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Yields of the Field Experiments 1898

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Leguminous Crops

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EXPERIMENTS ON THE GROWTH OF LEGUMINOUS CROPS.

I.—Beans, Peas, and Tares—Geescroft Field.

Experiments on the growth of Leguminous corn-crops (beans, peas, and tares), with different descriptions of manure, were commenced in 1847, about nine acres being devoted to the purpose.

Experiments with Beans were continued without a break, for thirteen consecutive seasons, to 1859 inclusive; but, during the later years, the crop fell off very much, and the land became very foul.

In 1860 the land was fallowed.

In 1861 a crop of wheat, without manure, was taken.

In 1862 beans were again sown, but with some variation in the manuring.

In 1863 the land was fallowed.

In 1864, 5, 6, 7, 8, and 9, beans were grown, with much the same manures on the same plots, each year, as in 1862.

In the winter of 1869-70, 5000 lbs. of fresh burnt lime were applied per acre, over all the plots.

In 1870 beans were grown with the same manures on the respective plots as in 1864-69.

In October 1870 winter beans were sown (without manure), but the plants were to so great an extent destroyed by the severe weather which followed, that, in April 1871, the crop was ploughed up, and the land left fallow.

During the winter and early spring of 1871-2, the land was so wet that it could not be prepared in time for sowing. It was therefore left fallow for 1872; at the end of May it was subsoiled to a depth of about 12 inches, and re-ploughed in July.

The winter and early spring of 1872–3 were also so extremely wet, that it was again impossible to prepare the land in time for sowing; it was, however, ploughed up towards the end of March, again left fallow, and re-ploughed in July and October (1873).

On February 2, 1874, the land was again set with Beans, but without manure.

In 1875 Beans were re-sown, with the same manures on the respective plots as in 1864-1870; but owing to the wetness of the land in the first instance, and the subsequent hindrance by other spring sowing, they were not put in until April 1 and 2.

The wetness of the winter 1875-6, again prevented the preparation of the land in due time; and, though the manures were sown, and the land ploughed, it was left fallow during the summer of 1876.

Early in October 1876, winter Beans were put in (drilled), without further manuring.

In 1878 the usual manures were sown, and beans were drilled on February 26.

Owing to the wetness of the winter, and the foul condition of the land, it was left fallow in 1879.

Owing to the continued wetness in the autumn, the severe winter, and foulness of the land, it could not be got into order for sowing, and remained fallow in 1880.

During 1880 the land was ploughed, scarified, and partially cleaned, but owing to the wetness of the autumn, and the wetness and severity of the winter, it was again impossible to work it in time for sowing.

In the months of May and June 1881, the land was ploughed, scuffled, and harrowed, and again on July 9–12; since this time, however, the experiments with beans have been finally abandoned.

On February 1–4, 1882, the land was ploughed and cleaned, and on September 6–7 was harrowed, rolled, and sown with grass-seeds. These germinated satisfactorily, but owing probably to the extreme wetness of the succeeding winter months, the plant almost entirely died off.

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Experiments on the Growth of Leguminous Crops—*continued.*

In April 1883, samples of soil were taken from many of the plots, generally to a depth of 27 inches, but in selected cases to a depth of 72 inches from the surface, and at that time very few grass plants could be seen. After the soil sampling, the whole field was scuffle-harrowed, and sown with Barley and Clover. In order to test the condition of the soil of the different plots of the continuous Bean and the alternate Wheat and Bean land, they were left unmanured; the remaining portion of the field, not recently under exact experiment, receiving 2 cwts. Nitrate Soda, and 2 cwts. Superphosphate per acre.

Notwithstanding the repeated failure of the Beans, though on the other hand the land had practically been fallow since 1878, the Clover came up very well, grew very rapidly, and on many of the plots to a great extent smothered the Barley; so that at harvest (1883) there was a very unusual proportion of Clover in the crop. The Clover plant remained strong through the mild winter, and gave heavy crops in June, and in August 1884; the two crops in many cases approaching, and in some exceeding, 4 tons of hay per acre. In 1885, a good plant remained on most of the plots, yielding a cutting on June 23, which in several cases approached, and in one exceeded, 2 tons of hay per acre. In fact, from several of the plots of this bean-exhausted land, the nitrogen in the surface soil of which had been much reduced, and was very low, more than 6 tons of clover-hay per acre, containing more than 300 lbs. of nitrogen, have been taken. It may be added, that the total yield has been greater on some of the previously continuous bean-plots than on those which had grown beans and wheat alternately. (See below.) After the cutting in 1885, the greater part of the land was thrown into the park for permanent grass; only the previously continuous bean-plots being still reserved for future experiment.

The general result of the experiments with Beans has been that mineral constituents used as manure (more particularly potash), increased the produce very much during the early years; and, to a certain extent, afterwards, whenever the season was favourable for the crop. Ammonium-salts, on the other hand, produced very little effect; notwithstanding that a Leguminous crop contains two, three, or more times as much nitrogen as a Cereal one grown under similar conditions as to soil, &c. Nitrate of soda has, however, produced more marked effects. But when the same description of Leguminous crop is grown too frequently on the same land it seems to be peculiarly subject to disease, which no conditions of manuring that we have hitherto tried seem to obviate.

Experiments with Peas were soon abandoned, owing to the difficulty of keeping the land free from weeds, and an alternation of Beans and Wheat was substituted; the Beans being manured much as in the experiments with the same crop grown continuously as above described. But the wetness of the winter of 1871–72 prevented the sowing of the Beans for the season of 1872; and again the wetness of the autumn and winter of 1872-3 prevented the sowing of the wheat until April 4, 1873, when Nursery wheat was put in, which, however, did not come to maturity, but was cut in the middle of September, yielding about 27 cwts. of gross produce per acre, containing too little corn to be worth thrashing. The land was ploughed in October 1873, and sown with beans February 3, 1874. On October 23, 1874, wheat was sown without manure. Beans should have been sown in 1876; indeed, the manures were sown, but, for the reason stated above, the land was left fallow; and wheat was put in October 24 (1876). In 1878 Beans were drilled, on February 26, with the usual manures. Owing to the wetness of the winter, and the condition of the land, it was left fallow in 1879; and it continued so up to September, 1882 when it was sown with grass-seeds; since which time it has been treated exactly as the continuous Bean Land. (See the bottom of the preceding page, and the top of this.)

