XXVII. Note on the Effects of Soot on some Coniferæ

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little older than that of fig. 88; *c*, cotyledon now beginning to curve on itself; *s*, suspensory cells. Magnified.

Fig. 90. Semi-diagrammatic projection of apex of primary axis, such as is presented in figs. 8 and 9. Only the three uppermost lateral shoots are here represented, but the lettering corresponds with that on those figures.

XXVII. *Note on the Effects of Soot on some Coniferæ.*—By DR
T. A. G. BALFOUR, President.

(Read July 1878.)

I fear that the heading in the billet may have misled some as to the nature of the communication which I propose to make. It does not refer to the *general* action of soot on conifers, but has a much more limited range, which I shall best explain by mentioning the circumstances which led to the experiments being undertaken. At one of our most popular spring meetings, when the subject of the influence of soot on forest trees was incidentally brought before the Society by Mr Sadler, Dr Aitken made a statement to the effect that a German professor had proved that soot was quite innocuous to arboreal vegetation, by enveloping a tree in that substance without interfering with its vitality. So astounding was the announcement that I suggested that the soot could not have been applied to the under surface of their leaves, else the stomata must have been occluded, but I was informed that the experiment was so conducted that that portion of the leaf could not have escaped from being covered with soot. My special object then was to ascertain whether or not the free application of soot or other substances so as to cover the stomata, &c., was unattended with injurious results; and it is in this point of view alone that my experiments can be of any value.

A second preliminary consideration to which I would allude is that the experiments are liable to objection in consequence of my having been unable to give the time necessary for close and continuous observation of the results, and still more from the fact that the experiments were not crucial ones, seeing that different kinds of plants were made

the subjects of them. But, as I feared from the first that the issue would be disastrous, I felt reluctant to ask for any plants for experimental purposes other than those which were kindly supplied to me; but still even this circumstance, though prejudicial in one respect, may have its advantages in another.

To a third preliminary point I should like to direct your attention, viz., to this, that questions such as those which were brought before us by Mr. Sadler can only be satisfactorily answered by experiments on a large scale, and where all the circumstances in connection with it are in every respect similar to those in the case in dispute,—thus, for instance, the kind of coal employed, the amount of iron pyrites in the clay or blackband ironstone being calcined, the distance from the plantation at which the calcination is effected, the general direction of the winds in the district, and the frequency and amount of rain which falls, must all be taken into account, and would require to be imitated as exactly as possible before reliable experiments could be adduced.

These considerations, taken in connection with the subject of *smoke*, to which I shall shortly refer, are sufficient to show that my experiments can have only a most distant and indirect bearing on the important general question which was before us at our previous meeting. The substances used in my experiments were only three—soot, lamp-black, and whitening. Sand was used in one instance, but it proved so heavy that it weighed down the plant inconveniently, and was therefore discarded. Now soot, as every one knows, varies in its composition according to the nature of the coal from which it is derived, and as it is the result of imperfect combustion of organic matters, even the height and nature of the chimney must exert an influence upon its composition. The better quality of the Bristol soot over that of Gloucester is said to be owing to the greater length of the chimneys. The analysis of Braconnot seems clearly to indicate from the presence of *acetates* that the combustion had been unusually deficient in the supply of oxygen, which would otherwise have changed them into carbonates.

Analysis of Soot by M. Braconnot.

Ulmic acid (a substance resembling that portion of the vegetable world which is soluble in caustic potash), .	302·0
A reddish brown soluble substance containing nitrogen, and yielding ammonia when heated,	200·0
Asboline,*	5·0
Carbonate of lime with a trace of magnesia, probably partly derived from sides of chimney,	146·6
Acetate of lime,	56·5
Sulphate of lime,	50·0
Acetate of magnesia,	5·3
Phosphate of lime, with trace of iron, .	15·0
Chloride of potassium,	3·6
Acetate of potash,	41·0
Acetate of ammonia,	2·0
Silica (sand),	9·5
Charcoal powder,	38·5
Water,	125·0
	<hr/> 1000·0

But yet there is an average composition, which, from the analysis of Dr Völcker, may be stated to be as in the following tables:—

Analysis of House-Coal Soot by Dr Völcker.

1. Substances present.

Moisture,	10·620
Organic matters and ammoniacal salts containing 1·22 of ammonia,	46·454
Oxides of iron and alumina,	15·691
Lime,	7·840
Magnesia,	·389
Potash,	·318
Soda,	·122
Sulphuric acid,	8·670
Phosphoric acid,	·259
Carbonic acid,	·497
Chlorine,	1·008
Soluble silica,	4·014
Insoluble siliceous matter (chiefly sand), .	4·157
	<hr/> 100·029

* From $\alpha\sigma\beta\omicron\lambda\eta$, soot, is a substance analogous to hamus or ulmic acid, but contains nitrogen.

