An Epidemic Occurrence of *Ustilago comburens* Ludwig on *Danthonia pilosa* R. Br., an Unrecorded Host for New Zealand.

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PLATES 26–27.

THE occurrence in 1928 in certain parts of the Nelson district of an epidemic of the smut *Ustilago comburens* Ludwig as a parasite of *Danthonia pilosa* R. Br. was first noticed owing to the two-fold effect of the fungus upon sheep grazing on the infected grass. In the first place the animals showed a slight affection of the mucous membrane of the nose due to irritation caused by inhaling the smut spores; and in addition the spore masses, which are greenish-bronze, imparted a noticeably dark colour to the wool. The wide infection of the grass by this smut, which is recorded as of only rare occurrence in New Zealand, was thought to warrant an investigation of the conditions under which it was occurring in the present instance, or was likely to occur again to a similar epidemic extent.

The grass concerned, *Danthonia pilosa* R. Br., grows in most parts of New Zealand from sea-level to a height of 6000ft., but it is to be found chiefly on poor land in dry situations, in many of which places it forms an important constituent of the pasture where other grasses will not flourish. It is also found commonly in similar situations throughout Australia and Tasmania. It is thus of considerable importance as pasture in its particular areas, and any disease threatening its existence either wholly or partly might induce deterioration in the feeding value and reproductive power of the grass to an economic degree.

Ustilago comburens Ludwig has been found in numerous places in Australia, but chiefly in Victoria and Tasmania, since the year 1892, when the original type specimens were secured at Murray Bridge in South Australia (Ludwig: *Zeitschrift für Pflanzenkrankheiten*, 3, 1893, p. 139). The type specimens were on an undetermined species of *Danthonia*, but in all subsequent collections in Australia the grass has been diagnosed specifically as *Danthonia pilosa* R. Br. (McAlpine: "*Smuts of Australia*," 1910, p. 154). In New Zealand on the other hand Cunningham (*Trans. N.Z. Inst.*, 1924, p. 413) records only a single collection of this smut, and in this case it was not on the common *D. pilosa*, but on the more rare *D. Buchanani* Hook f. Though this species of grass grows in many places in the hilly districts of Canterbury and Otago, the smut is recorded only from the locality of the Dunstan Mountains, Otago. *Danthonia pilosa* is therefore a new host plant for this species of smut in New Zealand (though in Australia it is the usual host), while

the Nelson province is a hitherto unrecorded locality in New Zealand for the occurrence of the smut on any host.

The effect of the smut upon the grass is to destroy the entire panicle, the stalk of which instead of growing into a compound inflorescence more than a foot in height remains a slender, unbranched, spear-like growth only two or three inches high with its top densely covered with the pulverulent spore-mass of the smut (Fig. 3). All the panicles on infected plants remain stunted in this manner, and the appearance in the mass of large numbers of smutted plants growing close together is conspicuously different from that of healthy plants (Fig. 4). Owing to the high percentage of grass infection and to the spores being produced in enormous numbers, the wool of sheep grazing or lying on infected grass, as already mentioned, soon becomes covered with the bronze spores, and in spite of the minute spore-size appears much discoloured even when the animals are viewed from a distance. Under microscopic examination the cause of the discoloration is revealed as an incrusting of the strands of wool by the spores (Fig. 1).

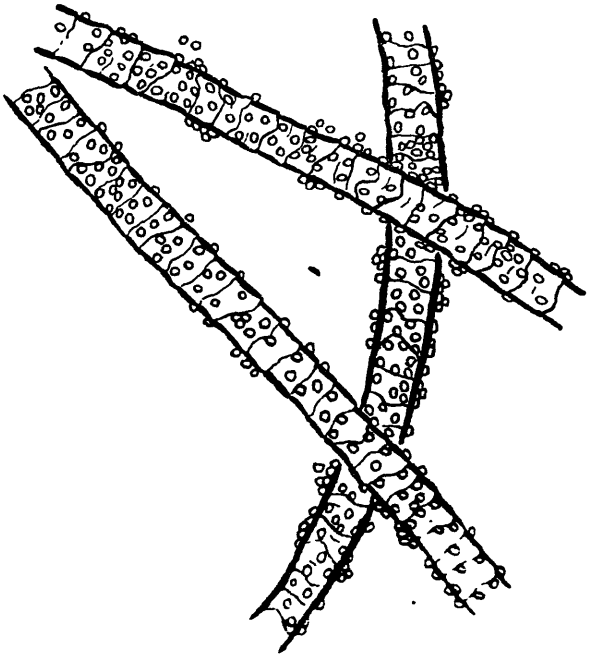

FIG. 1.—Strands of wool incrusted with spores of *Ustilago comburens* Ludwig × 218.

Characteristics of U. Comburens in the Field.

