Ch. oreophila (snow patch grass): Important associates are *Poa colensoi, Anisotome imbricata, Marsippospermum gracile, Celmisia sessiliflora* and, in places from Mt Cook to southern Fiordland, *Celmisia hectori.* The grassland is confined to sites with late-lying snow. These are concave sites and lee-slopes protected from radiation, above about 4,800 ft. (43° S.) and 3,800 ft. (45° S.). The soils occupied by *Ch. oreophila* vegetation range from well-drained young lithosols to gleys, shallow peats and shallow podsols. Deep winter snow is tolerated.

Other short grasslands found in the alpine zone dominated by *Festuca matthewsii, Poa colensoi* and *Notodanthonia setifolia,* are briefly dealt with by Burrows (1962), Mark (1962) and Wraight (1963). The more extensive areas of these grasslands seem to have been induced by fire and overgrazing.

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EXPERIMENTS CONCERNING CAUSES OF TIMBER LINE—A PROGRESS REPORT

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Experiments are being carried out on the Craigieburn Range (in Canterbury, New Zealand) with mountain beech (*Nothofagus solandri* var. *cliffortioides*), which is the local timber line species, and with timber line species from other parts of the world. The aims are to compare growth at different altitudes, to demonstrate symptoms of failure in seedlings set out above their natural limit, and to show whether timber lines in New Zealand are climatically equivalent to those in other lands.

The experimental sites are on a slope facing north-east, at the altitudes of 3,600 ft., 4,200 ft. (which is just below the natural mountain beech timber line before it was depressed by fire), 4,800 ft. and 5,400 ft. There is also a site on a tussock flat at 3,000 ft. for the purpose of testing whether lower or valley timber lines are governed in the same way as alpine ones. At each altitude 3 degrees of shading, i.e., full exposure and two-thirds and one-third of full exposure, are provided by appropriate spacing of laths. The plots are covered with bully netting, to exclude grasshoppers which nearly destroyed the earlier trials; this reduced the light intensity by an additional 20%. Other environmental variations are minimized in order to keep experiments to manageable size. The seedlings are grown in waxed paper pots, which allow small seedlings to be transplanted with minimum disturbance but do not inhibit the root

development of larger seedlings. The soil is a uniform potting mix which is brought to a good level of fertility so that the performance of seedlings does not become dependent on infection by symbiont microorganisms. Seedlings are watered during dry weather, and surrounded by gravel mulch in autumn to reduce frost heave.

Most of the work has been with *N. s. cliffortioides*. In most years, a shortage of viable seed has hampered tests to find whether seed can germinate above timber line (except in 1966, when germination occurred freely at all altitudes). Seed germinates as early as the beginning of November below timber line. Measurements of growth were made on seedlings which were transplanted into pots after they had germinated on the forest floor near timber line in November 1963. The results have not yet been fully analysed, but a number of points are already clear. Growth in height, expressed either in that of the best plants or in the mean of all plants at each altitude, tends to accelerate from year to year, and to decrease with increasing altitude. At 3,600 ft. and 4,200 ft., i.e. on the slope below timber line, the acceleration of growth is very marked, especially at the lower site, whereas above timber line and on the flat at 3,000 ft. there is near-stagnation. The numbers of leaves produced per shoot per year, the total number of living leaves on each plant, and the mean area per leaf show the same relationships. In addition, the mean area per leaf is positively related to degree of shading. The period during which shoots grew in summer 1965–66 was approximately between 21 October and 3 March at 3,000 ft. and 3,600 ft., shortening with increasing altitude to between 30 November and 3 March at 5,400 ft. The growing period in 1964–65 was of similar length.

The middle altitudes (3,600 ft. and 4,200 ft.) also favour survival. On the flat, plants survive only under maximum shade. The others all die during the winter half-year through drying out, often accompanied by frost heaving despite the gravel mulch. The flat experiences the lowest minimum temperatures (down to 6°F. in 1964), very wide daily fluctuations, and negligible protection by snow. The winter deaths at 3,600 ft. and 4,200 ft. also involve drying and frost heaving, but these agents account for few deaths at the highest altitudes. Here, almost as many plants die during summer as during winter, and in both seasons it seems that most of them simply lose vigour until they shrivel and die. Seedlings at the highest altitudes also succumb more frequently to summer drought and attack by insects than the more vigorous plants at lower altitudes.

Sophora chrysophylla is a small tree that forms timber line at about 9,000 ft. in Hawaii. In these New Zealand experiments, seed collected near timber line on Mauna Kea has germinated quite freely up to 5,000 ft. One or two seedlings are surviving precariously in the shaded plots at 3,600 ft., but on all other sites they have been killed by winter cold.

Pinus hartwegii forms timber line at 13,000 ft. on the volcanoes of southern Mexico. In the summer of 1965–66, seed germinated freely at all of the sites, but there is a lag of nearly 2 months between 3,000 ft. and 5,400 ft. The resulting seedlings do not yet show any differences in their linear measurements, but their weight is negatively correlated with altitude and degree of shading. Older seedlings, raised at Rangiora and Lincoln from seed collected at timber line, had begun to form dwarf shoots by the time they were transplanted to the Craigieburn Range, but in subsequent seasons they tended to form fewer dwarf shoots and their needles were shorter. This tendency was most pronounced at the higher altitudes and under deeper shade. Mortality showed the same pattern, and resulted from a gradual loss of vitality occurring mainly during summer and autumn. In its better performance in full light, the species contrasts with mountain beech. In timber line provenances of the North American *Picea engelmannii*, there were also distinct altitudinal differences in mean weights of plants at the end of the first summer, and even at the highest altitude there was measurable growth.

It is generally held that timber lines coincide with a certain level of summer warmth, and there is evidence linking this with ability to achieve positive net assimilation of carbon dioxide (see Wardle 1965, for references and discussion). Most of the results gained so far from the present experiments can be interpreted in these terms, but they do not compel rejection of alternative explanations of timber line.

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