STUDIES ON SOIL MICROBIOLOGY AND DECOMPOSITION OF ALPINE MEADOW AT HAIBEI STATION

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Qinghai-Xizang Plateau is the largest and highest plateau in the world, and alpine meadow is one of its main ecosystems. An understanding of the structure and function of the alpine meadow ecosystem is essential for increasing the productivity of forage and improving the animal husbandry. To accomplish this, our institute has established a field research station at Haibei in 1976. Since then, we have participated in this research program. We have been studying soil microorganisms of the subecosystem of decomposers at this station for many years. Our research includes studies of seasonal changes in the size and composition of the main groups of soil microorganisms; soil respiration; the decomposition of cellulose, plant roots and litter, and animal feces; bacterial biomass and bacterial generation rates; the quantities, activities, and seasonal dynamics of nitrogen metabolic bacteria; and the distribution and activity of non symbiotic anaerobic nitrogen-fixing bacteria. Following is a brief summary of these soil microbial studies in the alpine ecosystem.

1. Seasonal changes of the size and composition of the main groups of soil microorganisms in grazed and nongrazed sites

The main groups of investigated microorganisms included bacteria, actinomycetes, filamentous fungi, yeasts, azotobacters, oligonitrophiles, and cellulose-decomposing microorganisms. The peaks of microbial populations appeared form mid July to mid September; the populations tended to decline after late October. The numbers of microbes diminished with increasing soil depth in all investigated groups. The numbers of bacteria, filamentous fungi, yeasts, oligonitrophiles, and actinomycetes in the soil of nongrazed sites were higher than those in the soil of grazed sites. The numbers of bacteria were highest in the soil of forb meadow, while the numbers of actinomycetes and yeasts were highest in the soil of a *Kobresia humilis* meadow. The numbers of filamentous fungi and oligonitrophiles were highest in the soil of a *Potentilla fruticosa* shrub. The numbers of cellulose-decomposing microorganisms were very low in all soils, especially in the soil of a swamp meadow. Azotobacters were not discovered in all soils, but anaerobic nonsymbiotic nitrogen-fixing becteria were dominant everywhere.

2. Soil respiration

Soil respiration at Haibei Research Station has been extensively investigated during the last two years. Our research project includes following topics: The seasonal dynamics of soil respiration; the relationships of soil respiration to soil temperature, soil moisture and to the numbers of aerobic microorganisms; and the effects of grazing and cultivation on soil respiration activity.

The results indicated that significant seasonal changes of soil respiration take place in all experimental plots, including grazed and nongrazed sites, and natural and artificially cultivated pastures. Soil respiration activity was relatively low in mid May (0.9576—2.6711 gCO_2/$m^2 \cdot 24$ hr). Peak values of soil respiration activity occurred from mid July to late August (4.6355—7.3151 g $CO_2/m^2 \cdot 24hr$) After late August soil respiration gradually declined. The seasonal changes of carbon dioxide evolution were correlated with soil temperature and the total number of aerobic bacteria, fungi, and actinomycetes, and followed an exponential regression equation.

The results also showed that the degree to which soil temperature and soil moisture content were correlated with soil respiration activity was related to the specific weather conditions of the individual years. In 1980, soil temperature showed higher correlation with soil respiration activity than soil water content. The opposite was true in 1981; i.e., the correlation between soil water content and soil respiration activity was stronger than that between soil temperature and soil respiration activity. Apparently, this is related to precipitation which was considerably higher in 1981 than in 1980.

No statistically significant differences were found between the soil respiration in ungrazed and grazed plots, although it was usually higher in ungrazed than in grazed plots.

3. The decomposition of cellulose, plant roots, and litter

The mean monthly decomposition rate of dry buried cellulose was significantly correlated with mean soil temperature during entire year and following an exponential equation. The decomposition rate of moist buried cellulose was obviously higher than that of dry buried cellulose ($P < 0.001$), but its correlation with soil temperature was weaker.

The decomposition rates of roots and litter of *Kobresia humilis* in an artificially cultivated and a natural pasture showed no statistically significant differences. The decomposition rate of litter buried below the soil surface (at 10 cm depth) was significantly higher than that of litter exposed on the soil surface (for artificially cultivated pasture, $P < 0.001$; for natural pasture, $P < 0.01$).

The mean monthly decomposition rate of roots and litter of *Kobresia humilis* was highest between late May and late June (20.34—33.75%) and dropped in successive months to 2.45—8.81% between early June and mid October.

The total decomposition rates of cellulose, roots ,and litter were all higher below the soil surface than on the soil surface; they all followed a linear regression equation.

4. Bacterial biomass and its seasonal dynamics

The biomass of soil bacteria was determined by fluorescein microscopic counting techniques. The number of bacteria, their biomass and the energy content were highest in the soil of the *Kobresia humilis* meadow (2.04×10^9 cells/g dry soil, 2.22×10^{-3} g fresh weight/g dry soil and 2.78 cal/g dry soil) and lowest in the soil of the swamp meadow (0.54×10^9 cells/g dry soil, 0.59×10^{-3} g fresh weight/g dry soil and 0.74 cal/g dry soil); (mean values for four soil layers).

Direct bacterial counts decreased gradually with increasing soil depth. This was also true for plate bacterial counts. Direct bacterial counts were correlated with plate bacterial counts, and following a linear regression equation.

Direct bacterial counts were significantly higher than plate bacterial counts; the difference between them increased with an increase in soil depth. The ratios of plate bacterial counts and direct bacterial counts were the following: 1:41 at 0—10 cm soil depth, 1:411 at 10—20 cm, 1:1183 at 20—40 cm, and 1:2985 at 40—60 cm soil depth (mean for all five vegetation types).