In alternating Wheat with Beans, the remarkable result was obtained, that nearly as much wheat, and nearly as much nitrogen, were yielded in eight crops of wheat in alternation with the highly nitrogenous beans, as in sixteen crops of wheat grown consecutively without manure in another field, and also nearly as much as were obtained in a third field in eight crops alternated with bare fallow.

Experiments with Tares, like those with Peas, were soon abandoned, and for the same reasons. Beans were at first substituted, with some variation in the description of the manures employed; but this experiment also had to be abandoned.

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Experiments on the Growth of Leguminous Crops—*continued.*

II.—Red Clover (*Trifolium pratense*).

1. *Experiments on ordinary arable land.*—Hoos Field.

Experiments on the growth of Clover, on ordinary arable land, with many different descriptions of manure, were commenced in 1848–9, and, with the occasional interposition of a corn-crop, or fallow, were continued up to 1877, inclusive.

As with other *Leguminous* crops, the result was, that mineral constituents applied as manure (particularly potash) considerably increased the crops in the early years. Ammonium-salts had little or no beneficial effect, and were sometimes injurious. It may be added, that the beneficial effects of long previous applications of potash have been apparent whenever there was any growth at all. To go a little more into detail:—

In the first year, 1849, the crops were throughout very heavy; especially with mineral, and without nitrogenous manure.

In autumn 1849, wheat was sown, and in spring 1850, Red Clover. In 1851 small cuttings were taken; and in 1852, though the crops were not heavy, there was by no means a failure.

Since that time, however, all attempts to grow clover year after year on this ordinary arable land have failed to give anything like a full crop, or even a plant which would stand the usual time on the ground.

Small cuttings were obtained in the autumns of 1855 and 1859, from seed sown in the spring of those years; and small but rather heavier cuttings in June and August 1865, from seed sown in 1864.

In April 1868, a portion only of the land was sown with Clover, and the plant for the most part died off in the winter.

In April 1869, the same portion was re-sown, and gave a small cutting in September of that year; but the plant again died off in the winter.

In April 1870, Clover was sown over the whole of the experimental land, this time in conjunction with Barley; but on those portions which had also been sown in 1868 and 1869 the plant again died off during the winter and early spring; whilst from those which had not been sown in 1868 and 1869 two small cuttings were taken in 1871.

In the spring of 1872, the plant being then almost entirely gone, the land was ploughed up. It was again ploughed in July 1872, and in March 1873; the intention being to sow some other Leguminous crop; but owing to the wetness and lateness of the season this was not done, the land was again left fallow, and re-ploughed in the beginning of June and the end of July (1873).

On May 4, 1874, the land was again ploughed, and sown with Red Clover seed, May 5, without manure. The plant came up well, and was very forward in September, when the flowering stems were cut down, but left on the land. During the winter and early spring the plant on those portions from which cuttings had been taken in 1871 almost entirely failed, and the land was ploughed up in May, and again in August (1875); whilst on those from which none had been taken since 1869 a fair plant remained, and two small cuttings were obtained, namely on June 23, and on August 9 and 12 (1875). On September 22, this portion of the land was ploughed up.

In May (1876), the whole was re-ploughed, and again in July and September, and left fallow.

In May 1877, Barley and Clover were sown over the whole of the experimental land, without further manuring, but the clover plant completely died off during the winter.

On two occasions (1851 and 1854), heavy dressings of Farmyard dung were applied to some of the plots; and in 1854 some received a dressing of 20 tons of dung, and 5000 lbs. of lime, per acre.

On some portions of the land Clover was sown 12 times during the 30 years, 1848–1877, and more frequently alone than with a corn-crop. In 8 out of the last 10 trials the plant died off in the winter and spring succeeding the sowing of the seed; in 4 of these without giving any crop at all, and in the other 4, only very small cuttings.

In 1878, the land was devoted to experiments with *various Leguminous plants*, differently manured, and these experiments are still in progress (1898); for further particulars see pp. 46–7.

In reference to these field experiments on clover, it may be added that, in 1864, a portion of the land was trenched 2 feet deep, and one-third of the manure was mixed with the layer of soil from 24 to 16 inches, one-third from 16 to 8 inches, and the remainder from 8 inches

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upwards. Owing to the characters of the season, the mechanical condition of the land was at first very unfavourable after this treatment; but, although many years have now elapsed, and the excess of constituents supplied was in some cases considerable, the plant has died off as completely on these plots as elsewhere.

In the winter of 1867-8, a number of small beds, each 3 yards × 2, were arranged on the previously unmanured plot of the experimental land. These were dug, some to the depth of 9 inches, some to the depth of 18, some to the depth of 27, and some to the depth of 36 inches, and sown to the respective depths with different mixtures; supplying in some cases very large amounts of potash, soda, lime, magnesia, phosphoric acid, sulphuric acid, nitrate of soda, &c.

From three similar sized beds, the soil was removed to the depths of 9, 18, and 27 inches respectively, and replaced by soil taken at the same depths from a garden border, on an adjoining portion of which Clover had been grown successfully since 1854 (see pp. 42–4).

In April 1868, clover was sown on the whole of these small beds (as well as on some other portions of the experimental land); but the plant for the most part died off during the following winter.

In April 1869, the small beds (and the other portions as in 1868) were re-sown, small quantities of clover were cut in September of that year, but the plant again died off in the winter.

In April 1870, Clover was again sown on the small beds in conjunction with barley (as on all the rest of the experimental land), but the plant again died in the winter.

In the spring of 1871, the small beds were again re-sown, and the three with garden-soil were entirely enclosed, both around and above, by galvanised wire netting. Small cuttings were taken from these small beds in July 1872; and (excepting from the beds of garden-soil, which had yielded considerably more than the others in 1872), larger cuttings were taken in July 1873. The produce was the largest where potash and nitrate of soda were employed, and where they were applied in the largest quantity, and to the greatest depths.

