fishermen, who recognize the Caspian Tern to be a new bird on the lake, to date within the last few years. Indeed the earliest definite information regarding it was their report that three years previous to our visit, a wolf crossed to Pelican Island from Swampy Bay and destroyed all eggs and young birds in the colony. The species was not found by Dunlop when he visited the island in 1914 and it is hardly possible that he could have missed it had it been there. Capt. Goodman stated that, on Reindeer Island, Dunlop found the Caspian Terns breeding as late as mid-August.

REFERENCES.

1. American Ornithologists' Union, 1910, Check List of North American Birds, Third Edition, New York.
2. Atkinson, George E., 1904. Rare Bird Records of Manitoba. Transaction 65, The Historical and Scientific Society of Manitoba, Winnipeg.
3. Bell, Robert, 1879. Report on Expeditions on the Churchill and Nelson rivers, etc. Report Prog. Can. Geol. Society, 1878-79. Ottawa. Birds, pp. 67c to 70c.
4. Cooke, Wells W., 1913. Bird Migration. U. S. Dept. Agricul. Bulletin No. 185. Washington.
5. Macoun, John, and Macoun, James M., 1909. Catalogue of Canadian Birds. Department of Mines, Ottawa.
6. Nutting, C. C., 1893. Rep. on Zoological Explorations on the Lower Saskatchewan river. Bul. from the Laboratories of the State University of Iowa, Vol. II, No. 3. Article IV, pp. 235-293. January, 1893.
7. Preble, E. A., 1902. A Biological Investigation of the Hudson Bay Region, N.A. Fauna. No. 22, Wash. Birds, pp. 75-131.
8. Rowan, William, 1915. The Blakeney Point Ternery, Blakeney Point Publication No. 13.
9. Rowan, William, no date. The Little Tern, Blakeney Point Publication No. 17.
10. Rowan, William, Parker, K. M., and Bell, Julia, 1914. On Homotyposis and allied characters in the egg of the Common Tern. Biometrika, Vol. X, No. 1.
11. Seton, E. T., 1909. The Birds of Manitoba. A Handbook to Winnipeg. Pub. by the local committee Brit. Ass. Adv. Sci., Winnipeg.
12. Thompson, E. E. (—E. T. Seton), 1891. The Birds of Manitoba. Proc. U. S. Nat. Mus., Vol. xiii, pp. 457-643, Wash.

DOUGLAS FIR SUGAR

BY J. DAVIDSON, F.L.S., F.B.S.E., INSTRUCTOR IN BOTANY,
UNIVERSITY OF BRITISH COLUMBIA.

Much interest has recently been aroused over what appears to be phenomenal deposits of sugar on the leaves of Douglas fir *(Pseudotsuga taxifolia)* in certain areas of British Columbia. Although Douglas fir sugar has been known to the Indians of the dry-belt for many years, its occurrence seems to have been overlooked by the numerous surveyors and others who have travelled in the province; at least, in-so-far as the writer is aware, no record has been made of its occurrence previous to 1915, when an illustration appeared in the British Columbia Botanical Office Report for the year 1914, showing a branch of Douglas fir laden with white masses of sugar. This photograph was prepared from specimens received from Mr. Jas. Teit, of Spence's Bridge, B.C., who, in connection with his ethnological work on the plants used as food by the British Columbia Indians, wished to have an explanation of the deposits; Mr. Teit also forwarded samples of Douglas fir sugar to Dr. E. Sapir of the Geological Survey of Canada, who had the samples analyzed.

During the summer of 1917, when the European conflict caused an increase in the cost of living and the introduction of measures to economize sugar, interest in this phenomenon was renewed and intensified by the appearance of a glowing account supplied to one of the Vancouver newspapers by some irresponsible contributor. As a result, a number of people became quite enthusiastic regarding this "new" discovery and hastened to ascertain its commercial possibilities.

In view of the fact that many people in Canada are interested in the phenomenon, and at the request of Mr. Teit, the writer consented to give a summary of what is known regarding Douglas fir sugar and the factors influencing its exudation as deposits on the leaves. All the information relating to the distribution and habitats of sugar-bearing Douglas firs was supplied by Mr. Teit who, being resident in the heart of the dry-belt and having an intimate knowledge of the Indians of the interior, was best able to secure the necessary data.

It appears that Douglas fir sugar cannot be relied on as an annual crop. Some years it is abundant, other years little or none is found. It is therefore regarded by Indians as an extra, rather than a necessary part of their food supplies, but when available in quantity it is collected and may be kept for future use.

NOT THE WORK OF INSECTS.