The smut was first noticed in quantity in the Nelson district on pasture land in Pigeon Valley which lies about 20 miles from Nelson. The soil of the valley though varying somewhat in quality is chiefly of what is known locally as the Moutere-Hill type. It is fine in texture, low in phosphate and lime, and if unmanured produces poor quality pasture.

The first investigations were made on three farms adjoining one another in the valley and all consisting of a large area of hill country and a smaller area of flat land on the valley floor. In every case at least a portion of the land had been top-dressed at some time.

For the purpose of comparison three other farms forming a second group were also examined, one being on similar soil in a different locality, and the two others on dissimilar soils, in both cases of better quality. The first farm of this group lies in Redwood's Valley on soil of Moutere-Hill type, the second at the mouth of Pigeon Valley on Waimea loam (a fairly good alluvial soil which responds to manuring with phosphate and lime), while the third is on a steep hill-side of Heslington loam at Hope. The last farm has the highest fertility of all and contains adequate phosphate and lime but is of open texture, owing to which feature and its steep slope it has a tendency to suffer from drought during summer.

Original Pigeon Valley group of Farms.

The soil of the three farms in Pigeon Valley, though similar generally, grades in quality and bears a correspondingly different flora, the floral range being small on one farm and somewhat wider on the two others. The amount of *U. comburens* present on the *Danthonia* of the three farms is as follows:

(a.) Poor land with a small floral range. This farm includes manured and unmanured land, the former having been top-dressed with 1 ton of ground limestone and 4 cwt. of basic slag per acre. Throughout this farm *U. comburens* was uniformily distributed and the infection heavy, 63% of the inflorescences produced bearing this smut. On the hilly back-country the *Danthonia* was more unevenly distributed, growing chiefly on sun-exposed slopes. The smut here was co-extensive with the grass, and was found particularly on drier areas where the *Danthonia* had established itself to the exclusion of other grasses.

(b.) Poor land but with a larger floral range. This farm consists of some unmanured fields and others top-dressed with 4 cwt. of basic slag per acre. The *Danthonia* in this case was more sparsely scattered, growing chiefly in small patches on sunny shoulders or on slopes surrounding old root-hollows. The percentage of *U. comburens* was considerably less than on the first farm, being 39% as compared with 63%.

(c.) Slightly better land with a still larger floral range. One field manured with ¼ ton of basic superphosphate per acre showed a mixed flora of which only a small amount was *Danthonia pilosa*. *U. comburens* was not present on any part of this field. On another field of the farm, top-dressed for the last two years with ½ ton of basic superphosphate per acre, the flora was mixed but with *Danthonia pilosa* greatly preponderating and showing excellent vegetative growth. In its case also there was no smut infection.

Subsidiary group of Farms:

(a.) The Moutere-type area examined in Redwood's Valley had never been manured, had not been burnt during the last few seasons, nor had it been grazed for two years. The flora was extremely limited and consisted almost wholly of *D. pilosa* and *Leucopogon Fraseri* A. Cunn. This paucity of species was more marked than on the poorest of the Pigeon Valley lands, while the *Danthonia*, which was of stunted growth, significantly showed 99% infection by *U. comburens.*

(b.) The farm on Waimea loam had been slightly grazed and not top-dressed while its flora, which was mixed, included a moderate amount of *Danthonia.* No *U. comburens* was present. This result corresponded to that obtained in Pigeon Valley, where a slight improvement in soil-constituents and soil-texture and a consequent greater variety of flora were correlated with a fall in the percentage of the smut present.

(c.) The field at Hope on Heslington loam had never been top-dressed but the growth of the leaves and flowering panicles of the *Danthonia,* which was the chief component of the pasture, was much more vigorous than that seen in other localities, and, as mentioned before, general vigour of the grass was correlated with a complete absence of *U. comburens.*

Summary of the Prevalence of U. Comburens on Different Kinds of Pasture.

On sun-exposed slopes of Moutere-type soil in Pigeon Valley, where the floral range of the pasture is small with *D. pilosa* its chief constituent, the amount of infection was heavy—63%—whether the land had been top-dressed or not; on the same farms, but in parts where the floral range is wider, the amount of smut infection was considerably lighter—39%; on the other soil of pure Moutere type, in Redwood's Valley, where drought conditions prevail from early in the season and growth of the grass is consequently poor, the smut infection was extremely heavy—99%; on the better grade soils (Waimea and Heslington loams) with the growth of *Danthonia* vigorous in both cases, no smut was present.

From the above data it is concluded that drought and poor-grade soils are predisposing factors which combined tend to encourage an epidemic of the smut, on the one hand by increasing susceptibility in the grass and on the other by limiting the range of flora to such an extent that the susceptible host is the predominating constituent of the pasture, thereby facilitating widespread infection.