In April 1874, there was still some healthy plant on all the beds, but it was considered to be too irregular to preserve. It was, therefore, dug in. The artificially-manured beds were re-manured as before, but only to the depth of 9 inches, and seed was sown on May 4th, July 6th, and October 22nd; each time the plant coming up well, but subsequently dying off. On the three beds of garden-soil, the plant from the first sowing (May 4), for the most part stood; requiring only to be made good here and there on July 6; and in September small cuttings were taken.

More small beds were arranged in the spring of 1874; on these the manures were dug in, at the various depths, on May 11th to 14th, and the seed sown on May 16th. At this time, the wire netting was removed from above the three beds of garden-soil, but the whole series of small beds was now surrounded with netting, to keep out ground game. One series of the new plots received sulphate of potash only, another nitrate of soda only, and a third the two together. The plants came up fairly well, but there were some blanks in the rows, which were re-sown on October 22 (1874). A cutting was taken on June 22 and 23 (1875) from these new beds; the blanks in the rows were re-sown on July 24; a second cutting was taken on August 17; and the blanks were again re-sown on September 22 (1875). The plant was the most even on the beds with sulphate of potash, less so on those with nitrate of soda, and less still on those with both together. The amount of produce was also greater with each of the manures used separately, than with the mixture of the two.

In May 1875, the plant was entirely gone on the old artificially-manured beds, which were then dug up, and prepared for re-sowing. On the three beds of garden-soil, though the rows were imperfect, some healthy plants still remained, and gave a small cutting on June 22. On July 24 these beds were dug up; and they, as well as the artificially manured ones just referred to, were re-sown with seed. All came up well, but in May (1876), the plants on the beds of garden-soil were entirely gone, and those on the artificially manured ones nearly so, but they yielded small cuttings on July 17 (1876).

The plants on the new artificially manured beds, like those on the older ones, showed failure in the spring of 1876; but also, like them, gave small cuttings in July. All the small beds were dug up in August (1876); the artificially manured ones re-manured as in 1874, the manures dug in to a depth of 9 inches, and seed was sown on September 1, which came up, but the plants died off on all the plots in the winter of 1876–7.

In May 1877, all the small beds were dug up, and sown with Barley and Clover. To try the effects of shelter, the Barley stubble was left unusually high, but the young clover plants completely died off during the winter (1877–8).

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EXPERIMENTS ON THE GROWTH OF LEGUMINOUS CROPS—*continued.*

In the spring of 1878, the beds were dug up, and cleaned; and they were re-sown with Clover, without further manuring, on June 12 and 13. All came up well, but the plant was almost entirely destroyed by "Fly."

In May 1879, there remained about a quarter of a plant on the plot with the largest amount of mineral manure, including potash, and sown to the greatest depth, and perhaps a third of a plant where the same mineral manures, with nitrate of soda in addition, had been applied; but there was scarcely a single plant on any of the other plots. On June 9 and 10, 1879, all the beds were cleaned, and re-sown with seed, which came up well; but a very wet and cold season following, most of the plants died off during the summer and autumn.

Early in June 1880, all the small beds were cleaned, and forked up; and on June 10, they were re-sown with seed without further manure. All came up well, but the plants were for the most part destroyed by the severe winter which followed. In May 1881, there was perhaps half a plant on two or three only out of the forty small beds; namely, where the mixed mineral manure, including potash, was used without nitrogenous manure; and the greatest vigour was where the manure was applied in the largest quantity, and to the greatest depths. On no other beds, not even on the three made up of garden-soil, was there nearly as much plant; and on May 12 (1881), all the small beds were cleaned, the clover plants forked in, manures also forked in, as in 1876, to a depth of 8 or 9 inches, and clover seed sown, which came up well, but in most cases became very thin during the winter and spring of 1881–82. A small cutting was, however, taken on June 20, and another on August 18, 1882.

In May 1883, the beds were dug up, and sown with *Lucerne* without further manuring, but it gave no crop in that year. On April 3, 1884, the usual Nitrate Plots received Nitrate of Soda at the rate of 1000 lbs. per acre as a top-dressing. From all the plots, three cuttings were taken, viz. on June 27, August 16, and October 7. On March 9, 1885, the Nitrate plots received Nitrate of Soda at the rate of 500 lbs. per acre as a top-dressing; and three cuttings were taken, viz. on June 3, July 22, and October 10. In 1886 three cuttings were taken from all the plots, viz. on June 28, August 11, and December 3; and after the first cutting the usual Nitrate Plots received, on July 13, Nitrate Soda at the rate of 1000 lbs. per acre as a top-dressing. In 1887, three cuttings were taken, viz. on July 2, Aug. 15, and Oct. 12; and in 1888 two cuttings, viz. on July 6 and Sept. 26. In 1889 the usual Nitrate Plots received a solution of Nitrate of Lime, at the rate of 1490 lbs. per acre (= 86 lbs. of Nitrogen per acre); and two cuttings were taken from all the plots, one on July 5, and the other on August 31. In 1890, the plants on the garden-soil plots had almost entirely died off, and these beds were therefore dug up and re-sown with Lucerne on May 2; two cuttings were taken from each of the other plots, on July 5 and Sept. 2; and one cutting from the garden-soil plots on Sept. 2. In 1891, two cuttings were taken, viz. on July 8 and Sept. 15; in 1892, two cuttings, on June 27 and Aug. 30. In 1893, three cuttings, viz. on June 23, Aug. 3, and Oct. 5; in 1894, two cuttings, on July 9 and Oct. 28; in 1895, two cuttings, on May 30 and Aug. 2; in 1896, three cuttings, viz. on May 26, July 11, and Sept. 29; and in 1897, one cutting on June 8. After the cutting in June, there was a thin plant on most of the beds. In recent years they have required a great deal of hand-hoeing to keep down the weeds. The growth has usually been the more luxuriant where either Potash or Nitrate of Soda has been applied, but especially where the two were used together.