The large difference between the two counting techniques reflected the fact that the direct counts included all of the physiologically viable cells and of the rest cells of aerobic and anaerobic bacteria, while the plate counts included only the physiologically viable aerobic bacteria. Normally, the viable bacterial cells represent only a very small portion of the total bacterial cells: their, numbers are highest in the surface soil layer, and greatly decrease with the increasing soil depth.

Significant seasonal changes were observed in the surface soil layer (0—10 cm) of all investigated vegetation types: *Kobresia humilis* meadow, *Potentilla fruticosa* shrub, artificially cultivated *Elymus nutans* grassland, natural *Elymus nutans* meadow, and swamp meadow. Starting in June, the bacterial biomass gradually increased to a peak in June and August, then significantly decreased during September and October. The forb meadow soil was disturbed by rodents and the seasonal changes of bacterial biomass could not be determined.

5. Bacterial generation rate

Bacterial generation rates were determined by direct bacterial counts in, soils of two vegetation types from mid July to mid August. The bacterial generation rates in the 0—10 cm soil layers of the *Kobresia humilis* meadow and of the *Potentilla fruticosa* shrub were 64 hours and 42 hours, respectively. The numbers of generation within one month in these two vegetation types were nearly the same, i.e., 7.16 and 6.82 generations, respectively.

6. The numbers, activity, and seasonal dynamics of nitrogen metabolic microorganisms

The numbers of the physiological groups of nitrogen metabolic microorganisms were highest in the 0—10 cm soil layer and decreased with the increasing soil depth. The lowest numbers were counted in the 40—60 cm soil layer. In the surface soil layer, denitrifying bacteria were usually dominant, followed by anaerobic nonsymbiotic nitrogen-fixing bacteria; ammonifying and nitrifying bacteria were the least common.

The ammonifying and nitrifying bacteria were dominant in the soil of the swamp meadow (8.13×10^7 and 8.33×10^6 cells/g dry soil) and of the *Elymus nutans* meadow (4.69×10^7 and 1.41×10^8 cells/g dry soil); the numbers of denitrifying bacteria were very high in most soils at Haibei (from 1.44×10^6 to 1.80×10^{15} cells/g dry soil). The anaerobic nonsymbiotic bacteria were most important in the soil of the swamp meadow (6.65×10^{11} cells/g dry soil).

The ammonification on the 0—10 cm soil layer was relatively strong (mean 20.68 mg NH_4-N/g dry soil), while the nitrification was comparatively weak (mean 0.09 mg NO_3-N/g dry soil). Theifr ratio was 230:1. The quantitative changes of ammonification and nitrification activity were similar to the changes in ammonifying and nitrifying bacteria, and following a linear regression equation.

Azotobacter was not found in all soils at Haibei. Most probably, nitrogen fixation in carried out by anaerobic nonsymbiotic nitrogen-fixing bacteria and other microbes. This is characteristic for alpine meadow soils, as well as that the nitrogen fixation is stronger in the lower soil layers than in the upper soil layers. This probably reflects the nitrogen fixation efficiency of anaerobic nonsymbiotic bacteria in the corresponding soil layers (this assumption was supported statistically). The nitrogen fixation efficiency was significantly correlated with the nitrogen fixation activity according to a second degree polynomia regression equation.

The data also indicated that the degradation of these alpine meadows results in a decrease of soil fertility. For example, the ammonification, nitrification, and nitrogen fixation in the degraded *Elymus nutans* meadow were significantly lower than in the natural *Elymus nutans* meadow.

There were marked seasonal changes in the numbers and activities of nitrogen metabolic bacteria in all the investigated vegetation types. The peaks of activity occured between June and September and the highest numbers of bacteria between July and August. The environmental conditions are more favorable for microbial growth and reproduction during these months than during the rest of the season, probably mainly because the monthly mean soil temperature and monthly precipitation are significantly higher.

The numbers, metabolic activity, and seasonal changes of different physiological groups of nitrogen metabolic bacteria differred with the vegetation type. The seasonal changes were primarily influenced by the soil temperature and soil moisture content.

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高寒草甸土壤微生物学及分解作用的研究

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中文摘要

土壤微生物学及分解作用是生态系统研究极其重要的一环。多年来，我们主要研究了土壤微生物主要类群的数量、分布、季节性动态；土壤呼吸作用；纤维素、植物根、枯枝落叶以及牛、羊和鼠粪分解作用；不同季节、不同植物地上部分表面细菌、放线菌、真菌的数量分布；土壤中及植物叶面上细菌生物量；细菌的世代率；氮素代谢微生物的数量、活性、分布及季节性动态；土壤固氮作用及嫌气性自生固氮菌的数量、分布等。通过长期的研究工作，发现了生态条件严酷的高寒草甸土壤微生物一系列重要特征：

1. 高寒草甸土壤中未发现有好气性自生固氮菌，大气氮素固定者主要为嫌气性自生固氮菌，固氮作用强度平均为 1.68 毫克氮/克干土。

2. 高寒草甸土壤氨化作用强，而硝化作用弱，虽有嫌气性自生固氮菌固定大气氮素，但由于反硝化菌数量很高，限制了土壤肥力的提高。

3. 草场退化也导致了土壤氨化作用、硝化作用和固氮作用的降低。

4. 纤维素分解菌数量低导致有机质分解缓慢，也是限制土壤肥力提高的一个重要因素。