corresponds to about 11 ppm in density. Thus the total density variation in meteoric waters produced by these isotopes is about 17 ppm, of which about 65 percent is due to O^{18}. The atomic weight variations in hydrogen and oxygen in these waters are about 5.7×10^{-5} and 1.9×10^{-4} atomic mass units respectively.

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Effect of Low Concentrations of Carbon Dioxide on Photosynthesis Rates of Two Races of Oxyria

Abstract. Alpine plants of *Oxyria digyna* have higher apparent photosynthesis rates at various carbon dioxide concentrations than arctic, sea-level plants of the same species. The ability to utilize carbon dioxide effectively at low concentrations may be involved in the survival of plants at high elevations.

The volumetric concentration of atmospheric carbon dioxide in parts per million varies little with altitude (*1*). On the other hand, the partial pressure of CO_2 in the atmosphere decreases with altitude and with lowered total atmospheric pressure. As Decker (*2*) has pointed out, diffusion of CO_2 into a leaf is a function of CO_2 pressure. This has led to the suggestion (*2, 3*) that the altitudinal gradient of CO_2 pressure may be an important factor in the zonation of plant species on high mountain ranges.

Since any possible effect of low CO_2 pressure on alpine plant metabolism would be difficult to detect in the complex of environmental factors operating under field conditions, it is necessary to test this hypothesis under controlled conditions. In the laboratory, Decker (*4*) measured the effects of different CO_2 concentrations (in parts per million) on apparent photosynthesis rates of plants from a lowland (elevation, 150 feet) clone of *Mimulus cardinalis* Dougl. and of a hybrid between this clone and a high elevation (10,700 feet) form of *M. lewisii* Pursh from the Sierra Nevada Range of California. The results of his experiments showed no consistent differences between the two clones in apparent photosynthesis rates at different CO_2 concentrations and, thus, yielded no support for the hypothesis.

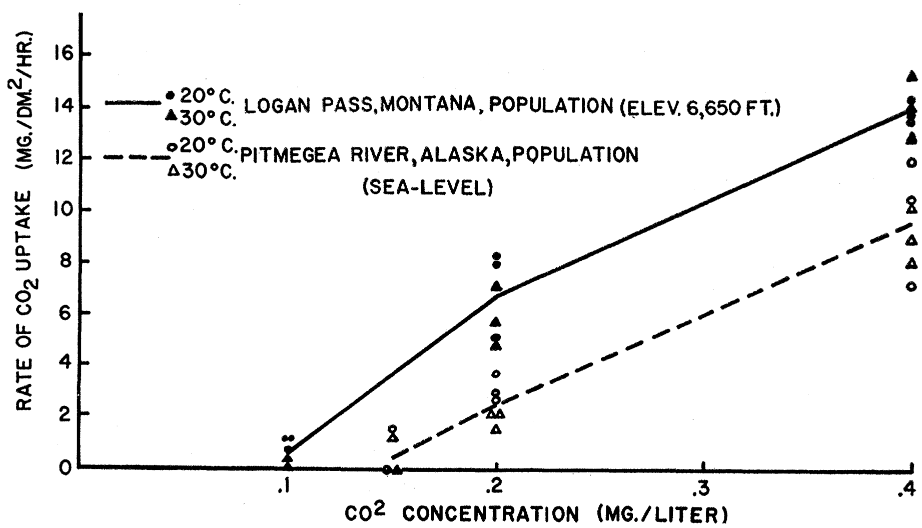

Fig. 1. Apparent photosynthesis rates of *Oxyria* leaves at low CO_2 concentrations. Points are averages of two to four determinations on a single plant.

In our experiment we used plants of *Oxyria digyna* (L.) Hill, a wide-ranging, arctic-alpine herbaceous species whose photosynthesis rates are relatively well known (*5, 6*). The sea-level race was from the northern coastal plain of Alaska at the mouth of the Pitmegea River (68°56′N), while the alpine race was from Logan Pass, Montana (48°42′), at an elevation of 2027 m. The plants were all the same age (4 months), grown from seed (*7*) under controlled conditions of continuous photoperiod and alternating 12.5°C and 1.5°C thermoperiods of 12 hours each. Apparent photosynthesis rates were measured with an infrared gas analyzer by the techniques described by Mooney and Billings (*6*). Two to four determinations were made at 20° and at 30°C on single attached leaves of three plants from each race under 1850 ft-ca of light. As in Decker's method, the plant was allowed to reduce the CO_2 in the dry air system from above 0.4 mg/lit. down to the compensation concentration, which was usually between 0.1 and 0.2 mg/lit. Results are expressed as averages of milligrams of CO_2 uptake per square decimeter of one leaf surface per hour; they are shown in Fig. 1.

Throughout the entire range of CO_2 concentrations at which apparent photosynthesis was measured, the plants from the alpine race were clearly more effective in fixing CO_2. Moreover, the compensation concentrations of the alpine race were not reached until near or below 0.1 mg of CO_2 per liter. None of the plants of the sea-level race had any apparent photosynthesis at this low CO_2 concentration, which approximates the CO_2 tension at an altitude of 12,200 m. Even at a concentration of 0.4 mg/lit., which approximates the CO_2 tension at 3000 m, plants of the sea-level race were only about 70 percent as effective photosynthetically as those of the alpine race.

While there was a slight tendency for plants of both races to be more effective at 20° than at 30°C, there was no clear-cut effect of temperature on apparent photosynthesis and compensation concentration as observed by Decker in *Mimulus*.

The data presented here appear to give substance to the hypothesis that low CO_2 pressures may limit the upward distribution of plants of certain species and races on high mountain ranges (*8*).

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7. Since it is not feasible to clone alpine oxyrias because they lack rhizomes (which arctic forms have), the plants used for measurement in both populations were randomly selected genotypes. Each plant has a recorded code number.
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