It will be observed that, although in the earlier years, the three small beds in the field which had been artificially made up of surface-soil and subsoil brought from a highly manured kitchen garden, maintained a plant of clover, and yielded better crops than the artificially manured beds, yet they finally failed quite as much as the rest.

In 1898, owing to the thinness of the plant, and the great prevalence of weeds, the whole of the small beds were ploughed up, and the experiment was abandoned. (See plan and foot-note, p. 36.)

2.—*Experiments on rich garden-soil.*

In view of the failures in the attempt to grow Clover continuously on ordinary arable land it is a fact of much interest, that in 1854 Red Clover was sown in a garden, scarcely half-a-mile distant from the experimental field, on soil which had been under ordinary kitchen garden cultivation for probably two or three centuries, and it has shown very luxuriant growth almost every year since.

From the produce of the seed sown in 1854 (March 29), two cuttings were taken in 1854, three in 1855, two in 1856, three in 1857, two in 1858, and two in 1859.

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EXPERIMENTS ON THE GROWTH OF LEGUMINOUS CROPS—*continued.*

In 1856, the plot was divided into three equal portions, one being left without manure, another receiving gypsum, and the third a mixed mineral manure containing potash. In 1857 the surface-soil was sampled to a depth of 9 inches.

Seed was re-sown in 1860 (end of May); and yielded one cutting in October of that year, two in 1861, two in 1862, two in 1863, and two in 1864.

Seed was again sown in 1865 (April 22); and this sowing yielded one cutting in September of that year, two in 1866, two in 1867, and one very small cutting in April 1868.

Gypsum and the mixed mineral manure were again applied; and seed was re-sown, April 29, 1868; and from this sowing there were obtained two cuttings in 1869, and one in 1870.

The same manures were again applied March 30, and fresh seed was sown April 10, 1871; yielding one cutting in August of that year, two cuttings in 1872, and two in 1873.

Notwithstanding some injury from Dodder in 1873, there still remained too much plant to break up in the spring of 1874; and accordingly fresh seed was sown *between the rows* on May 4, and this failing, again on July 7, 1874. The manures had been applied between the rows on April 16. Three very small cuttings were taken in 1874 (in June, July, and September); and a small cutting again in June, 1875.

In 1875 (July 13), the old plants were dug in, and seed again sown, and this failing, seed was re-sown September 22. In spring 1876 there was luxuriant growth, but deficient plant, which yielded two small cuttings, on June 26, and August 7.

In 1876 (September 1), the beds were dug up, and re-sown with seed, which came up fairly, but the plant suffered during the winter, and in May 1877 it was dug up and re-sown. From this sowing a small cutting was taken on September 5, 1877; and three cuttings in 1878 (on June 10, July 26, and November 1).

In May 1879, there remained some fairly vigorous plants, but not nearly enough for a crop, so the ground was dug up (the soil sampled to a depth of 18 inches), the plants then dug in, and fresh seed was sown, on May 21. From this sowing a cutting was taken on September 13.

Owing to injury from Dodder in the autumn (1879), and the subsequent severity of the winter, the plant again died off, and seed was sown afresh on April 17, 1880. From this sowing two cuttings were taken in that year (August 5 and September 24).

In April 1881, there being too much plant to break up, but not enough to cover the ground, the blanks in the rows were re-sown with seed (April 29), and two small cuttings were afterwards taken, on June 23 and August 16.

On April 6, 1882, there being again many blanks in the rows, these were re-sown with seed. Three cuttings were afterwards taken—on June 14, August 8, and October 20, of the same year.

On April 18, 1883, the same manures were sown on the same portions as in 1874, and the ground was dug, the old plants being dug in. Fresh seed was sown on May 17, which gave one cutting on August 13, 1883; three cuttings in 1884, viz. on June 17, August 11, and October 6; and three cuttings in 1885, viz. on June 2, July 16, and August 31.

Owing probably in great part to the severe winter of 1885–6, the plants nearly all died, and on April 14, 1886, the few that remained were dug in, and fresh seed sown, without further manure, from which one cutting was taken on August 11. In 1887, owing to some destruction of the plant by a mole, a portion of the Unmanured Plot was re-sown with seed on April 21. Two cuttings were taken, viz. on July 8 and August 29.

The plant died during the winter, fresh seed was sown on April 13, 1888, the rows were mended on June 12, and a small cutting was taken on September 6. In April 1889, the rows were again mended, after which two cuttings were taken, viz. on June 21 and October 25.

In April 1890, the plants had almost entirely died off; and the beds were therefore dug up and re-sown with seed, which gave one crop, on August 12. Later in the autumn, however, many plants were destroyed by a dog after mice, so that the rows had to be mended with fresh seed, in May 1891, and cuttings were taken on July 15 and September 25.

During the winter of 1891–2 most of the plants died, the ground was therefore dug up and re-sown with seed on May 7, 1892. The seed germinated well, but some of the young plants were destroyed by "Fly," and the rows were mended on May 27, and one cutting was taken on August 26.

During the winter of 1892–3 some of the plants died, and the rows were accordingly mended on April 20, 1893, and cuttings were obtained on June 24, and on August 22.

In 1894 the rows were again mended on April 19 and gave two cuttings on July 9 and September 4. The plants had now become exceedingly thin and the soil covered with seed-weeds; the beds were therefore dug up later in the autumn, left fallow during the winter, and

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re-sown with seed on April 19, 1895. The seed germinated well, but was afterwards destroyed by "Fly," and was again sown on May 20; but owing to drought and heat the seed did not germinate, and a third sowing was made on July 2; no crop was, however, obtained in1895.

During the winter of 1895, and early spring of 1896, most of the plants died, the plots were therefore cleaned from weeds, and prepared for re-sowing. On April 23, 1896, the soil was sampled at two places on each of the three portions. Each sample taken was $4 \times 4 \times 9$ inches deep; and a similar sample was taken of the second 9 inches of depth. The top 9 inches of soil of each of the three portions was then taken out, a mixed mineral manure was then dug into the second 9 inches, and a similar quantity of the same mineral manure was mixed with the surface soil, which was then returned to its position. Seed was sown on July 1, which, however, gave no crop.