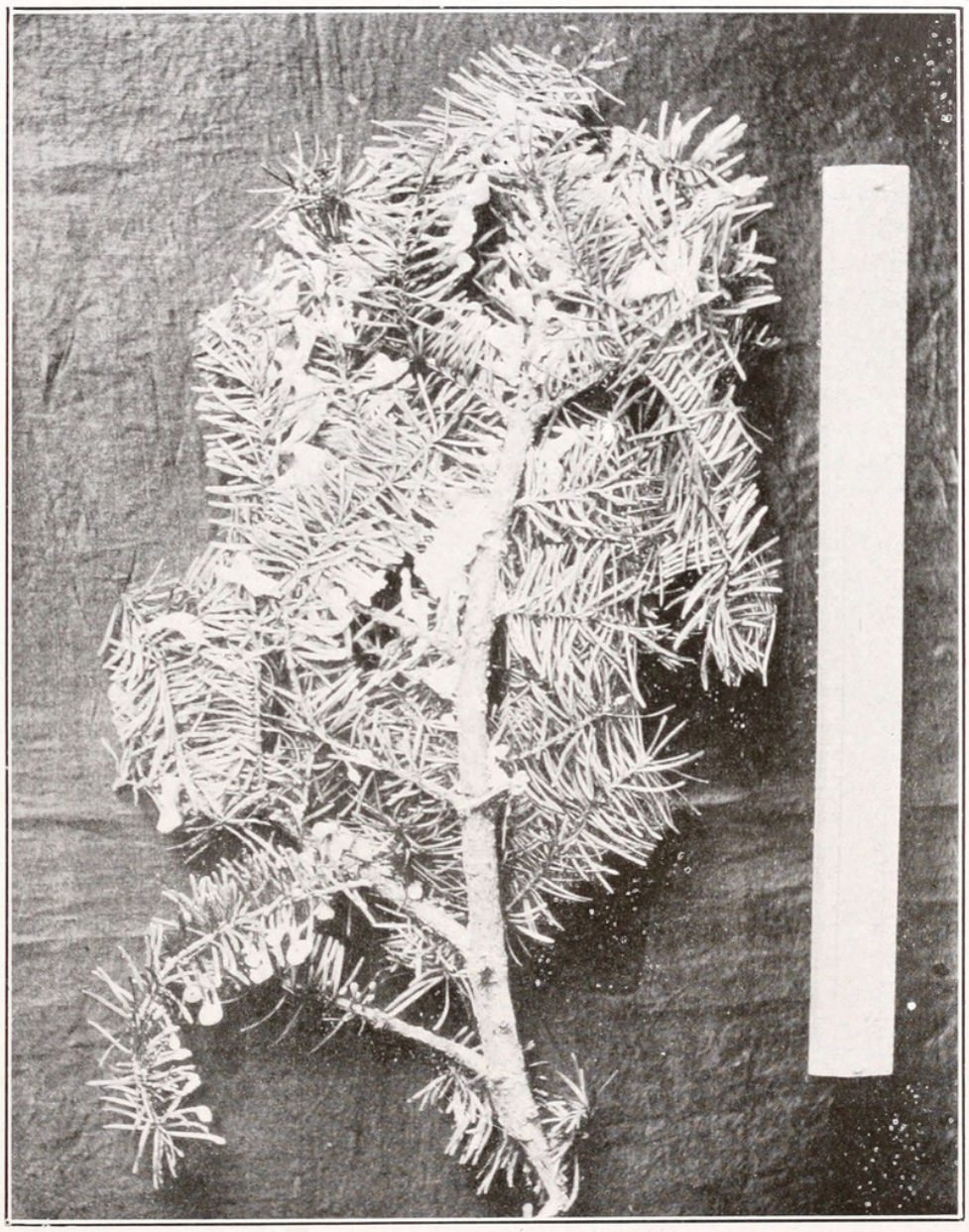
Previous to having seen the specimens, the writer suspected that the sugar had been produced as an exudation on the leaves through punctures made by insects possibly aphides; such as is said to occur on *Tamarix mannifera* which, when attacked by a *Coccus*, yields a kind of mucilaginous sugar—the manna of Mt. Sinai; but information to the effect that only healthy trees produced the sugar and that such trees were practically free from insects,

with the exception of such as were feeding on the sugar, led one to suspect that the sugar might be related to the manna of commerce, obtained from several species of ash *(Fraxinus)* as an exudate which assumes the form of flakes or fragments.

