal plot.	B. Grown on plot manured with $\text{FeSO}_4$ and artificial manure.	C. Grown on plot with <i>only</i> artificial manure.
<i>Iron oxide, <math>\text{Fe}_2\text{O}_3</math> .....</i>	1·10	4·23	1·56
<i>Potash, <math>\text{K}_2\text{O}</math> .....</i>	28·99	27·86	29·02
<i>Soda, <math>\text{Na}_2\text{O}</math> .....</i>	15·52	12·10	14·34
<i>Lime, <math>\text{CaO}</math> .....</i>	17·07	14·92	16·42
<i>Magnesia, <math>\text{MgO}</math> .....</i>	7·90	7·63	7·84
<i>Silica, <math>\text{SiO}_2</math> .....</i>	3·64	4·81	3·59
<i>Phosphoric oxide, <math>\text{P}_2\text{O}_5</math>...</i>	7·84	9·92	8·32
<i>Sulphuric oxide, <math>\text{SO}_3</math>.....</i>	5·64	5·90	5·97
<i>Chlorine .....</i>	12·30	12·62	12·92
	100·00	99·99	99·98

It will be seen from the analyses of the ashes of the plants that the ferric oxide is increased in the ashes of the crops grown with an iron manure, and also the phosphoric oxide increases as the iron increases. The potato crop grown with the artificial manure, plus  $\frac{1}{2}$  cwt. of iron sulphate, gave a much larger yield of produce than either of the other two crops.

*Retentive Properties of Iron Sulphate for Ammonia and Phosphoric Acid.*

From my previous papers on this subject, and also the present one, it will be observed that all those crops grown with iron sulphate gave an increase of phosphoric acid,  $\text{P}_2\text{O}_5$ , in their ashes over those not so manured. Therefore I am inclined to think, from these practical results, that iron sulphate (or the iron manure) has a retentive property for phosphoric acid contained in soils. Ferrous sulphate has also a retentive property for ammonia contained in soils. This I have proved experimentally, for by preparing a thick layer of soil (placed in a wide glass tube about one yard long) containing iron sulphate, and then allowing a solution of ammonium sulphate to percolate through this layer, a large amount was absorbed—the liquid which came through the soil containing much less ammonium sulphate than the amount in the original solution. Again, when the same quantity of soil (*minus* the iron sulphate) was treated exactly in the same way, a much larger amount of ammonium sulphate was found in the percolated liquor.



*Duration of Iron Sulphate in the Soil.*

It was at the suggestion of Mr. Bischof, F.I.C., that I should ascertain how long after manuring a soil with ferrous sulphate any ferrous sulphate can be detected in the soil. I have found that after manuring a soil with ferrous sulphate it could be distinctly detected in the soil after the lapse of six weeks.

*Method of Applying Iron Sulphate to the Land.*

The question "Which is the best way to apply iron sulphate to the land?" has been repeatedly asked by numerous inquirers.

I. I have found it *best* to apply the iron sulphate as a top-dressing to the land after the crops have appeared above the ground. The sulphate is capable of withstanding (during a comparatively *dry* season) beyond a mere superficial oxidation, for some weeks on the surface of the soil—it being gradually dissolved and passing into the soil.

II. The amount of iron sulphate I have used in all my experiments is  $\frac{1}{2}$  cwt. to the acre.

Sir John B. Lawes, F.R.S., kindly writes me, that he has found that  $1\frac{1}{2}$  cwt. of iron sulphate per acre "was rather too much, although it did not kill the plants."

*Experiments with Iron Sulphate on Rose-trees.*

Last spring I treated several young rose-trees (climbing, about 2 feet in height from the soil) with iron sulphate. By the end of July they had attained the height of 16 to 20 feet—increasing almost in the same proportion laterally. The rose-trees produced numerous roses of the most perfect form and colour. All new buds produced by these trees resisted the attack of the "green fly." In former years young rose-trees on the same land grew very slowly—some never flowering at all. From these experiments, and also others performed by several friends, I am able to say that iron sulphate is a good manure for rose-trees.

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