Most of the plants died during the winter of 1896–7. The beds were accordingly dug up in April 1897, and seed was resown on April 29, and gave two cuttings, viz., Aug. 7, and Oct. 27.

At the beginning of the winter of 1897, there was a strong and even plant; but it gradually declined, and in January, 1898, failure was very marked. On January 27 the plots were microbe-seeded, with the watery extract of the rich kitchen garden soil at Rothamsted. This did not, however, arrest the failure. Many of the plants were covered with a white fungus; the foliage was destroyed, and the crowns blackened and rotted away, very few plants remaining healthy. Early in March specimens of the plants were forwarded to Mr. Carruthers, who decided that they had suffered from the attack of the fungus "*Sclerotinia Trifoliorum.*" Eventually, all the diseased plants were taken up and removed. The surface soil was also, little by little, removed, very carefully examined, the Sclerotia carefully picked out, and then the soil was returned. About 6 ozs. of the Sclerotia were thus picked out from the surface-soil of an area of not quite 10 square yards. It was thought desirable, however, to apply a fungicide to the soil before resowing with clover-seed, and bisulphide of carbon was selected for the purpose, as leaving less permanent residue than others. Accordingly, a small dressing of this was applied on May 7, and it was immediately raked in. It was hoped that by the application any remaining Sclerotia would be killed, and that the Leguminous nodule-microbes might not be injuriously affected. On June 2, that is nearly 4 weeks after the application of the bisulphide, clover-seed was again sown.

This (1898) is the 45th season of the growth of Clover, year after year, on this plot of rich garden ground. From the foregoing statements, it will be seen that seed was sown in 1854, 1860, 1865, 1868, 1871, 1874 (twice—between the rows), 1875 (twice), 1876, 1877, 1879, 1880, 1883, 1886, 1888, 1890, 1892, 1895 (3 times), 1896, 1897, and 1898; and in addition, the blanks in the rows were filled up in 1881, 1882, 1887, 1888, 1889, 1891, 1892, 1893, and 1894. Including the partial sowings to mend the rows, seed has been sown thirty-three times in the 45 years; only five times in the first 20 years, but 28 times in the last 25. It is obvious, therefore, that the plants stood very much longer in the earlier, than in the later years. It may be added that the produce of the first five sowings (1854, 1860, 1865, 1868, and 1871) was rather more than one and a-half time as much as has been obtained since. Lastly, the reduced persistence of the plant, and the reduced produce, have been coincident with a considerable reduction in the stock of nitrogen in the soil. Still, there has frequently been very luxuriant growth, even in the later years; and the produce over 40 years, to 1893 inclusive, was equivalent to an average of nearly 3 tons of clover hay per acre per annum.

Conclusions; Fixation of Free Nitrogen, &c.

The general result of the experiments on ordinary arable land in the field has been—that neither organic matter rich in carbon as well as other constituents, nor ammonium-salts, nor nitrate of soda, nor mineral constituents, nor a complex mixture, supplied as manure, availed to restore the clover-yielding capabilities of the land; though, where some of these were applied in large quantity, and at considerable depths, the result was better than when they were used in only moderate quantities, and applied only on the surface.

On the other hand, it is clear that the soil in the garden, which at the commencement contained in its upper layers about four times as much nitrogen as the arable land, and would doubtless be correspondingly rich in other constituents, has supplied the conditions under which clover can be grown year after year on the same land for many years in succession.

The results obtained on the soil in the garden seem to show that what is called "clover-sickness," cannot be due to the injurious influence of excreted matters upon the immediately succeeding crop.

That Clover frequently fails coincidently with injury from parasitic plants, or insects,

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cannot be disputed; but it may be doubted whether such injury should be reckoned as the cause, or merely the concomitant, and an aggravation, of the failing condition.

The results of the experiments seem, therefore, to exclude the supposition that the *primary* cause of failure is either destruction by parasitic plants or insects, injury from excreted matters, or the shade of a corn-crop, and to indicate that it must be looked for in exhaustion of some kind within the range of the roots.

Still there remain several open questions. Is it exhaustion of certain organic matters rich in carbon, of nitrogenous food, or of mineral constituents? Again: is there an absolute deficiency in the soil of some of the substances in question, or only an unfavourable condition of combination, or, so to speak, of *soil-digestion* of them, for the requirements of Leguminous plants? Or, is there only an unfavourable distribution of them within the soil, considered in relation to the extent and character of the root-range of the crop? Or, lastly, is the failure connected with the condition, the distribution, or the exhaustion, of the organisms, the development of which in symbiosis with leguminous plants, has been shown by recent experiments to be associated with the fixation of free nitrogen? For futher reference to this point, see next page, also page 7.

In reference to these various questions, it is a fact of much significance that from October 1857 to May 1879, the diminution in the amount of nitrogen in the garden-soil to the depth of 9 inches only, represented approximately two-thirds as much as was estimated to have been taken out in the crops of the 21 intermediate seasons; and it was concluded that there had been reduction in the lower depths also.

The subject cannot be further considered within the limits of this brief notice, which may be concluded by the following quotation from Rothamsted papers ('Journal of the Royal Agricultural Society of England,' vol. xxi. Part I. p. 178; and 'Journal of the Royal Horticultural Society of London,' vol. iii. p. 86, 1872):—

"When land is not what is called 'clover-sick,' the crop of clover may frequently be increased by top-dressings of manure containing potash and superphosphate of lime; but the high price of salts of potash, and the uncertainty of the action of manures upon the crop, render the application of artificial manures for clover a practice of doubtful economy.

"When the land is what is called 'clover-sick,' none of the ordinary manures, whether 'artificial' or natural, can be relied upon to secure a crop.

"So far as our present knowledge goes, the only means of insuring a good crop of Red Clover is to allow some years to elapse before repeating the crop upon the same land."