When specimens were received, however, in the summer of 1914, it was seen that none of the previously recorded sugars corresponded with the peculiar masses formed by Douglas fir. A careful search for information as to its chemical analysis revealed nothing to show that even its occurrence was known. On account of its interest and novelty at the time, the photograph in the Botanical Office Report was supplied to record its occurrence and illustrate the phenomenon, pending an investigation into the circumstances under which it was formed, and pending the results of the analysis which was then being carried out by Dr. F. T. Shutt, Dominion Chemist, at Ottawa.

APPEARANCE OF THE SUGAR.

The sugar appears as white masses varying in size from ¼ of an inch to 1½ or 2 inches in diameter. The smaller masses are formed like white drops at the tips of single leaves, occasionally two or three leaf-tips are inbedded in larger drops, while the largest masses are usually scattered irregularly over the leaves and branchlets.



Branch of Douglas fir laden with white masses of sugar. (From B. C. Bot. Office Rep., 1914).

The sugar tastes decidedly sweet, passing temporarily into a pasty consistency during dissolution in one's mouth; it is completely soluble. When collected it is quite hard and dry, with no tendency to be sticky. A slight rain is sufficient to dissolve the

sugar off the trees, and patches of recrystalized sugar may then be found at the base of trees or on the ground. Frequently, however, in this situation it does not recrystalize but may be found in a fluid or semi-fluid condition which is attractive to flies and other insects. Sometimes, as above mentioned, insects feed on the sugar while still on the trees, and it is reported that bears go after it, causing the breakage of many branches.

EXUDATIONS BY OTHER PLANTS.

As is well known, many plants have structures known as waterpores,, situated usually at the tip or apex of the leaves, and, in the case of lobed leaves, often at the tips of the lobes or teeth along the margin. Occasionally when the root-pressure is very active, so much water is forced up into the plant that the leaves become gorged with water which escapes through these water-pores—comparable to a kind of safety valve. Most people are familiar with the drops of water at the tips of grass leaves in the morning after a hot dry summer day and a cool, clear night, giving origin to the Scotch saying, "Ilka blade o' grass keeps its ain drap o' dew".

In some localities, where the soil is calcareous, minute white incrustations of lime are found around the water-pores; these incrustations may be found on grasses, and are of common occurrence on certain species of Saxifrages which show them on every tooth along the margin of the leaves, such incrustations are small, and are only formed under certain ecological conditions, in which temperature of the soil and atmosphere, and water content of the soil are important factors.

FACTORS INFLUENCING EXUDATION OF SUGAR.

A review of the distribution, and various factors influencing the production of sugar by Douglas fir, will prove of especial interest to physiological and ecological botanists, to whom the phenomenon will serve as a splendid illustration of the influence of environment on a plant which under ordinary conditions in British Columbia does not exude sugar.

DISTRIBUTION.

The region in which sugar-bearing Douglas firs are most abundant, lies between the 50th and 51st parallels and between 121°-122° long. This includes the driest and hottest part of the dry-belt of British Columbia. Within this area they are rather common in the Thompson valley west of the mouth of the Nicola river, also near the junction of the Thompson and Fraser rivers at Lytton; they have been found a little above Lilloet in the Fraser valley, but according to present information are not known to occur north of Clinton in this region.

About 10 miles north of the apex of the angle formed by the junction of the Thompson and Fraser rivers, lies Betani valley, at an altitude of between 3,500 and 4,000 feet, some years sugar is comparatively abundant on trees in this region; the geology and flora is very different from that of the adjacent Thompson or Fraser valleys; here one may find sugar-bearing Douglas firs growing on the southern and south-western slopes having the greatest sun exposure. The soil produces a thick covering of grass and other vegetation, indicating a plentiful supply of available soil moisture; differing in this respect from the dry gravelly southern and south-western slopes of the main valleys of the Fraser and Thompson.

Suitable habitats are found at intervals over a considerable area of the dry-belt regions, in addition to samples received from the north and south sides of the Thompson river near Spence's Bridge, Douglas fir sugar has been reported from around Kamloops and Savona, also from the Nicola and Similkameen valleys, and is said to be found in the southern part of Okanagan valley. In-so-far as the chief of the Kootenay Indians is aware, it is not known in the Kootenay country although it is reported by an Indian as being found in eastern part of Washington state, United States.

HABITATS.

The habitats in which sugar-bearing firs are found, are usually on gentle slopes facing east or north in that region of the dry-belt where the Douglas fir is encroaching on the dry-belt flora. The trees are in comparatively open areas with abundant exposure to the sun.

SOIL MOISTURE.

As a rule, sugar is not found on trees situated on fully exposed southern or western slopes, nor on areas where Douglas fir forms a dense forest. Southern and western slopes, exposed to the full heat of the sun, dry out much sooner than ground gently sloping to the east or north; the greater abundance of soil moisture in the latter is a point to be kept in mind.