2. These substances combined as salts.

Moisture,	10·620
Organic matter,	44·736
Chloride of ammonium,	·933
Silicate of ammonia,	3·580
Chloride of sodium,	·231
Chloride of potassium,	·503
Oxides of iron and alumina,	15·691
Sulphate of lime,	11·051
Phosphate of lime,	·530
Carbonate of lime,	1·129
Lime as silicate,	2·290
Magnesia as silicate,	·389
Soluble silica (partly combined with lime and magnesia,)	4·159
Insoluble siliceous matter (chiefly sand),	4·159
	<hr/> 99·856

Here I must guard you against supposing that smoke is identical in composition with soot; the former may be very deleterious, while the latter may prove innocuous. The soot gives us only those substances which have been condensed in the flues or chimneys; but the volatile gases, which refuse to be condensed, or which, having been condensed at first, are again volatilised as the temperature in their neighbourhood increases, these volatile gases, I say, escape with unconsumed carbon and other substances into the atmosphere, and are carried by the wind in various directions. No one who reflects on the existence of iron pyrites, which is an ingredient in all coal, and remembers that arsenic is contained within it, can fail to see that portions of the sulphur which have escaped the oxidation into sulphuric acid will be discharged from the chimney as sulphuretted hydrogen, while the arsenic will either be so oxidised as to form arsenious acid, or combine with hydrogen and give rise to arseniuretted hydrogen, all of which are substances most injurious to vegetation.

I am perfectly aware of the fact that the soot from ordinary house coal is, under certain circumstances, of great advantage to particular plants and crops.

Thus, it is most beneficial as a top-dressing for wheat, oats, and barley, in the proportion of 20 to 30 bushels per

acre. It is also of great value when applied to onions, potatoes, turnips, and carrots; indeed for the two last there is probably no better manure.*

I know also that many greenhouse plants are forced into vigorous growth by a judicious use of soot. Pelargoniums, fuchsias, solanums, chrysanthemums, &c., are thus benefited. Applied to grass lawns when they are wet it soon improves the sward.

One has but to glance at the tables before you to understand why soot should be so good as a manure; for the presence of organic matter and of salts of ammonia—especially of these last, which vary from 1 to 5 per cent. of the weight of soot—at once solves the problem.

But while freely admitting all this, we must never forget that in all these cases soot must be used with caution, and, in some of them, the liquid form is alone admissible; for soot is a powerful stimulant, and, as farmers say, is of a burning nature, and has been known to prove injurious when too freely applied. In some instances, indeed, such as in the case of gooseberry and currant bushes, where the buds had in previous years been stripped off by birds, a stronger application has been borne; the soot mixed with lime was here dusted over the bushes when wet, and while the buds were thus preserved from the birds, no injury accrued to the bushes, even though in one year the dose was twice administered. In this case, however, the soot was used early in the season, and before the leaves were developed. Taking everything into consideration, we cannot but regard the free application of soot to plants in leaf as really injurious, and the proof of this, as respects some conifers, is patent before you, for

1. *Cupressus Lawsoniana*, var. *stricta*, is certainly in a moribund condition. There is still a slight indication of life, but that is all. The question naturally suggests itself, How was it treated? It was first well watered, and then soot from an ordinary chimney was dusted over it, all the soot that fell on the soil being removed by the hand, so that that source of error might as far as possible be avoided. It

* Mr Fleming made experiments on Swedish turnips at Barochan, near Paisley, and found that fifty bushels of soot, applied alone, gave an increase of 4 tons in the crop.

experienced five dustings, the first being on March 15th of this year, and the last on the 4th of July. On April 2d it was becoming brown at points of branches, and on the 23d of that month its general appearance was quite brown, as if burnt up, but at the top there was slight indications of life. On the 3d of May there was a decided improvement, new growth being found at the summit; and some of the branches near the central stem were looking somewhat green, but fully a half of the plant looked still brown and dead. A fresh dusting took place at this date, and a third application of the soot was made on May 15th.

On June 4th the plant seemed nearly all dead, some small terminal portions alone being exempt from the disaster. On June 25th the green terminal portions have increased in dimensions. Soot was again applied, but without any special injury, till July 4th, when the last dose was administered, which was soon followed by a great change for the worse; and the present melancholy aspect of the shrub betokens a speedy dissolution.

2. The next plant to which I would refer is this *Picea Douglasii*, which shows a considerable amount of green at the extremities of stem and branches, though subjected to seven applications of soot, the first being on March 20th and the last on July 4th. The second dusting with soot was on March 30th. On April 2d the report is, "the needles do not fall off when touched." April 23d, the needles are now quite brown, but the buds are not dead. On May 3d the buds look healthy, but several of the needles have fallen off. While many of them at the lower portions of the plant are quite brown, others on the branches above are browned only about one-half their length.* Soot was applied, and on the 15th of same month it was again covered with soot as far as practicable, for it was found very difficult to get the soot to adhere to the first leaves of the new sprouts, though these were watered. It reminded me of the difficulty of wetting a cabbage blade, seeing that the particles

* Two specimens were taken at this date and put in brine, the one was from an unsooted shrub and the other from this sooted one. The unsooted one, though in every other respect similar to the sooted one, has the buds about twice as well developed. It is proper, however, to mention that the sooted shrub had been transplanted into the pot before experimenting on it, which may have caused some delay.

of water have stronger tendency to *cohere* and form globules than to *adhere* to the blade and spread over its surface, so here the particles of soot seemed more inclined to form balls than to adhere to the wetted leaves.