Germination of the spores of U. Comburens.

Although the smut was originally found in Australia in 1892, Ludwig (loc. cit.) apparently did not attempt to germinate the spores. McAlpine (loc. cit) tried several times to germinate those obtained from material gathered in 1902, but met with no success. In January of 1909, however, he succeeded in inducing the germina-

tion, in water-suspension, of spores collected during the previous October. But with this three-months' old material germination was slow, as it did not occur until after nine days. Nor was it complete, for development of the promycelium was arrested at the latest at the formation of the first septum, the normal tri-septate stage never being reached. This is the only successful recorded attempt in Australia to germinate the spores, while in New Zealand only one attempt has been made, in this case by Cunningham (loc. cit.), who however failed to induce germination.

In the present investigation attempts at germination met with greater success. The material was collected on November 16th, and on the 17th spores were set to germinate in water. Germination took place in 24 hours. By 48 hours about 40% of the spores had developed a promycelium, which by that time was to be seen in all stages from the continuous to the four-celled. In most cases the promycelium was straight (Fig. 5). Other successful attempts to germinate the spores were made later, but chiefly while the material was still fresh. In some of the later cases the spores were suspended in water, while in others a weak solution of lactose was used. In all cases a proportion of the spores germinated in less than 24 hours, while after two days all stages in the growth of the promycelium could be seen, from the small bud to the abstriction of conidia.

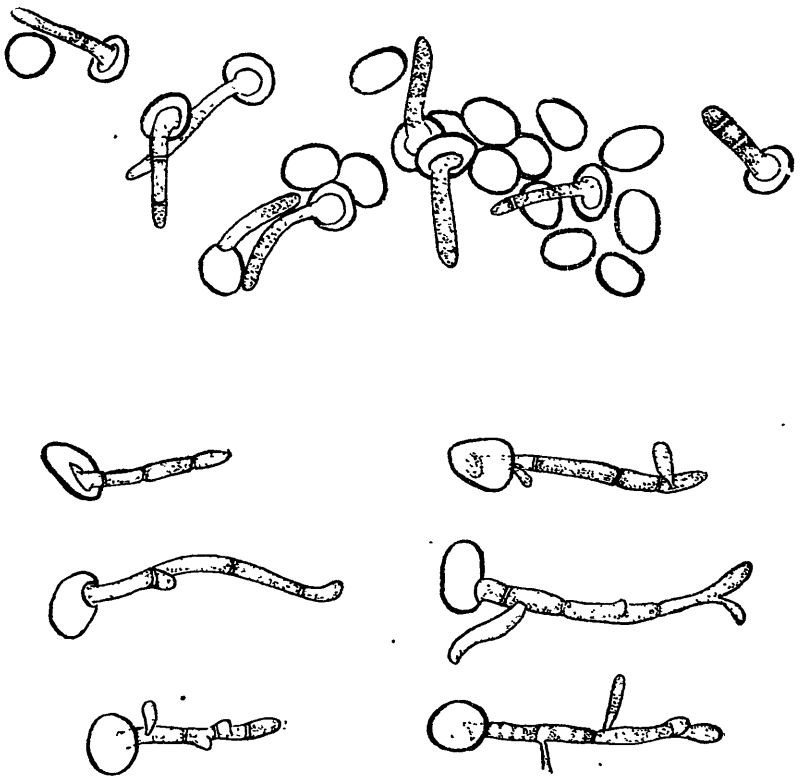

FIG. 2.—Stages in the germination of *U. comburens* Ludwig × 2000.

Conidial development did not usually begin until all three septa were formed. The bud usually arose just beyond the septum, gradually lengthened, and finally became abstricted when at a length of about 3.3 μ (only rarely exceeding that size), while the width was seldom more than 1.2 μ. It is considered that although three was the largest number of conidia seen on any promycelium, four is the normal number, the conclusion being based partly on the readiness with which the conidia separate from the promycelium, partly on the normal presence after 48 hours of masses of conidia free in the nutrient solution, and partly on the fact that under mass-examination conidia were seen in all four possible positions on the promycelium (Fig. 2). In no case was a conidium-initial seen to grow into a long filament, nor was more than one promycelium formed from any one spore. In both these features the germinating spore of *U. comburens* differs from that of *U. Readeri,* the common *Danthonia* smut in New Zealand. Some of the longer promycelia of *U. comburens* were undulating in form at maturity, while sometimes in the younger ones the direction of growth changed soon after the tip emerged from the spore, with the result that near the spore the promycelium became set at an angle to its original direction.