ABUNDANT SUNSHINE.

In the region above mentioned the descending zone of the Douglas fir and the ascending zone of yellow pine overlap, so that the trees are well exposed to the sun, not being so crowded as to limit the foliage to a narrow crown, as happens in dense forests. An abundance of leaves exposed to the sun will result in an abundant formation of carbohydrates during the day; under ordinary conditions these carbohydrates would be removed from the leaves and transported to growing tissues or storage tissues during the night. This normally takes place in most plants, including Douglas fir in its natural habitat in the coast area where it forms dense forests of gigantic trees.

TEMPERATURE OF SOIL AND AIR.

In the dry-belt area it is evident that Douglas fir trees are exposed to the sun for a greater number of hours per day, the soil and atmosphere is warmer, the forests are more open, with freer circulation of air, than Douglas fir forests in the coast area.

MAXIMUM ROOT-PRESSURE.

It appears then that in years when Douglas firs are fully exposed to a long succession of hot, cloudless days in midsummer, and provided with the requisite soil conditions (*i.e.*, temperature and available water) the trees gradually accumulate an excess of carbohydrates during the many hours daily exposure to sun, the increasing temperature of the soil enables the cells of the roots to maintain or increase their activity during the night, which in dry-belt regions in midsummer is very short, and during which root-pressure is at its maximum.

DRY ATMOSPHERE.

When night comes on, the chlorophyll-containing guard-cells have ceased photosynthesis, the guard-cells become isotonic (*i.e.*, of equal concentration) with the surrounding cells, and the stomata close; so that even during warm nights little evaporation can take place from leaves so well protected with cutin. As a result of the increased root-pressure and cessation of transpiration the leaves become gorged with water in which the sugar—formed by the reconversion of starch into sugar—is dissolved and exuded as drops at the tips of the leaves. The warm dry atmosphere at that time of the year causes the rapid evaporation of the water, leaving the sugar in the form of drops of various sizes as a deposit at the tip. Occasionally two or three such drops come in contact with each other and fuse to form one large drop, frequently they become so large that they fall from the leaf tips onto the leaves or branches below; a succession of these large drops cause the formation of the larger irregular deposits referred to above.

There is no doubt about the exudation of the sugar from the leaf-tips; deposits may be found in all stages, from mere traces up to large drops, in some cases just dried as they were about to fall.

With a knowledge of the ecological conditions under which Douglas fir exudes sugar, one can understand why it may be rare or absent in some years; one or two dull, cool, or wet days would suffice to alter one or more of the factors which play a necessary part in promoting its exudation. A dull day would enable the tree to utilize much of the excess sugar or store it as starch or other reserve food. A cool day would diminish the activity of the sugar forming cells in the leaves, and by lowering the temperature of the soil would lessen the activity of the roots, thus diminishing the root-pressure and exudation of water, while a wet day and subsequent evaporation from the soil would more effectually lower both the soil and atmospheric temperatures. Other factors would be affected, but the above summarizes the main points.

ANALYSIS OF THE SUGAR.

The results of Dr. Shutt's analysis of two samples—one supplied in 1914, the other in 1917—indicate a high degree of constancy of composition of Douglas fir sugar.

The preliminary analysis made in 1914 gave the following results:

Total sugars after hydrolysis	96.25%
Reducing sugars	23.3

The analysis of the 1917 sample furnished the following data:

Total sugars after hydrolysis	91.91
Reducing sugars	24.86
Foreign matter, etc., insoluble in water	.64
Moisture	7.00

Subsequent to the analysis, a contribution* from the Carbohydrate Laboratory of the Bureau of Chemistry, U.S. Department of Agriculture, Washington, D.C. a laboratory especially equipped for the examination of saccharine substances, reports a complete analysis of the same product.

A summary of their findings is as follows:

"The sample of Douglas Fir manna yielded about 50% of pure crystalline melezitose, and there is evidence that the manna contains sucrose and some reducing sugar probably a mixture of glucose with a smaller quantity of fructose. The percentage composition of the sample of dry manna that we examined was approximately:

Melezitose	75-83%
Sucrose	2.9%
Reducing Sugars	11.5%"

Melezitose is an extremely rare trisaccharide of the formula $C_{18}H_{32}O_{16}$ which on hydrolysis yields glucose and turanose, the latter is very difficultly hydrolysed to glucose and fructose but in the conventional methods of sugar analysis, the only product of hydrolysis having direct reducing action is glucose.

*The Occurrence of Melezitose in a Manna from the Douglas Fir, by C. S. Hudson and S. F. Sherwood (Journal of the American Chemical Society, Vol. XL, No. 9, 1918).