June 4th: Much as before, but terminal sprouts more developed. Soot was again applied, and in order to overcome the previous difficulty, the new sprouts, after being well watered, were rubbed into the soot, but with no great success.

On June 25th the sprouts were considerably grown, some of them being $2\frac{1}{2}$ and 3 inches long. Soot was again applied.

On July 4 a fresh application was made by Mr Lindsay, and the plant is now before you to enable you to judge of the effects.

3. The next plant to which I would call your attention is this *Picea Webbiana*, to which soot was six times applied, beginning on March 20th and ending on the 4th of July.

On April 2d it is reported as going fast, needles browned and drop off at once on being touched. Even the least movement of the plants causes some leaflets to fall.

Mr M'Nab had judiciously suggested to apply the soot to the plants on one side of the pot only, and in this case a very interesting circumstance occurred, which made the experiment more exact and satisfactory. One of the branches of a plant, or the unsooted side, stretched over among the plants to which the soot was applied, and consequently partook of the fuliginous doses which they received. The plants in this pot, on the side which the soot was not applied, are quite healthy, but the branch which stretched over to the sooted side is undergoing the same brownness and decay as the others on this side.

April 23d: Needles quite brown; the buds are healthy.

May 3d: Terminal buds are coming out healthily, but not luxuriantly, except in the case of the branch coming over from the other plant.

Taking one plant we find that the terminal buds, which consist of three, are healthy; one of the lateral ones is pretty well developed. The two branches immediately below have terminal buds; the one to the right well developed, with one slightly developed bud beside it; the

other branch has two buds only slightly developed. The branch immediately below has a very small and scarcely swollen bud. The four branches below are quite dead.

I need not trouble you with minute details, but shall simply mention that while on some branches the needles were quite brown, or only so at the tip, in others, where a few needles only remain, they are green.

One plant behind has all the branches dead, except the tips of the five uppermost, and all these five except the central one have the buds feeble and undeveloped.

The unsooted plants, however, are observed to have their buds scarcely more developed than the sooted ones.*

Soot reapplied.

May 15th : Soot dusted on again.

June 4 : Terminal growth of young buds considerable, but much less than adjoining one. The first portion of all the branches are free of needles, while the healthy adjoining one has them all thickly on.

Re-sooted on this date and also on July 4th.

4. Let me now leave the conifers for a moment, and direct your attention to the *Hedera Helix*, var. *maculata*, which has wonderfully survived the applications of soot, though at one period it seemed dying.

It was sooted five times, beginning on March 15th and ending July 4th.

On April 23 it is reported as dying, but on May 3d it had more leaves alive than dead, and the smaller leaves seemed to have been those that suffered most.

June 4 : A large number of young leaves, fresh and healthy-looking, were observed. Buds were coming from both sides of the branches, at the extremities of which there had been dead leaves.

June 25 : Maintains its improved appearance.

5. To return to the conifers, the next plant chosen was *Pinus excelsa*, and here lamp-black was employed. There were several specimens in the pot, and only one-half was dusted with the lamp-black for the first time, on May 2d. As the powder was nearly all off, it was redusted on the following day (May 3d), the lamp-black being removed from the soil.

* One of the sooted buds taken to show stage of development on May 3d 1878.

June 4: Growth apparently not affected.

June 25: Carbonaceous matter again applied, but no distinct difference on the two sides of pot. Re-applied on July 4th.

The result here need not surprise us, as lamp-black is very different from soot, and, if we except the oil, and sometimes a little naphthaline, is more allied to pure carbon. Indeed, when calcined in a covered crucible the oil is quite destroyed. Now, so far as I can learn regarding the experiment of the German professor, it seems to have been more of a resinous or oily substance which was employed, so that we can scarcely wonder that lamp-black was not injurious, seeing that in the case of *Pinus excelsa* no very prejudicial effect was produced, if indeed any at all.

6. The next experiment was with soft chalk (whitening) on *Cupressus sempervirens*, which was applied when wet to that plant, on May 2d. On May 3d the plant is still covered and no apparent change—whitening was freshly applied after wetting. On May 15 rewhitened.

June 4: Does not seem affected, except in the case of one or two of the lower plants, which are brownish and dead. The chalk is sticking well to all the plants, except at the points.

On July 4 it was rewhitened. The plant is still pretty healthy, as you may see (July 11th).

At this late hour I shall not detain you with any further remarks; but, I think, from what you see before you, that few will contend that soot, applied as in these cases, is not injurious to conifers, and that all will admit that the injury done is not owing to mere clogging of the leaves (as witness experiments 5 and 6), but to something deleterious in the soot itself.