It would appear from these germination tests, correlated with those previously attempted by McAlpine, that under natural conditions the spores germinate almost immediately after being shed. The wall is thin, and therefore affords relatively slight protection against desiccation. Also owing to the small quantity of reserve protoplasm in the minute spore, slightly adverse conditions are quickly reflected in inhibition of growth. These factors probably explain why McAlpine obtained only occasional one-septate promycelia from three-months' old spores, and also why even a large number of promycelia from fresh spores from Pigeon Valley remained at the continuous or one-septate stage. That the spores can germinate in considerable numbers under natural conditions is obvious from the fact that in both Redwood's and Pigeon valleys large areas occurred on which not a single healthy panicle of *Danthonia* could be found.

Summary of the characteristics of Spore Germination.

1. Spore germination took place readily in 24 hours.
2. In many cases the promycelium was three-septate after 48 hours.
3. Conidial formation occurred soon after formation of the septa; three conidia per promycelium were often found, but it is believed that 4 is the total number.
4. The conidium is about 3.3 μ long and 1.2 μ wide.
5. Hyphal growth instead of conidial production, such as is common in *U. Readeri* on *Danthonia pilosa* did not occur in the germination of the spores of *U. comburens.*

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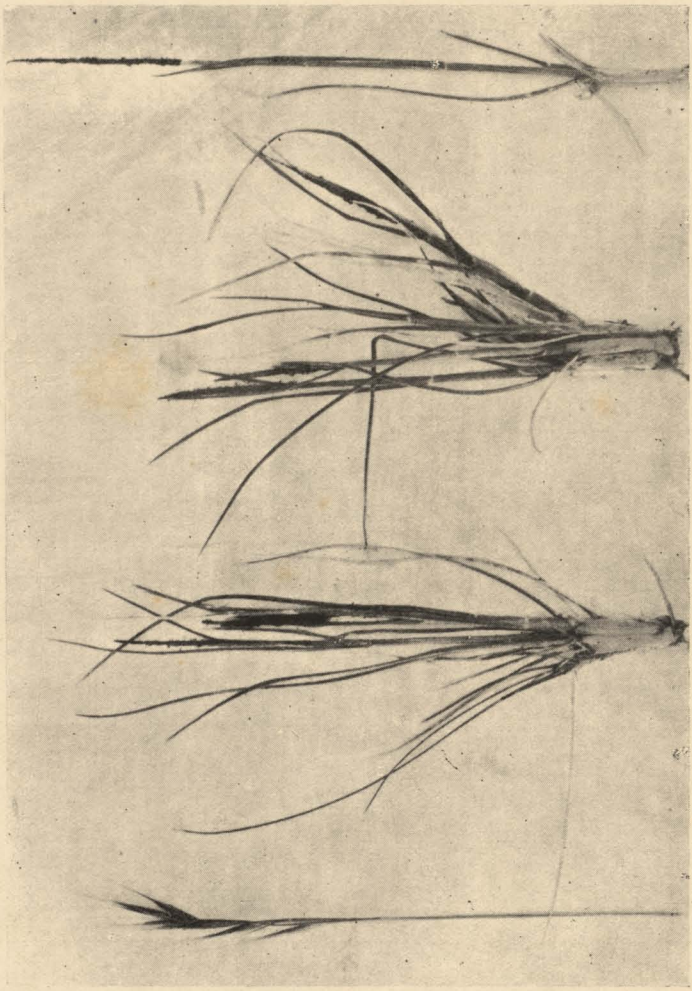

FIG 3.—*Danthonia pilosa* R. Br. infected with *Ustilago comburens* Ludwig.

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FIG. 4.

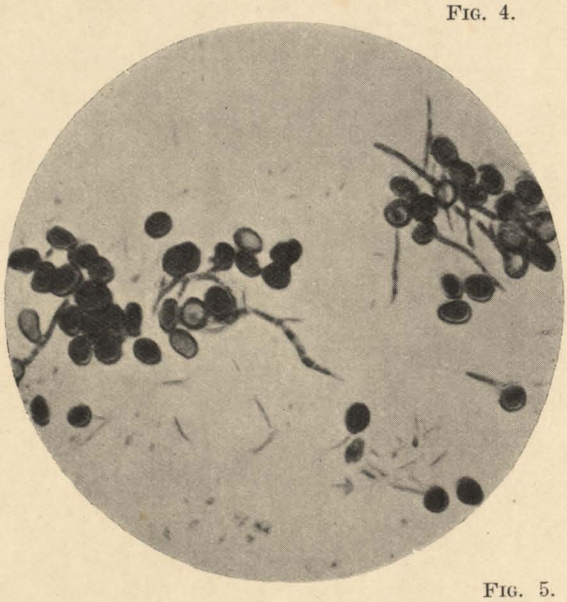

FIG. 5.

FIG. 4.—Group of plants of *D. pilosa* from Redwood's Valley showing 100% of the inflorescences infected by *U. comburens*.
FIG. 5.—Germinating spores of *U. comburens* × 1500.