Recent experiments at Rothamsted have confirmed those of others, in showing that by adding to a sterilised sandy-soil growing leguminous plants, a small quantity of the watery extract of a soil containing the appropriate organisms, a marked development of the so-called leguminous nodules on the roots is induced, and that there is, coincidently, increased growth, and gain of nitrogen. There is no evidence that the leguminous plant itself assimilates free nitrogen; the supposition is rather, that the gain is due to the fixation of nitrogen in the growth of the lower organisms in the root-nodules, the nitrogenous compounds so produced, being taken up and utilized by the leguminous plant.

It would seem, therefore, that in the growth of leguminous crops, such as clover, vetches, peas, beans, sainfoin, lucerne, &c., at any rate some of the large amount of nitrogen which they contain, and of the large amount which they frequently leave as nitrogenous residue in the soil for future crops, may be due to atmospheric nitrogen brought into combination by the agency of lower organisms. It has yet to be ascertained, however, under what conditions a greater or less proportion of the total nitrogen of the crop will be derived—on the one hand from nitrogen-compounds within the soil, and on the other from such fixation. It might be supposed, that the amount due to fixation would be the less in the richer soils, and the greater in soils that are poor in combined nitrogen, and which are open and porous. On the other hand, recent results obtained at Rothamsted, indicate that, at any rate with some leguminous plants, there may be more nodules produced, and presumably more fixation, with a soil rich in combined nitrogen, than in one poor in that respect.

In conclusion, as referred to above, the question remains—how far the failure of clover, and other leguminous crops, may be due to the exhaustion of available combined nitrogen, or mineral constituents, within the range of the roots, and how far to the exhaustion of the organisms necessary for the bringing about of the fixation of free nitrogen?

For further particulars on the Question of the Fixation of Free Nitrogen, see No. 92, Series I. (in the list of papers at page 14), pages 119–145; or, No. 93, Series I., pages 137–166.

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EXPERIMENTS WITH VARIOUS LEGUMINOUS PLANTS.—HOOS FIELD.

The arable land (in Hoos Field) upon which attempts had been made to grow Red Clover in frequent succession since 1849, was devoted to experiments with *various* Leguminous Plants in 1878; so that the present season, 1898, is the twenty-first year of these experiments.

The object was to ascertain whether, among a selection of plants all belonging to the Leguminous family, but of different habits of growth, and especially of different character and range of roots, some could be grown successfully for a longer time, and would yield more produce, containing more nitrogen as well as other constituents, than others; all being supplied with the same descriptions and quantities of manuring substances, applied to the surface soil. Further, whether the success in some cases, and the failure in others, would afford additional evidence as to the source of the nitrogen of the Leguminosæ generally, and as to the causes of the failure of Red Clover in particular, when it is grown too frequently on the same land.

Below are given, in a Tabular form, lists of the Plants grown in previous years, and now growing (June 1898); and below the Table, the dates of sowing seed are given.

As the details show, there were at first 14 descriptions of Leguminous Plant grown, but that some of these, which more or less failed, have been given up; whilst others have been transferred from one plot to another. Indeed, the object during the last few years has been to reduce the number from 14 to 7, taking two plots instead of one for each description. The land had, however, notwithstanding much hand-hoeing, become very foul, and after cutting the crops of 1892, all but the Medicago sativa plots were ploughed up, thoroughly cleaned, and re-arranged; with one exception (9 and 10), two of the original plots being ploughed into one, and permanent paths of separation left, between the now larger plots; and in 1896, the Medicago sativa on No. 10 having failed, the two lands (9 and 10) were then thrown together, and devoted to Trifolium repens.

As the tabular statement shows, the arrangement at the present time (1898), is as follows:—

Nos. 1 and 2, Medicago sativa (Lucerne).
Nos. 3 and 4, Pisum arvense (Field Peas), or Faba vulgaris arvensis (Field Beans), alternately.
Nos. 5 and 6, Melilotus leucantha (Bokhara Clover).
Nos. 7 and 8, Onobrychis sativa (Sainfoin).
Nos. 9 and 10, Trifolium repens (White or Dutch Clover).
Nos. 11 and 12, Trifolium pratense (Red Clover).
Nos. 13 and 14, Vicia sativa (Common Tare or Vetch).

Below, is also given a Table showing the description and quantities of the manures applied to the different plots. Up to 1897 inclusive there were 3 "*Series*": Series 1, comprising 5 plots, and Series 2 and 3 each 6 plots. The same mineral manure (if any) has been applied to the same plot of each of the 3 *Series*:—*Series* 1, mineral manures only; *Series* 2, the same mineral manures, and nitrate of soda or lime; *Series* 3, the same mineral manures, with ammonium-salts, or rape-cake, or cows' urine, in addition. The manures have been applied in the quantities per acre stated in the Table, and the foot-notes thereto.

The general result is—that very much more nitrogen has been removed in some of the other plants than in the Red Clover; the average annual yield in which over the 5 years of the 8 (1878–85), when there was any crop, was only about 22 lbs. per acre, giving over the 8 years an average of only 14 lbs. of nitrogen. Against this, Melilotus leucantha yielded in 1879 about 130 lbs., in 1882 about 145 lbs., and over the 8 years (1878–85) an average of about 70 lbs. per acre; Vicia sativa gave over 3 years (1882-84) an average of 120 lbs., and over the 8 years (1878–85) an average of about 84 lbs.; and, lastly, Medicago sativa yielded, in 1884 nearly 340 lbs., in 1885 about 270 lbs., and over the 6 years (1880–85), an average of about 153 lbs., of nitrogen; and over the 12 years ending 1891, it gave an average of 160 lbs. of Nitrogen per acre per annum. Further, as late as 1895 even red clover yielded very fair produce under some conditions of manuring, and sainfoin and Bokhara clover much more; whilst in 1897, Bokhara clover yielded very large crops.

Notwithstanding these remarkable results, there has, in recent years, been a tendency to failure, especially of the weaker plants; due largely to the difficulty of keeping the land clean. It was, therefore, decided early in 1898 to reduce the area from 3 acres to less than one acre; and it is hoped that with so much less land it may be possible to keep it properly cultivated and cleaned, and so obviate one serious source of failure—foulness. The plots of Series 1, with the mineral manures which have yielded the most important results, being retained, the manure, crop, and soil history is substantially continued. (See Plan and footnotes thereto at p. 36.)

(Area under Experiment, about 3 acres; each Plot about $\frac{1}{5}$th acre.)

PLANTS GROWN ON EACH PLOT. There were originally 14 Plants on each Plot; but the number is now reduced to 7.

Years.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Years.
1878								Trifolium procumbens (*Yellow Trefoil or Hop Clover*).	1878
1879								Trif. tardiflora incarnatum (*Late Red Clover*).	1879
1880	Trifolium pratense (*Common Red or Broad Clover*).	Trif. prat. perenne (*Perennial Clover or Cow-grass*).	Trif. prat. hybridum (*Suttons' Hybrid—Cow Clover*).		Trif. rep. perenne (*Giant perennial White Clover*).		Trifolium incarnatum (*Early Red or Crimson Clover*).	Trif. tardiflora album (*Late White Clover*).	1880
1881								Trifolium minus (*Yellow Suckling Clover*).	1881
1882				Trifolium repens (*Common White or Dutch Clover*).					1882
1883						Trifolium hybridum (*Alsike Clover*).	Lupinus hirsutus (*Blue Lupin*).	Lupinus luteus (*Yellow Lupin*).	1883
1884									1884
1885									1885
1886	Lupinus hirsutus (*Blue Lupin*).	Lupinus luteus (*Yellow Lupin*).			Faba vulg. arvensis (*Field Beans*).		Trifolium pratense (*Common Red or Broad Clover*).	Trifolium pratense perenne (*Perennial Clover or Cow-grass*).	1886
1887	Medicago sativa (*Lucerne or Purple Medick*).								1887
1888	,, ,, ,,		Pisum arvense (*Field Grey Peas*).						1888
1889	,, ,, ,,								1889
1890	,, ,, ,,			Fallow.		Melilotus leucantha.	Onobrychis sativa (*Sainfoin*).		1890
1891	,, ,, ,,			Faba vulg. arvensis (*Field Beans*).	Melilotus leucantha (*Bokhara Clover.*)			,,	1891
1892	,, ,, ,,				,,			,,	1892
1893			Pisum arvense (*Field Grey Peas*).						1893
1894	,, ,, ,,		Faba vulg. arvensis (*Field Beans*).		,,			,,	1894
1895	,, ,, ,,		Pisum arvense (*Field Grey Peas*).		,,			,,	1895
1896	,, ,, ,,		Faba vulg. arvensis (*Field Beans*).		,,			,,	1896
1897	,, ,, ,,		Pisum arvense (*Field Grey Peas*).		,,			,,	1897
1898	,, ,, ,,		Faba vulg. arvensis (*Field Beans*).		,,			,,	1898

EXPERIMENTS WITH VARIOUS LEGUMINOUS PLANTS.—HOOS FIELD—*continued.*

Years.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	Years.
1878		(Not sown).				Lathyrus pratensis (*Meadow Vetchling*).	1878
1879	Medicago lupulina (*Black Medick or Non-such*).			Lotus corniculatus (*Bird's-foot Trefoil*).			1879
1880							1880
1881							1881
1882							1882
1883			Melilotus leucantha (*Bokhara Clover*).		Vicia sativa (*Common Tare or Vetch*).	Onobrychis sativa (*Sainfoin*).	1883
1884							1884
1885							1885
1886				Melilotus leucantha (*Bokhara Clover*).			1886
1887	Vicia sativa (*Common Tare or Vetch*).	Medicago sativa (*Lucerne or Purple Medick*).					1887
1888							1888
1889							1889
1890			Trifolium pratense (*Common Red or Broad-leaved Clover*).			Fallow.	1890
1891			,,		Vicia sativa (*Common Tare or Vetch*).		1891
1892	Trifolium repens (*Common White or Dutch Clover*).		,,		,,		1892
1893			,,		,,		1893
1894			,,		,,		1894
1895			,,		Fallow (Plant failed).		1895
1896	Trifolium repens (*Common White or Dutch Clover*).		,,		Vicia sativa (*Common Tare or Vetch*).		1896
1897	,,		,,		,,		1897
1898	,,		,,		,,		1898

DATES OF SOWING SEED, &c.

No. 1. Trifolium pratense—May '78; May '80; April '81; March '82; April '83; April '84; Lupinus hirsutus—May '86. **No. 2.** Trifolium pratense perenne—May '78; May '80; April '81; March '82; April '83; April '84; Lupinus luteus—May '86.

Nos. 1 and 2 together. Medicago sativa—April '87; May '96; June '98.

No. 3. Trifolium pratense hybridum—May '78; May '80; April '81; March '82; April '83; Pisum arvense—Feb. '84; March '85; March '86; Feb. '87; April '88; Feb. '89; Feb. '90; March '91; Feb. '92. **No. 4.** Trifolium repens—May '78; May '80; April '81; April '83; April '84; April and June '88; April '89; Faba vulgaris arvensis—March '91; Feb. '92.

Nos. 3 and 4 together. Pisum arvense—March '93; Faba vulg. arvensis—March '94; Pisum arvense—March '95; Faba vulg. arvensis—Feb. '96; Pisum arvense—March '97; Faba vulg. arvensis—April '98.

No. 5. Trifolium repens perenne—May '78; May '80; April '81; April '83; Faba vulgaris arvensis—Feb. '84; March '85; March '86; March '87; April '88; Feb. '89; Feb. '90. **No. 6.** Trifolium hybridum—May '78; May '79; May '80; April '81; March '82; April '83; April '84; May '86; April '87 (mended); April and June '88; April '89; Melilotus leucan.—May '90.

Nos. 5 and 6 together. Melilotus leucantha—(No. 6, April '90, and No. 5, April '91);—April '93; April '94; June '96; June '98.

No. 7. Trifolium incarnatum—May '78; May '79; May '80; April '81; Jan. and Sept. '82; Lupinus hirsutus—April '83; April '84; April '85; Trifolium pratense—May '86; April '89. **No. 8.** Trifolium procumbens—May '78; May '79; Trif. tardiflora incarn.—May '80; April '81; Trif. tard. album—May '81; Trif. minus—Oct. '81; Trif. incarn.—Sept. '82; Lupinus luteus—April '83; April '84; April '85; Trif. prat.—May '86; April '89.

Nos. 7 and 8 together. Onobrychis sativa.—May '90; April '93; April '94; June '98.

No. 9. Medicago lupulina—May '78; May '79; May '80; April '81; Vicia sativa—Sept. '82; Oct. '83; Sept. '84; Sept. '85; Oct. '86; Sept. '87; Oct. '88; Oct. '89; Trifolium repens—April '91; April '93; April '94. **No. 10.** Medicago sativa—May '79; May '80; April '81; April '83 (mended).

Nos. 9 and 10 together. Trifolium repens—May '96; May '97; June '98.

No. 11. Melilotus leucantha—May '78; May '80; April '81; April '83; April '84 (mended); March '85 (mended); May '86; May and June '88 (mended); April '89. **No. 12.** Lotus corniculatus—May '78; May '79; May '80; April '81; Melilotus leucantha—Sept. '82; April '83; April '84 (mended); March '85 (mended); May '86; May and June '88 (mended); April '89.

Nos. 11 and 12 together. Trifolium prat.—May '90; April '93; April '94; May '97; June '98.

No. 13. Vicia sativa—May '78; May '79; May '80; April '81; Sept. '82; April '83 (mended); Oct. '83; Sept. '84; Sept. '85; Oct. '86; Sept. '87; Oct. '88; Oct. '89. **No. 14.** Lathyrus pratensis—May '78; Onobrychis sativa—May '79; May '80; April '81; April '83 (mended); April '84 (mended); April '85 (mended); May '86 (mended); April '89. [April '98.

Nos. 13 and 14 together. Vicia sativa—Sept. '90; Sept. '91; Sept. '92; Sept. '93; Oct. '94; Sept. '95; Oct. '96,

MANURES; QUANTITIES PER ACRE.

Plots.	Series 1; 5 Lands.(1) Without Manure, or with Mineral Manure only. The Mineral Manures were applied in the quantities stated below, or in half the quantities in the years given in parentheses, in 1878, 1880, (1882), (1883), (1884), (1885), 1887, (1889), 1893, and 1898. In October 1883, 2000 lbs. of fresh-burnt Lime (slacked) were applied per Acre over all the Plots of Series 1.(5) [In 1898, 400 lb. Basic Slag throughout used instead of Superphosphate.]	Series 2. 5 Lands (1); Each Plot as Series 1, and—	Series 3; 5 Lands. 2 lands (2); Each Plot as Series 1, and—	3 Lands (3); Each Plot as Series 1, and—
1	Without Mineral Manure. (Series 1, portion devoted to the experiments on "Small Beds," 1867–8, and since. See pp. 31–2)	Nitrate of Soda, 550 lbs. in 1878, '82, and '84; 275 lbs. in 1879, '80, '81, '85, '86, and 1887. 1889. (6)	Ammonium-salts, 400 lbs. in 1878, '82, and '84; 200 lbs. in 1879, '80, and '81; 225 lbs. Sulph. Amm., 1887.	Rape Cake, 2000 lbs. in 1878, 1880, 1882, and 1884; 500 lbs. in 1885; 1000 lbs. in 1887.
2	5 cwts. Superphosphate of Lime(4)			
3	1000 lbs. Sulphate Potash			
4	1000 lbs. Sulphate Potash, 5 cwts. Superphosphate			
5	1000 lbs. Sulph. Potash, 250 lbs. Chloride Sodium (in 1884–5 and '87 Sulph. Soda instead), 250 lbs. Sulph. Lime, 250 lbs. Sulph. Magnesia			
6	1000 lbs. Sulph. Potash, 250 lbs. Chlor. Sod. (in 1884–5 and '87 Sulph. Soda instead), 250 lbs. Sulph. Lime, 250 lbs. Sulph. Mag., 5 cwts. Superph.			

(1) In November 1879, Lime was applied to the fifth land of Series 1, and to the adjoining land of Series 2, in addition to the other manures.

(2) One of the two lands had received Cows' Urine, 6120 lbs. per acre in 1879; and in 1885 both lands received Cows' Urine, at the rate of 21,500 lbs. per acre.

(3) In 1880, the Rape-cake was applied on only two lands (2nd and 3rd of the 3), Cows' Urine, at the rate of 6120 lbs. per acre, having been applied to the 1st of the 3 lands in 1879.

(4) "Superphosphate of Lime," 1878 to 1887 inclusive, made from 300 lbs. Bone-ash, 225 lbs. Sulphuric acid sp. gr. 1·7 (and water); 1889, made from high percentage mineral phosphates, and containing 37 per cent., or more, of soluble phosphate.

(5) In November 1887, fresh-burnt Lime (slacked), at the rate of 1000 lbs. per acre, was applied over the whole of the three Series. In November 1893, 2 tons of Chalk (crushed) per acre was applied over the whole of the three Series.

(6) On September 13, 1889, instead of Nitrate of Soda, a solution of Nitrate of Lime (1490 lbs. per acre), corresponding to 550 lbs. Nitrate of Soda, and to 86 lbs. Nitrogen per acre.

NOTE.—In addition to the manures above described, a top-dressing of 550 lbs. Nitrate of Soda, 400 lbs. Ammonium-salts, or 2000 lbs. Rape-cake, per acre, was applied to the respective portions of **No. 10** (Medicago sativa), **No. 11** (Melilotus leucantha), and **No. 14** (Onobrychis sativa), on September 20, 1882. In 1898, all sown in rows; Beans 20 inches apart; Vetches 12 inches; Lucerne, Melilotus, Sainfoin, White Clover, and Red Clover, each 11 inches apart.